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Receiver function imaging of crustal suture, steep subduction, and mantle wedge in the eastern India–Tibet continental collision zone

Danian Shi [a,*], Zhenhan Wu [b], Simon L. Klemperer [c], Wenjin Zhao [b], Guangqi Xue [a], Heping Su [a]

[a] *MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, CAGS, 26 Baiwanzhuang Road, Beijing 100037, China*
[b] *Chinese Academy of Geological Sciences, 26 Baiwanzhuang Road, Beijing 100037, China*
[c] *Department of Geophysics, Stanford University, Stanford, CA 94305-2215, USA*

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ABSTRACT

To understand the along-strike variation of crustal deformation and tectonic processes in the India–Tibet continental collision zone, we deployed a linear array of broadband seismic stations along 92° E to image lithospheric structure. Our receiver-function cross-section reveals a prominent negative converter dipping ∼20° north from ∼10–55 km depth below sea-level, almost through the whole crust, beneath the southern Lhasa terrane. We interpret it to be a manifestation of the Yarlung–Zangbo suture zone (YZS) separating the continental crust of the Indian and Eurasian plates. This implies the hypothesized channel-flows of Indian middle crust extruding southwards from Tibet are limited at this longitude to the southernmost portion of the Lhasa terrane. A positive converter, consistent with previous suggestions of eclogite formation, is seen about 10–15 km above the Moho and continuing 50 km north of the 20°-dipping YZS converter. We image this positive converter continuously from ∼60 km south of the surface trace of the YZS to the vicinity of the Jiali fault, supporting the interpretation of sub-horizontal underplating of Tibetan crust by Indian crust to ∼31° N at 85° E on the Hi-CLIMB transect. However, we also show a negative mantle converter sub-parallel to the crustal YZS converter, from the northern limit of the underplating Indian lower crust to at least 140 km depth, that we interpret as the base of Tibetan lithosphere overlying an asthenospheric mantle wedge. Based on the lithospheric structure observed in this and other studies, we infer that Indian mantle lithosphere currently detaches from Indian lower crust at the "mantle suture" that is nearly 50 km south of the surface trace of the YZS at 92° E, south of the mantle suture suggested by INDEPTH transect beneath the surface trace of the YZS at ∼90° E, and far south of the mantle suture suggested to be at the 31° N northern limit of underthrusting Indian lower crust suggested by Hi-CLIMB transect at ∼85° E. A change from underplating in the west to steep subduction in the east can reconcile all these observations.

1. Introduction

The Tibetan Plateau is the spectacular consequence of the ongoing India–Eurasia continental collision beginning ∼50 Myr ago (e.g., Argand, 1924; Molnar and Tapponnier, 1975; Yin and Harrison, 2000; Leech et al., 2005). Numerous seismic studies over the last three decades have studied the formation and evolution of the plateau. There is now widespread agreement that Indian lower crust is underthrust beneath the Himalaya (Zhao et al., 1993; Schulte-Pelkum et al., 2005) and has underplated beneath southern Tibet to ∼31° N (Kind et al., 2002; Nábělek et al., 2009). Because of the great thickness of Tibetan crust, the preferred method of imaging Tibetan lithosphere has become receiver-function common-conversion point (CCP) images along linear transects, the best-known of which are INDEPTH at c. 90° E (e.g. Kind et al., 2002; Kosarev et al., 1999; Kumar et al., 2006; Shi et al., 2004; Zhao et al., 2011) and Hi-CLIMB at ∼85° E (e.g. Nábělek et al., 2009; Wittlinger et al., 2009) (Fig. 1, inset). Even on INDEPTH and Hi-CLIMB, however, the Yarlung–Zangbo suture zone (YZS) that separates Indian and Asian continental crust has largely eluded imaging, and the plate geometry within the mantle has remained controversial.

The post-collisional convergence between the two continents is estimated to be at least 1000–1400 km, and about a quarter of the

* Corresponding author. Tel.: +86 10 68999061; fax: +86 10 68327263.
E-mail addresses: shidanian@cags.ac.cn (D. Shi), wuzhenhan@sohu.com (Z. Wu), sklemp@stanford.edu (S.L. Klemperer), zhaowj@cae.cn (W. Zhao), xueguangqi@cags.ac.cn (G. Xue), suheping1950@163.com (H. Su).

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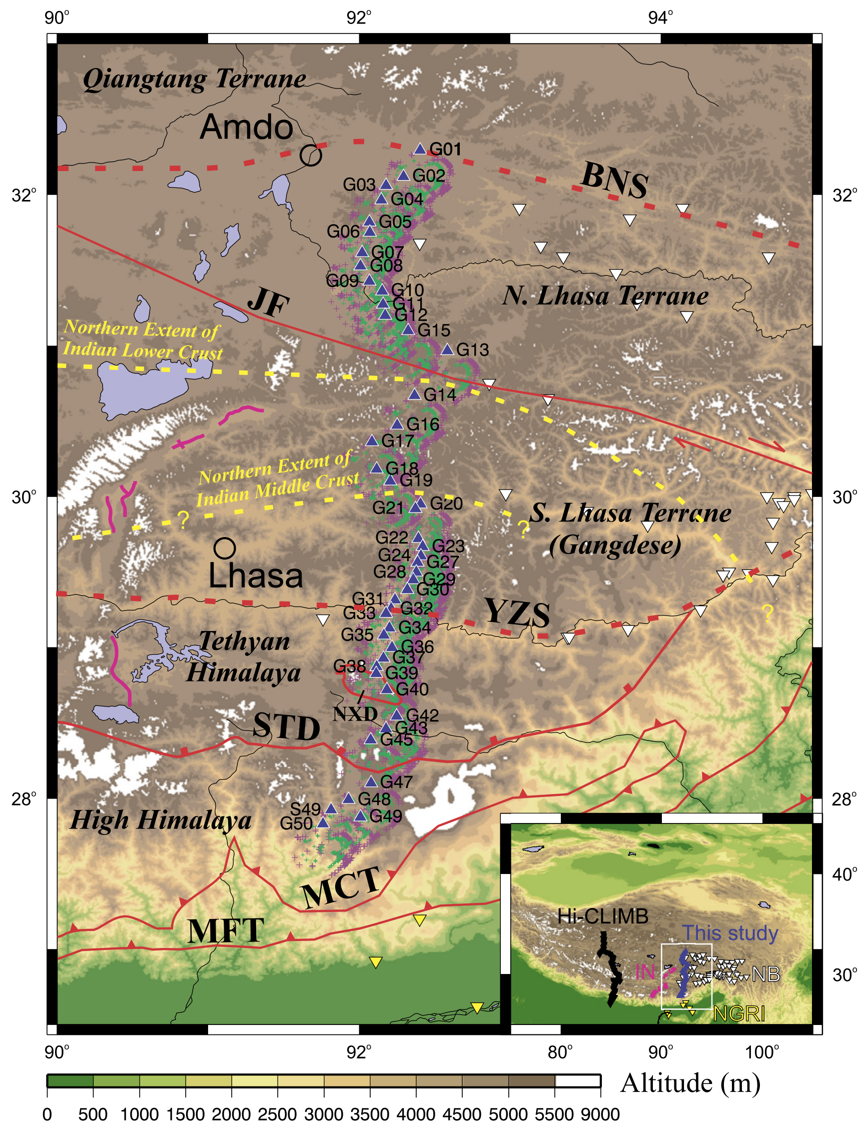

Fig. 1. Location of our broadband seismic stations (blue triangles) deployed across the India–Tibet collision zone. Dashed red lines mark the Yarlung Zangbo (YZS) and Bangong–Nujiang (BNS) sutures. Red lines delineate the Main Frontal Thrust (MFT), Main Central Thrust (MCT), South Tibet Detachment (STD), Nielaxiongbo dome (NXD) and the dextral Jiali fault (JF). Dashed yellow lines show the inferred northern limits of middle and lower Indian crust from observations of the doublet in this study and by Zurek (2008). Small green and purple crosses indicate all the piercing points of P-wave receiver functions at 45 and 65 km b.s.l., corresponding approximately to the positions of the top and bottom of Indian lower crust. Pink lines show INDEPTH reflection profiles. White triangles are seismic stations of the Namche Barwa experiment (Zurek, 2008). Yellow triangles are Indian stations used by Uma Devi et al. (2011). Inset shows the extent of this map (white rectangle), the Hi-CLIMB main-profile seismic stations (black), INDEPTH reflection profiles (pink, "IN"), the Namche Barwa seismic stations (white triangles, "NB") and National Geophysical Research Institute seismic stations (yellow triangles, "NGRI") on the topographic map of the Tibetan plateau.

convergence is believed to have been absorbed across the southern Tibetan plateau (>360 km across the Himalaya, and >60 km across the Gangdese thrust system) (Yin and Harrison, 2000). How this shortening has been accommodated is not well known and a variety of mechanisms have been proposed to explain the formation and tectonic evolution of the plateau. One class of models holds that the large and fairly uniform elevation of the plateau is achieved by diffuse deformation of Asian lithosphere (e.g. England and Houseman, 1989), that the outward growth of the plateau and the varying gradients of its margins are controlled by channel flow within a partly ductile lower crust (Clark and Royden, 2000; Beaumont et al., 2004), and that the superimposed east–west extension observed within the plateau is derived from subsequent delamination or convective removal of thickened mantle lithosphere (e.g. England and Houseman, 1989). Another class of models regards the Indian and Tibetan lithospheres as relatively rigid plates, with the convergence accommodated by partitioning into strike-slip and thrusting deformation due to the oblique configuration between the strike-slip faults and the northward subduction of the Indian plate (Dewey and Burke, 1973; Tapponnier et al., 2001). Numerical modeling shows Indian continental lithosphere is subductable if its upper crust is scraped off, so that Indian subduction is theoretically feasible (Capitanio et al., 2010). A third class of models suggests that cratonic Indian lithosphere is not subductable, and that Indian lithosphere may underthrust horizontally immediately beneath the crust of the overlying plate (Argand, 1924) after the break-off of the Indian oceanic slab at ∼45 Ma (Powell and Conaghan, 1973). The interpreted receiver-function image of sub-horizontal underplating of Indian lower crust beneath southern Tibet (Nábělek et al., 2009) and the efficient propagation of Pn and Sn waves beneath the southern Tibetan plateau (Ni and Barazangi, 1983) are supporting evidence for the underplating model.