Forum

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

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Hoorn et al. commented on the following aspects of our 2005 Geology article: 1) the age of the sediments, 2) the interpreted brackish water affinity of the studied deposits, and 3) the possible connection between Paraná and western Amazonia depositional systems during the late Miocene.

Hoorn et al. suggest that the stratigraphically lower section (Cocha Cashu) may not be late Miocene in age. However, the mollusk fauna from this section suggest a late Miocene age (i.e., "post-Pebas;" Wesselingh, 2003). The chronostratigraphical knowledge of these strata will be further improved when the upcoming pollen analyses are completed.

Hoorn et al. also argue that tides do not necessarily indicate an oceanic connection, and state that tides also take place in such continental settings as large lakes (e.g., the Great Lakes). The tidal-lake scenario, which is often invoked in literature pertaining to Miocene western Amazonia (see Hoorn, 2006) is suggested without reference to the limited tidal range characteristic of closed systems. It is important to note that there are no noticeable astronomically controlled tides in the Great Lakes, nor in other modern closed or semi-closed basins (e.g., the Black Sea, Caspian Sea, and Baltic Sea) (Eisma et al., 1998). The theoretic spring tidal maxima in the Great Lakes is < 5 cm, which is masked by the greater fluctuations in lake levels produced by wind and barometric pressure changes (NOAA, 2005). Consequently, such a system (or an even larger one) is probably incapable of producing many of the tidal features observed in the Amazonian basin, such as widespread cyclic tidal rhythmites, centimeter-scale couplets in rhythmites, tidally influenced Upper Flow Regime deposits, and the dominance of tidal channel complexes in the sedimentary record (e.g., Rebata et al., in press). Moreover, a closed equatorial lake would probably have a diurnal tidal regime (de Boer et al., 1989). We report statistically verified semidiurnal tidal bundles.

We agree that proximal parts of funnel-shaped rivers or embayments that have a well-established connection to the ocean are a feasible explanation for most of the sediments we studied. These environments are sedimentologically termed as estuarine or delta-related systems, depending on the relative sea level change (Dalrymple et al., 1992). We suggested that most of the sediments we studied represent inner estuarine environments close to the inferred fluvio-tidal transition. Occasionally some of the facies display undisputed brackish water ichnofabrics indicating that, at times, more distal ("middle estuarine") conditions presided at various locales. Such low-diversity brackish water ichnofabrics are more widespread in the tidally and seasonally influenced inclined heterolithic stratification (IHS)–channel complexes in the adjoining Acre Sub-basin.

Hoorn et al. also questioned the value of ichnofossils in the delineation of palaeosalinity, and stated that they instead believed in isotope data from mollusc shells. We would like to clarify that there are no isotope data from these deposits. The referred isotope data that indicate a freshwater setting come from the early and middle Miocene levels of the Pebas formation that outcrops in northwestern Amazonia, 1000 km north of our study area. These isotope data pre-date the studied deposits by several million years. In addition, recent studies (Lorrain et al., 2005) have indicated that the isotope concentrations in mollusc shells are not fully controlled by environmental factors (e.g., salinity), indicating that care must be taken when applying these valuable data sets to palaeoenvironmental reconstructions.

Finally, Hoorn et al. state that a Miocene connection between Paraná and western Amazonia does not seem plausible. Yet both fossil faunal similarities between southwestern Amazonia and Paraná, as well phylogenetic analyses (e.g., on river dolphins), suggest that a Miocene hydrographic connection between these areas is feasible (e.g., Hamilton et al., 2001).

Recent studies show that late Miocene tidal/marine-influenced deposits outcrop widely over western Amazonia, Bolivia, and Argentina, indicating that an extensive ingression took place during that time (e.g., Hernández et al., 2005; Rebata et al., in press). These embayment strata are closely interbedded with pedogenically altered horizons that bear continental ichnofabrics and diverse continental fossil faunas. All the evidence points to a highly complex depositional system characterized by extremely low gradient and shallow accommodation space, which created high-frequency shifts of the shoreline. Multidisciplinary approaches are needed in order to gain a complete picture of the paleoenvironmental conditions of the Miocene Amazonia.

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