Forum

Petrologic case for Eocene slab breakoff during the Indo-Asian collision: Comment and Reply

COMMENT

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Kohn and Parkinson (2002) proposed a conceptual model invoking Eocene slab breakoff to explain the generation of Eocene eclogites and Miocene leucogranites in the Himalaya and ''late Eocene K-rich magmas'' in southeastern Tibet. Kohn and Parkinson further argued that the slab breakoff and its resultant events have no direct implications for Tibetan topography. In comparison with the Himalayan eclogites and leucogranites that have ages and distribution that are both well documented, the occurrence of the late Eocene K-rich magmas in the Lhasa terrane, southeastern Tibet is now found to be problematic. Thus, the slab breakoff model that Kohn and Parkinson (2002) proposed satisfies only Himalayan geology and should be applied with caution when interpreting Tibetan magmatic and tectonic evolution.

Kohn and Parkinson's model is essentially based on two independent observations: (1) the Eocene eclogites from different parts of the Himalaya and (2) the late Eocene K-rich magmas from southeastern Tibet. The latter is solely based on our previous work (Chung et al., 1998), in which we dated 40 K-rich lavas from northeastern Tibet to define a magmatic duration ca. 40–30 Ma. We then correlated this late Eocene K-rich magma suite with its potential counterpart that appears to occur in southeastern Tibet; such a correlation, however, was made using only literature data (Bureau of Geology and Mineral Resources of Xizang Autonomous Region, 1993). Our recent work from southeastern Tibet indicated that igneous rocks there consist of Cretaceous to early Paleogene granitoids (the Gangdese Batholith) and associated volcanics (Lee et al., 2001; Lee et al., 2003). Those coined to be ''late Eocene'' or younger in the literature are virtually deformed and/or sheared granitoids, which are all confined to the dextral Jiali fault zone. The Gangdese Batholith represents an Andean-type magmatic arc resulting from northward Neo-Tethyan subduction. This arc magmatism ceased ca. 40 Ma. After an ~15 m.y. igneous quiescence period from the late Eocene to Oligocene, ultrapotassic and high-K calc-alkaline lavas formed in the Lhasa terrane between ca. 25 and 10 Ma (Coulon et al., 1986; Miller et al., 1999; Williams et al., 2001). Hence, there are no late Eocene K-rich magmas in southeastern Tibet.

Based on a more comprehensive observation of the tempo-spatial variations in Tibetan postcollisional magmatism, we propose two geodynamic events to have occurred in southern Tibet. These were breakoff of the Neo-Tethyan slab ca. 45 Ma and delamination of thickened Lhasa lithospheric root ca. 25 Ma. The former, which is constrained by onset of the hard collision between India and Asia (Lee and Lawver, 1995), corresponds to the petrologic evidence and timing discussed by Kohn and Parkinson (2002). However, we argue that the slab breakoff did not cause any Eocene K-rich magmas and resulted in substantial uplift in southern Tibet, although southern Tibet did not attain its present elevation until ca. 25 Ma, when thickened Lhasa lithospheric mantle was removed and replaced by the asthenosphere so that the ultrapotassic lavas formed by small degree melting of the remaining, enriched lithospheric mantle (Miller et al., 1999; Williams et al., 2001). The slab breakoff, moreover, may have accounted for the prevailing asthenospheric mantle signature observed in the youngest phase of the Gangdese granitoids, which, as depicted by Davies and von Blanckenburg (1995), is owing to replacement of the oceanic lithosphere by hotter asthenosphere, which could have induced stronger mantle convection and elevated mantle heat flow. Loss of the slab pull would have led to not only rapid exhumation of the Greater Himalayan rocks but also uplift of the entire orogen; i.e., where is now southern Tibet even though a high (3–4 km) but relatively narrow (~300 km) mountain range, similar to the central Andes, may have already existed in the region since Cretaceous time (Fielding, 1996). Voluminous sediments therefore eroded appear to have been deposited not directly in the foreland, but in the Bengal-Ganges-Brahmaputra and Indus-Pakistan sedimentary complexes. In the Ganges-Brahmaputra Delta, for example, sedimentation started to grow rapidly ca. 40 Ma with an increase in sediment flux and development of prograding clastic depositional sequences (Lindsay et al., 1991).

Lastly, we note that in the Lhasa terrane the Miocene high-K calc-alkaline lavas with compositions that show a significant contribution by crustal materials (Miller et al., 1999) are geochemically distinct from coeval leucogranites produced by Greater Himalayan crustal anatexis. This distinction supports the argument by Kohn and Parkinson (2002) that the leucogranites are not the extruded equivalent of modern partial melts in southern Tibet. The latter, if they do exist so extensively (Nelson et al., 1996), highlight a fundamental question of why such melts have rarely extruded along the north-south–striking normal faults widespread in southern Tibet where no magmatism has been identified since ca. 10 Ma.

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REPLY

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We thank Chung et al. (2003) for their comment, which permits further discussion of Indo-Asian tectonics. In our paper (Kohn and Parkinson, 2002), we presented three petrologic lines of evidence for slab breakoff, including (1) Himalayan eclogites, (2) partial melting of the Greater Himalayan Sequence, and (3) putative Eocene K-rich volcanic rocks in southeastern Tibet (Chung et al., 1998). We argued that the first two observations are necessary consequences of continental subduction and rapid exhumation, and that insofar as K-rich volcanic rocks are associated with several ultrahigh-pressure (UHP) terranes (Parkinson and Kohn, 2002), their reported occurrence in southeastern Tibet was consistent with slab breakoff. Chung et al. (2003) agree with us regarding the first two observations, but correct Chung et al. (1998) by noting that the ‘‘Eocene K-rich volcanic rocks’’ in southeastern Tibet are simply miscorrelated bodies of the Gangdese Batholith. If so, then we agree that the occurrence of these rocks is not good evidence for slab breakoff.

We believe there may yet be igneous evidence in the hinterland for Eocene slab breakoff, but on further review it has become unclear to us which rocks are truly best suited for testing this hypothesis. Compositional changes ca. 40–45 Ma within the Gangdese Batholith could reflect slab breakoff and asthenospheric upwelling (Chung et al., 2003). A. Yin (2002, personal commun.) also kindly suggested to us that evidence for Eocene slab breakoff may lie ~300 km due north of Nepal in the Paleogene Linzizong volcanic rocks, which are associated with the Gangdese Batholith. Another possibility is the 24–42 Ma, southeastern China and Indochina high-K intrusive and volcanic suite (Wang et al., 2001). Both Yin and Harrison (2000) and Wang et al. (2001) have argued that the Linzizong volcanic rocks and southeastern China and Indochina high-K rocks were influenced geochemically by continental subduction. The southeastern China and Indochina high-K rocks may, however, correlate with rocks of similar age and chemistry in the Qiangtang block, which are over 500 km north of the Greater Himalayan Sequence, much farther distant than ordinarily found in other UHP terranes. Finally, it is worth reiterating that Davies and von Blanckenburg (1995) predict that initiation of K-rich magmatism will post-date slab breakoff by 0–25 m.y. Thus, although we focused on Eocene rocks, the widespread initiation of K-rich igneous activity ca. 25 Ma in southern Tibet (e.g., Miller et al., 1999) may well be the delayed consequence of Eocene slab breakoff. In sum, Chung et al. (2003) agree with us that slab breakoff likely occurred in the late Eocene, with clear implications for eclogites and migmatites in the Himalaya, and for igneous activity in Tibet, but at least four igneous suites—the Gangdese Batholith, the Linzizong volcanic rocks, Eocene-Oligocene southeastern China and Indochina high-K rocks, and Miocene high-K rocks of southern Tibet—all have ages, chemistry, and proximities to the Greater Himalayan Sequence explainable in part by Eocene slab breakoff.

In the remainder of their comment, Chung et al. argue for two geodynamic events—slab breakoff ca. 45 Ma and lithospheric delamination ca. 25 Ma—both causing significant topographic uplift in southern Tibet. Tibetan geodynamics and topography were not major points of our paper, but are worth discussing. We agree this interpretation has logical consistency and may be correct. However, our original point was that occurrence of K-rich rocks may be consistent with delamination, but is insufficient to prove it, and hence is topographically inconclusive. There are certainly instances where K-rich volcanic rocks do not occur in high plateaus, e.g., in K-rich igneous provinces proximal to the Appalachian and Alpine orogens. Conversely, there are more definitive indicators of high topography and plateaus, such as oxygen isotope depletions in rainwater (e.g., Rowley et al., 2001) and monsoons (Dettman et al., 2001). Thus, if paleoelevations are to be linked to geodynamics, we favor stable isotope studies (e.g., Garzione et al., 2000; Dettman et al., 2001; Rowley and Currie, 2002) that have documented monsoons by 11 Ma, modern elevations (5 km) in the southern plateau as early as 15 Ma, and moderate elevations (up to 2 km) in the northern plateau by the Eocene.

Overall, Chung et al. (2003) agree with us on most of the main tectonic points, particularly the occurrence and timing of slab breakoff. Our disagreements center on Tibetan geodynamics, and the igneous and topographic consequences in Tibet. These issues fortunately are the focus of much ongoing research by several research groups, and presumably will be resolved shortly.

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