Forum

Miocene semidiurnal tidal rhythmites in Madre de Dios, Peru: Comment

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Hovikoski et al. (2005) acknowledge that their results contradict Campbell et al. (2000) who described the Madre de Dios Formation in SW Amazonia as the last major cycle of Cenozoic continental deposition. Yet they propose that their rhythmite statistics settle the debate (also with Hoorn, 1996) that the sediments are of marine origin. However, Hoorn et al. believe Hovikoski et al. have not provided sufficient proof for the existence of a long-lived marine connection between Amazonia and the sea during the Late Miocene.

First, the stratigraphic positions of the sections Hovikoski et al. present are not comparable in age. The sediments described at Cocha Cashu are situated below the described regional unconformity and are thus undated and not necessarily Late Miocene, whereas Cerro Colorado is positioned above this unconformity and is presumably 9 million years old as proposed by Campbell et al. (2001).

Secondly, Hovikoski et al. base their interpretation of a tide-dominated, brackish-water estuary on sedimentological and ichnological data. Hoorn et al. agree that their evidence points to tidal cyclicity, but tidal features are not necessarily marine. Such features can also form in rivers, large lakes, and long, narrow embayments where the open-ocean tide can freely enter, especially when the dimensions of the basin allow tidal resonance amplification and/or the development of an amphidromic system (Sztanó and de Boer, 1995).

Tides, for instance, affect the present day Amazon River ~900 km inland near Obidos (Brazil), and tidal-flow reversal and associated deposits are known to occur hundreds of kilometers inland in low-gradient rivers. Tidal neap-spring erosion-sedimentation cycles have been documented >150 km upstream along the Seine River (France), a small high-gradient river (Guezennec et al., 1999). Tidal cyclicity is also generated within large continental water bodies such as the Great Lakes of North America (Ayers, 1962). Indeed, the geometry of the Miocene Amazonian embayment may have fallen within a "tidal amplification window" that could lead to resonant amplification and efficient inland propagation of semidiurnal ocean tides, but in its upper reaches such an embayment is not necessarily saline (Pickrill et al., 1981).

Both freshwater and restricted marine conditions are clearly discernable in Amazonian fossil assemblages. Pollen, mollusks, and fish from the middle to late Miocene Pebas Formation point to a freshwater system that was only occasionally affected by marine incursions (Hoorn, 1994; Monsch, 1998; Wesselingh et al. 2002). These conditions may also explain why Amazonia currently has an aquatic fauna with unique marine constituents such as dolphins, manatee, anchovies, stingrays, and needlefish. Brief marine influxes, creating 'empty' ecological niches, may have allowed normally marine lineages to invade and adapt to the freshwater conditions (Lovejoy et al., 2006).

In addition to this, strontium isotope data from outcrops at Pebas and other localities clearly indicate a freshwater environment of Andean and cratonic sources (Vonhof et al., 2003), as do the low values and clear seasonal cyclicity in $\delta^{18}O$ and $\delta^{13}C$ records in Pebasian bivalves. (Kaandorp et al., 2005). The only exception for the geochemical data is Buenos Aires (Colombia), which has a distinct brackish water signature. This leads us to believe that "mesohaline" trace fossils cannot be considered as definitive indicators of salinity.

Finally, the authors speculate about a marine connection between western Amazonia and southern South America based on the presence of a suite of foraminifera in the La Plata River region (Boltovskoy, 1991). However, there is no resemblance between Miocene and present freshwater mollusks from these regions (F.P. Wesselingh, 2005, personal commun.). Moreover, phylogenetic and biogeographic analyses of several fish groups suggest affinities between Amazonia and the Caribbean (Lovejoy et al., 1998, 2006).

In summary, Hoorn et al. agree with the evidence for tidal deposition, but caution that in shallow, flowing embayments, tidal features are not necessarily diagnostic for marine influence. Degree of salinity can more conclusively be identified by geochemical signatures of calcareous fossil assemblages. The taxonomic composition of fossil assemblages is also a reasonable indicator of salinity but must be treated carefully, because many taxa have both marine and freshwater representatives. Hoorn et al. maintain that Miocene Amazonia was predominantly a freshwater system with some tidal cyclicity, and only episodically subject to marine influence.

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