Surface uplift of Tibet and Cenozoic global cooling

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Continental weathering on a global scale influences ocean chemistry and imposes a net drawdown of atmospheric CO₂ that modulates global climate (Walker et al., 1981; Berner et al., 1983). This observation, in addition to seawater Sr records that suggest an increase in continental weathering after ca. 40 Ma, led researchers to suggest that the uplift and erosion of the Himalayan-Tibetan orogen over the past 40 m.y. has drawn down atmospheric CO₂ and cooled the globe, leading to the glacial climate that persists today (e.g., Raymo and Ruddiman, 1992; Edmond, 1992). Modeling of tectonic-climate feedbacks associated with increased weathering of the Himalaya and Tibet suggests that two primary biogeochemical processes, silicate weathering and organic carbon burial, can account for the lowering of atmospheric CO₂ necessary to force global cooling (Raymo et al., 1988; Zachos and Kump, 2005). At the time of these inferences, accurate records of both atmospheric pCO₂ and the surface uplift history of the Himalaya and Tibet were lacking. Now, in light of a growing body of atmospheric pCO₂ reconstructions and paleoelevation records, we can test the theory that increased weathering associated with growing mountain belts leads to the drawdown of atmospheric CO₂ and global cooling.

The Eocene-Oligocene transition (EOT) at ca. 34 Ma marks the first major decline in Cenozoic global temperatures and the initiation of Antarctic glaciation. Critical to the argument that continental weathering has caused the drawdown of atmospheric CO₂ is documentation of the temporal relationship between the surface uplift of the Himalayan-Tibetan orogen relative to major cooling events, such as the EOT. Dupont-Nivet et al. (2008, p. 987 in this issue) and other researchers focused on the early elevation history of Tibet (Cyr et al., 2005; Graham et al., 2005; Rowley and Currie, 2006; DeCelles et al., 2007) to provide constraints on the timing and magnitude of the early surface uplift of Tibet (Fig. 1). Rowley and Currie (2006) and DeCelles et al. (2007) use stable isotope paleoaltimetry to show that central Tibet has been at an elevation similar to its modern elevation since ca. 40–26 Ma. Precise age constraints reported by DeCelles et al. (2007) indicate a minimum age of 26 Ma at which high elevations were obtained. However, neither of these studies documents a change in surface elevation that pinpoints the timing of surface uplift in central Tibet. Another paleoaltimetry study based on stable isotopes in the Hoh Xil basin of north-central Tibet (Cyr et al., 2005) suggests ≤2 km paleoelavation at a loosely constrained age of ca. 35–40 Ma. However, the ability to determine the precise timing of surface uplift of the Hoh Xil basin is limited by the poorly constrained ages of Hoh Xil lake deposits, large uncertainties in applying conventional stable isotope paleoaltimetry in northern Tibet (e.g., Quade et al., 2007), and the lack of a recorded increase in paleoelavation in the Hoh Xil basin. Yet another stable isotope study by Graham et al. (2005) documents a regional trend toward more positive δ18O values in Eocene to Oligocene time in the southern Tarim basin and western Qaidam basin, north of Tibet, which they attribute to anadification associated with the initial topographic growth of the Tibetan plateau. The lack of good age constraints on these Tarim and Qaidam basin deposits precludes the ability to discern whether this of the Tibetan plateau. The lack of good age constraints on these Tarim and Qaidam basin deposits precludes the ability to discern whether this of the Tibetan plateau. The lack of good age constraints on these Tarim and Qaidam basin deposits precludes the ability to discern whether this of the Tibetan plateau. The lack of good age constraints on these Tarim and Qaidam basin deposits precludes the ability to discern whether this...
correspondence between the seawater Sr curve and $p$CO$_2$ supports the inference that continental weathering imparts a significant effect on the drawdown of atmospheric CO$_2$. The observation that at least northeast Tibet in Cenozoic global cooling. Better resolution of the sedimentary records in marginal marine basins will provide more accurate reconstructions of the sedimentary flux from the Himalaya and Tibet (e.g., Clift, 2006) to evaluate whether long-term erosion rates were sufficiently high to impart a global effect on atmospheric CO$_2$. Recent studies of riverine Sr flux (Bickle et al., 2005, and references therein) have established a solid understanding of the relative contribution of silicate weathering versus carbonate weathering to the riverine flux of Sr to the oceans, and the conclusion for the Himalaya is that approximately half of dissolved Sr in Himalayan rivers is derived from silicates (Bickle et al., 2005). A remaining challenge is to understand the relative contribution of silicate weathering in the Himalayan-Tibetan orogen within the global silicate weathering budget.

REFERENCES CITED


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Figure 2. Cenozoic seawater Sr and paleoatmospheric CO$_2$ in ppmV (parts per million by volume). Sr curve is shown as black line (McArthur et al., 2001) inverted for comparison to the pCO$_2$ curve. Compilation of Cenozoic atmospheric pCO$_2$ proxy records (modified from Tipple and Pagani, 2007). Red circles with error estimates are from boron isotope records (Pearson and Palmer, 2000), yellow circles with error bars are from pedogenic carbonate records (Ekart et al., 1999; Royer et al., 2004), and the blue field shows the upper and lower estimates from alkenone records (Pagani et al., 1999, 2005). Timing of the Eocene-Oligocene transition (EOT) is labeled, and timing of the first appearance of conifers (inferred to reflect surface uplift) in northeast Tibet is labeled with a green bar.