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Preface

Continental collision, partial melting and ductile deformation in the Tibetan-Himalayan orogenic belt

Over the past decade, case studies, both observational and theoretical/computational, have demonstrated that integrative approaches hold the best promise to comprehend the diffuse, complex nature of continental collision over the entire thickness of the lithosphere – a last frontier in the aftermath of plate tectonics. This special issue derives from a Tectonics special session “Continental Collision -- the Lithospheric Scale” at the 2007 AGU Fall Meeting in San Francisco, USA. The session emphasizes studies that take a holistic view of continental collision zones, aiming to better understand the coupling between processes near the surface and deep-seated dynamics in the mantle. The special issue includes eight papers that present new observations and/or modeling results from various disciplines about partial melting and ductile deformation in the Tibetan-Himalayan orogenic belt, the most outstanding natural laboratory that results from the continent-continent collision between India and Asia for us to study the complex geologic processes through which collisional orogeny evolves.

The issue starts with three papers that report age and geochemical data of pre-, syn- and post-collisional magmatic rocks, respectively, from southern Tibet. Chiu et al., by reporting the first combined zircon U–Pb and Hf isotopic data of the Transhimalayan batholiths from the eastern part of the Lhasa terrane, explore the temporal distribution of the two main magmatic suites, i.e., the northern plutonic belt and the southern Gangdese Batholith, which represent the widespread intrusive products resulting from northward subduction of the Neo-Tethyan oceanic lithosphere before the India-Asia collision. Their results significantly improve our understanding of the pre-collisional magmatic/tectonic evolution and lithospheric structure of southern Tibet. Lee et al. present $^{40}\text{Ar}/^{39}\text{Ar}$ age and geochemical constraints from the Paleogene Linzizong volcanic successions in the Lhasa terrane, which suggest southward migration and intensification of the volcanism with a period of magmatic “flare-ups” at ca. 50 Ma. These observations lead the authors to argue rollback and then breakoff of the subducted Neo-Tethyan slab that occurred ahead and in the early stage, respectively, of the India-Asia collision. The interpretation that involves a major Eocene tectonomagmatic activity, and concomitant topographic uplift, in southern Tibet appears to be consistent with Himalayan metamorphic data, regional sedimentary records and seismic tomography. Chung et al., based on zircon U–Pb and Hf isotopes and whole rock geochemistry of postcollisional adakites in the Lhasa terrane, propose that the Tibetan crust underwent a significant tectonic thickening between ca. 45 and 30 Ma and the lower part of the thickened crust consisted dominantly of mafic lithologies as a consequence of intense basaltic underplating due to the Neo-Tethyan subduction. The later processes may have given rise to a thermally weakened lithosphere in southern Tibet. Thus, this study emphasizes the importance of precollisional geodynamic processes that could have asserted a pivotal control to the initial conditions and evolution of the Himalayan-Tibetan orogenesis.

Subsequent three papers apply seismological methods to image the present-day crustal and upper mantle structures in the surrounding areas of the orogenic belt. Li et al. present a high resolution image of the crust and upper mantle beneath the western Tien Shan, which indicates a pair of large, elongated high wavespeed regions dipping in opposite directions from the near surface to depths of at least 400 km. The authors suggest that they represent downwelling side-limbs of a lithospheric delamination beneath the central part of Tien Shan, possibly by siphoning of the bordering continental lithosphere as the central part descends. Caldwell et al. analyzed regional earthquakes in the western Himalaya and Tibet from five

geologic provinces: the Tibetan plateau, Ladakh arc complex, Indus Tsangpo suture zone, Tethyan Himalaya, and Himalayan thrust belt. Their velocity models show a low-velocity layer with 7–17% velocity reduction centered at ~30 km depth and apparently continuous from the Tethyan Himalaya to the Tibetan plateau. The result, in comparison with laboratory measurements and theoretical models, and the physical conditions of the region, leads the authors to conclude that partial melting and active mid-crustal channel flow may be present in the NW Himalaya. Monsalve et al., using a finite element model, establish a link between the upper mantle seismicity beneath the Himalayan collision zone and flexural bending of the Indian lithosphere. The mantle seismicity can be explained by modeling the response of the Indian Plate to loads corresponding to the weight of the sediments of the Ganga basin, the Himalaya and the southernmost Tibetan plateau, combined with the effects of a horizontal force per unit length acting upon the lithospheric plate. Modeling results show that beneath the Ganga basin and the southernmost Himalaya, earthquakes at near-Moho depths do not need to show extension, nor is the lower crust required to be weak, in order to infer that the uppermost mantle yields by brittle failure. However, additional factors such as the presence of lateral heterogeneities or the action of pore fluids may play a fundamental role in bringing the upper mantle materials to brittle failure.

The following paper is by Chambers et al. that reports a detailed investigation of an exhumed high-grade orogenic core, NW India, and casts some empirical constraints on the extrusion mechanisms. The authors model the pressure–temperature–time–deformation paths for two pelitic rocks, which reveal three distinct stages of metamorphism, and use monazite growth ages and muscovite $^{40}\text{Ar}/^{39}\text{Ar}$ ages to derive an initial exhumation rate of ~1.3 mm/yr for the studied rocks. In comparison with the underlying Greater Himalayan Sequence that was exhumed at a faster rate of 2.2 to 3 mm/yr during this time, the difference in exhumation rate between these two major rock units of the region is considered as reflecting Early Miocene displacement on the intervening South Tibetan Detachment. The issue ends up with the paper by Bendick and Baldwin about dynamic modeling for metamorphic core complex formation and scaling. In their numerical solutions, characteristic features shared by metamorphic core complexes at collision zones are reproduced for gravity-driven collapse of a viscous crustal region under conditions where vertical stress is continuous through thickened lithosphere. Such solutions allow inversion for effective mechanical properties and crustal geometry from direct observations of aspect ratio and exhumation velocity.

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