Geophysical Research Abstracts
Vol. 18, EGU2016-9841-1, 2016
EGU General Assembly 2016

The South Tibetan Tadpole Zone: Ongoing density sorting at the Moho beneath the Indus-Tsangpo suture zone (and beneath volcanic arcs?)

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Some Himalayan cross-sections show Indian crust thrust beneath Tibetan crust, with no intervening mantle wedge (e.g., Powell & Conaghan 73), others indicate thickening of both crustal sections, juxtaposed along a steep suture (e.g., Dewey & Burke 73), and many combine features of both end-members (e.g., Argand 24). To understand crustal scale structure and related phenomena, we focus on data from an area in southern Tibet at 28-30°N, 84-91°E.

21st century observations in this area show a horizontal Moho at ca 80 km depth, extending from thickened Indian crust, across a region where Tibetan crust is interpreted to overlie Indian crust, into thickened Tibetan crust (Zhao et al 01; Monsalve et al 08; Wittlinger et al 09; Nabelek et al 09; Kind et al 02; Schulte-Pelkum et al 05; Shi et al 15). About half the subducted Indian crustal volume is present, whereas the other half is missing (Replumaz et al 10). Vp/Vs indicates the alpha-beta quartz transition is at ca 50 km depth (Sheehan et al 13). Miocene lavas include primitive andesites probably formed by interaction of crustal material with mantle peridotite at > 1000°C (Turner et al 93; Williams et al 01, 04; Chung et al 05). Thermobarometry of xenoliths in a 12.7 Ma dike records ~ 1100°C at 2.2-2.6 GPa and 920°C at 1.7 GPa (Chan et al 09). Biotite-rich pyroxenites among the xenoliths, similar to those in central Tibet (Hacker et al 00) and the Pamirs (Hacker et al 05), may form via reaction of hot crustal lithologies and mantle peridotite (e.g., Sekine & Wyllie 82, 83). These data, taken together, indicate Miocene to present day temperatures exceeding 800°C from ca 50 km depth to the Moho, unlike thermal models with a hot mid-crust and cold Moho (McKenzie & Priestley 08, Craig et al 12, Wang et al 13; Nabelek & Nabelek 14), and despite the observation of numerous, near-Moho earthquakes (Chen & Molnar 83; Chen & Yang 04; Monsalve et al 06; Priestley et al 08; Craig et al 12) interpreted by many as brittle failure at less than 700°C (e.g. Jackson 02).

We build on earlier studies (LePichon et al 92, 97; Schulte-Pelkum et al 05; Monsalve et al 08) to develop the hypothesis that there is rapid growth of garnet at 80 km and 1000°C within subducting Indian crust, causing increased rock densities. Dense eclogites founder into the mantle, while relatively buoyant lithologies accumulate in thickening lower crust. Mantle return flow plus radioactive heating in thick, felsic crust maintains high temperature, facilitating formation of hybrid magmas and pyroxenites. The crustal volume grows at 760 cubic m/yr/m of strike length. Moho-depth earthquakes may be due to localized deformation and thermal runaway in weak layers and along the margins of dense, foundering diapirs (e.g., Larsen & Yuen 97; Braeck & Podladchikov 07; Kelemen & Hirth 07; Lister et al 08; Kufner et al 16). A similar process may take place at some convergent margins, where forearc crust is thrust beneath hot, magmatic arc crust, leading to extensive, Moho-depth density sorting and hybrid crust-mantle magmatism in Arc Tadpole Zones.