The Paleogene Latitude of Asia and the Proto-Tibetan Plateau

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The Himalayan-Tibetan orogen is one of the most distinctive topographic features on Earth, yet just how it is the product of intracontinental deformation caused by the India-Asia collision remains poorly understood. Importantly, how, where, and when the >1500 km of post-Early Eocene convergence between India and Asia is distributed throughout the orogen is crucial for determining the processes responsible for the remarkably high elevation, low relief, and thick crust of the Tibetan plateau. Most tectonic models for the surface uplift of the Tibetan plateau assume that crustal thickening began after the onset of India-Asia collision. Therefore, the age of collision between Indian and Asian crustal units, as well as the latitude of Asian crustal units throughout the Cenozoic, provide fundamental first-order constraints on tectonic development of the Tibetan Plateau.

The age at which collision began is currently debated, however. Here collision is defined as when Asian or ophiolitic detritus first appears in Tethyan Himalayan sediments, by the last marine deposition in the Himalaya, and when the paleolatitude of Greater India and Southern Tibet are statistically indistinguishable from each other. Paleogeographic reconstructions based on plate velocities determined from marine magnetic anomalies and geologic data are consistent with the interpretation that the leading edge of the Indian subcontinent (i.e., Greater India and the Tethyan Himalaya) collided with the southern margin of Asia at approximately 55±10 Ma. Previous paleomagnetic-based reconstructions, however, have led to estimated collision ages that range from 70 to 30 Ma. The large disparity between paleomagnetic-based collision ages is due largely to the poor quality or large uncertainty of existing paleomagnetic data from Asia, which typically are not corrected for sedimentary inclination shallowing, are poorly dated, and, in the case of volcanic rocks, do not sufficiently characterize the time-averaged behavior of the geomagnetic field (secular variation). Thus, the paleolatitude of Asian crustal units, from Southern Tibet to Central Asia, is poorly defined.

Here we present paleomagnetic data from well-dated Paleogene volcanic rocks from Southern Tibet, Central Tibet, and southern Mongolia to calculate the latitude of these Asian crustal blocks. We then use these paleolatitude calculations to refine the paleomagnetically-determined age of the collision between Greater Indian units and southern Asia, as well as Cenozoic upper-crustal shortening budgets for Asia. The paleomagnetic results presented here are free of inclination shallowing-biases and are the first Cenozoic volcanic data from the Tibetan Plateau and Central Asia with enough sampling units to average secular variation well enough to yield reliable paleolatitude estimates. In southern Tibet, 54-47 Ma lavas and tuffs from the Linzizong Formation ~50 km north of Lhasa indicate that the southern margin of Asia was 22.8±3.3°N latitude at approximately 50 Ma. Late Paleogene (~37 Ma) lavas from Central Tibet record a paleolatitude of 25.9±5.6°N, consistent with the paleomagnetic results from the Linzizong Formation and the structural record of upper-crustal shortening between Southern and Central Tibet. In southern Mongolia, 40-30 Ma lavas record a paleolatitude of 38.5±3.0°N. These paleomagnetic data from Mongolia indicate that stable Asia was located ~10° of latitude farther south in the late Paleogene than predicted from the Eurasian reference poles traditionally used to reconstruct the paleogeography of Asia. The geophysical mechanism for the discrepancy between the predicted and observed paleolatitudes for Mongolia is presently debated, but may be due to non-rigid behavior of the Eurasian lithosphere, small non-dipole geomagnetic fields, or a combination of these processes. Importantly, the paleomagnetic data from Mongolia suggest that the Eurasian reference poles do not correctly predict the Cenozoic paleogeography of Asia, and therefore are not suitable for reconstructing the Asian side of the India-Asia collision.

Paleolatitudes calculated from the 54-47 Ma Linzizong Formation and inclination-shallowing-corrected marine limestones from the Tethyan Himalaya imply that the paleomagnetically-determined age of collision between Southern Tibet and Greater Indian units occurred at approximately 48 Ma (95% confidence interval between 57 Ma and 40 Ma) at ~20±5°N latitude. These results are consistent with tomographic anomalies locating the India-Asia collision at 15-25°N latitude, and with independent 56-46 Ma collision age estimates inferred from the plate-velocity record for the Indian plate and from the age of a) high pressure metamorphism, b) end of marine sedimentation, and c) first occurrence of Asian detritus on the Greater Indian margin.

Moreover, the volcanic-based paleolatitude calculations for Tibet and Mongolia presented here suggest that there has been less than 700 km of convergence, or lithospheric shortening, between Central Tibet and Stable Asia since 40 Ma. Structural studies of mountain belts separating Central Tibet and Southern Mongolia indicate at least 360 km but probably not more than 500 km of upper crustal shortening between these regions. Thus, shortening budgets for the Tibetan orogen calculated from geologic and high-quality paleomagnetic studies are consistent and together suggest that intra-continental shortening of Asian lithosphere is on the order of a few 100s of km since 40 Ma, and not 1000s of km.

Furthermore, the southern margin of Asia is the late-stage product of plate convergence and terrane accretion throughout Central Asia that began in the Paleozoic. It is expected, then, that convergence-related intracontinental deformation and surface uplift of the Tibetan plateau may have begun much earlier than the India-Asia collision. Indeed, the last marine facies are replaced by non-marine deposystems throughout Southern and Central Tibet beginning in the Cretaceous (~120 Ma). The development of the Gangdese volcanic arc and associated retro-arc fold-and-thrust belt on the southern margin of Asia is the most likely cause for this pre-India-Asia collision phase of crustal thickening and surface uplift. Collectively, recent geological observations from the plateau interior and our new paleomagnetic-determined latitudes suggest that the southern margin of Asia may have been characterized by a high elevation, subtropical, continental plateau prior to the onset of the India-Asia collision.

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