Pre-Collisional Evolution of the Himalayan-Tibetan System: Numerical Tests of Alternative Cretaceous-Tertiary Tectonic Settings

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The Indus Yarlung Zangbo Suture Zone (IYZSZ) is a >2000 km long by roughly 30 km wide first-order tectonic structure (Fig. 1a) stretching across the southern Tibetan Plateau. It is interpreted to contain the remnants of the Neo-Tethys Ocean, which separated India from Eurasia (Lhasa Block) prior to the main continental collision. This once 4000 km wide ocean is thought to have vanished along at least two subduction zones during the Jurassic and the Cretaceous; one intraoceanic and one under the Eurasian margin. Relic Neo-Tethyan oceanic lithosphere has been preserved in the IYZSZ as the discontinuous Ladakh and Yarlung Zangbo Ophiolites (YZO). The sedimentary record and deformation structures within and south of the IYZSZ indicate that the obduction of the YZO over the Greater Indian passive margin had already started at 65 Ma (e.g. Ding et al. 2005). However, data from multiple sources, including UHP metamorphic ages from the Indian margin, support the onset of the main collision at around 55-50 Ma, 10-15 My later (e.g. Najman et al. 2010). Paleomagnetic data indicate that during that period, the convergence rate between India and Asia was on the order of 15 cm/y, suggesting that 1000-1500 km of convergence occurred between the obduction of the ophiolites and the onset of continental collision.

We investigate two tectonic hypotheses that may explain these observations, Cases 1 and 2 (Fig.1b). In Case 1, only one Andean-type subduction zone (SZ1) is active adjacent to the Eurasian (Tibetan) margin, whereas in Case 2 there is a second coeval intraoceanic subduction zone (SZ2). The generic upper-mantle-scale numerical models are designed to replicate four phases in the evolution of the system and to investigate the major system controls during these phases. These controls include rates of ocean floor spreading and subduction, slab pull and ocean ridge push forces, and the geometrical, rheological and thermal properties of the tectonic plates and their margins. During Phases 1 and 2, divergent kinematic velocity boundary conditions initiate continental rifting followed by oceanic spreading and the self-consistent growth of rifted continental margins and oceanic lithosphere. In Phase 3, the boundary conditions are changed to convergence with the inception of SZ1 (Case 1) and SZ1 and SZ2 (Case 2) subduction zones, followed by ocean closure and continent-continent collision in which India and Asia respectively correspond to the pro- and retro-sides of the system. The results are interpreted in terms of tectonic architecture, metamorphic P-T-t paths for the passive margins, and convergence rate variations at both trenches, and compared to relevant well documented natural examples like the India-Asia collision zone and the Gulf of Oman system.

The 2D upper-mantle scale thermo-mechanical finite element numerical models comprise a large-scale (LS) low-resolution model (10x2, 10x10 km elements) containing a nested (embedded) high-resolution (2x2 km) small-scale (SS) model. For each time step, the models are solved sequentially with the SS velocity and temperature boundary conditions derived from the LS model solution. The modelling techniques and model properties are similar to those of Beaumont et al. (2009) and Huismans and Beaumont (2008).

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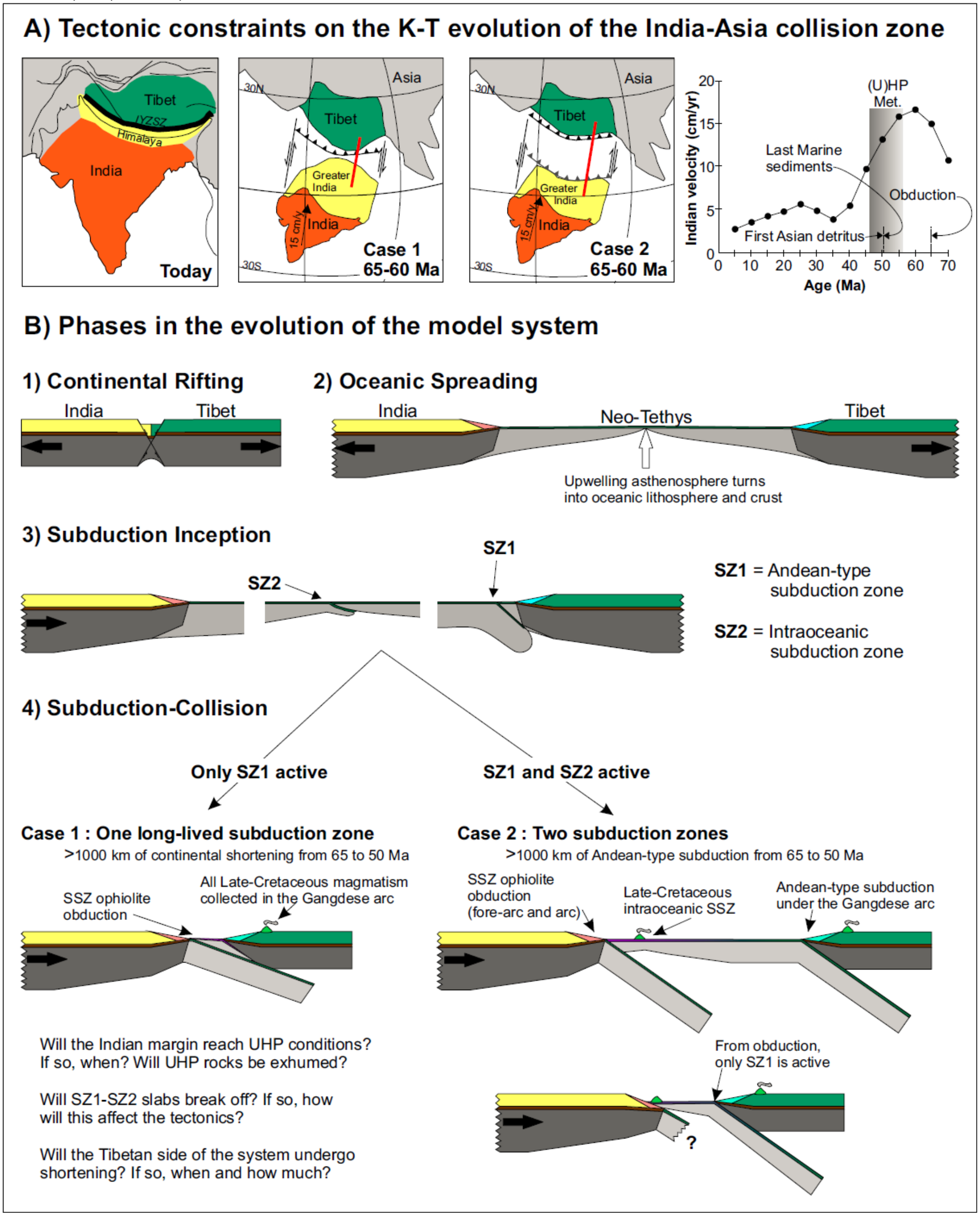

Figure 1: . A) Tectonic constraints on the Cretaceous-Tertiary evolution of the India-Asia collision zone. For paleomagnetic constraints, thermochronological ages and depositional ages see Ding et al. (2005), Dupont-Nivet et al. (2010), Najman et al. (2010), and references therein. B) Phases in the evolution of the model system. See text for explanation of Case 1 vs Case 2. SZ1, SZ2 = Andean and intraoceanic subdction zones, respectively; SSZ = suprasubduction zone.