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Indo-Asian Collision: Transition from Compression to Lateral Escape Tectonics

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The Indo-Asian collision produced the Tibetan plateau, the Himalayan orogen and E- to SE-ward lateral escape of continental blocks out of central Tibet. The transition mechanism from N-S compression to escape tectonics in Southeast Asia is the key for understanding of the Cenozoic tectonic evolution of Asia. Based on our field mapping, microstructure analysis and geochronological results in southern Tibet, the Namche Barwa syntaxis, Nepal Himalaya cross section and Yunnan province, we established a link between the Himalayan orogen and the Southeast Asian escape system. Here we represent (1) 3-D extrusion tectonics of the hot Greater Himalayan Complex (GHC) under N-S compression, (2) Eastward flow of the GHC in the Namche Barwa Syntaxis, and (3) Drawer-tectonics and crustal decoupling of the SE Tibet plateau.

(1) 3-D extrusion tectonics of the hot Greater Himalayan Complex (GHC) under N-S compression

The GHC in the Himalayan orogen consists of high-grade metamorphic rocks exhumed from the middle to lower crust, characterized by widespread migmatites and high-temperature deformation. The GH is regarded as the metamorphic core of the Himalayan orogen and represents a “hot” collisional orogeny during the Indo-Asian collision. Many 2-D models have been proposed to explain extrusion of the GHC between the South Tibet Detachment (STD) and the Main Central Thrust, including the wedge extrusion (e.g., Burchfiel and Royden, 1985; Grujic et al., 1996), channel flow (e.g., Beaumont et al., 2001; Hodges et al., 2001), and tectonic wedging (Webb et al., 2007, 2011). Based on field observations, kinematics analysis and geochronological data, we found widespread orogen-parallel ductile extension in the GHC in the late Oligocene and Miocene (Xu et al., 2013). The sub-horizontal mylonitic foliation and near E-W trending stretching lineation are well preserved in the upper part of the GHC, south to and structurally lower than the STD. The shear sense of the shear zones is predominant top-to-the-east (or NE) in the eastern Himalaya, but appears both top-to-the-west and top-to-the-east in the central Himalaya, and top-to-the-west in the Pulan area and top-to-the-east in the Gangotri area. The orogen-parallel extrusion occurred under upper-amphibolite (up to 650-700 ºC) to greenschist facies conditions. U-Pb ages of metamorphic zircon rims by SHRIMP and LA-MC-ICP-MS analyses yield 28-26 Ma for initiation of the Yadong and Nyalam shear zones, and 22-15 Ma for activation of the Pulan shear zone. In addition, $^{40}Ar/^{39}Ar$ cooling ages of biotite and muscovite suggest cessation of ductile sharing at 13-11 Ma on the Yadong shear zone, coeval with activation of the STD.

Combined with previous studies, we propose 3-D extrusion process of the GHC since the Oligocene as follows: (1) Initial partial melting of a thickened crust in the late Eocene (45-36 Ma), which resulted in a weak and hot middle crust in the proto-Himalaya; (2) Initial orogen-parallel gravitational collapse in the late Oligocene (28-26 Ma), (3) Coeval orogen-parallel extension and southward exhumation of the GHC in the Miocene (23-11 Ma).

The Namche Barwa Syntaxis in the eastern corner of the indented Indian plate is composed of amphibolite to granulite facies and migmatites, and separated from the Lhasa terrain by the bent Indus-Tsangbo suture zone. The active age of the NBS and its strike-slip boundary faults was coeval to lateral flow of the GHC, suggesting that the lateral flows of the GHC continued eastward to the eastern Himalaya syntaxis (Xu et al., 2012).

（2）Extrusion tectonic processes of the GHC

A Cross section of the Nepal-Himalaya showing an older ductile thrusting shear zone (TSZ) started at 26Ma by monozite at the lower part of the GHC (Carosi et al., 2010), and older than the MCT and STD (23-17Ma) (Godin et al., 2006). We found this ductile thrust zone with high-temperature quartz fabrics (> 650° C) and top-to-the-S shearing,which is a large-scale one occupied in almost total Great Himalaya and the upper part of Lesser Himalaya. New zircon U-Pb data from the mylonitic granitic gneiss in the upper part of the TSZ shows the initiated TSZ began at >31Ma and progressively migrated

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to the south.

Therefore, we suggested that extrusion tectonic processes of the GHC as following: (1) partial melting in 45-36Ma resulted in the weak and hot middle crust in the GHC, (2) orogen-parallel gravitational collapse occurred in the GHC at 28-26Ma, (3) High-temperature ductile thrusting occurred at 31- 26 Ma and progressively migrated to the south (4) Extrusion stage: thrusting on the MCT and normal faulting on the STD coexisted in the Miocene (23-17Ma).

(3) Drawer-tectonics and crustal decoupling of the SE Tibet plateau.

The SE Tibetan plateau (e.g. the Indochina block) displays an eastward-opened triangular shape that rotated clockwise around the NE corner of the Indian plate during the Indo-Asian collision. Two end-member models have been proposed for the Cenozoic deformation in this region: (1) Escape of rigid continental blocks by development of lithospheric strike-slip faults along boundaries (Tapponnier et al., 1982, 2001); (2) SE-ward flow of deep crust from Tibet (Clark et al., 2005). The northern Indochina block in western Yunnan province consists of the Simao, Baoshan and Tengchong terrains, which are separated by the steeply dipping Ailaoshan-Red River, Chongshan-Lancangjiang, Jiali-Gaoligong and Sagaing strike-slip shear zones from east to west, respectively. The activation time of the strike-slip shear zones in the Indochina block since 36 Ma has been determined by previous $^{40}Ar/^{39}Ar$ dating studies.

Based on new field observations and kinematic analysis, we recognized widespread sub-horizontal shear zones (décollement) in the Tengchong, Baoshan and Simao terranes in western Yunnan province, which reflect decoupling between the overlying Paleozoic sedimentary sequence and the Precambrian metamorphic basement. The penetrative stretching lineation of these décollements is nearly parallel to that in nearby steeply dipping strike-slip shear zones. $^{40}Ar/^{39}Ar$ cooling ages of biotite from gently dipping mylonites indicates the ductile deformation in the Dengchong décollement at 35-23 Ma, in the Baoshan décollement at ~20 Ma and in the Dianchanshan decollement at 23 Ma. These flat-lying shear zone were active coeval with strike-slip shear zones, such as the Yingjiang sinistral strike-slip shear zone (35 Ma), the Gaoligong dextral strike-slip shear zone (35-21 Ma), the Langcangjiang dextral (northern segment) / sinistral (southern segment) strike-slip shear zone (32-14 Ma), the Ailaoshan-Red River strike-slip shear zone (35-21 Ma), the Sagaing shear zone (35-15 Ma) and Nabang shear zone (43-20 Ma). Consistent shear senses of these décollements and strike-slip shear zones suggest the Baoshan and Simao terranes moved southward relative to the Yangze block to the east and the Tengchong terrane to the west.

Therefore we propose a drawer-tectonics model in the SE Tibetan plateau from Middle Eocene to Early Miocene. Decoupling between the hanging wall Paleozoic sedimentary sequence and footwall Protorozoic basement occurred during the strike-slip faulting. Large crustal blocks have been displaced E- or SE-ward on the flat-lying décollements between strike slip faults with opposite senses of movement, like drawers between their side walls. This crustal escape mechanism does not require lithospheric strike slip faults for continental escape, but raise the question on the relationships between crustal and lithospheric processes during continental collision.

Key words: continental collision, Greater Himalayan Complex, Namche Barwa, Indochina block, extrusion, decollement

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