Kaolinite distribution in Paleocene/Eocene boundary strata of northeastern United States and Pakistan – climatic and stratigraphic implications

THOMAS G. GIBSON, LAUREL M. BYBELL, ELLEN THOMAS, and JAMES C. ZACHOS

During the latest Paleocene (upper part of calcareous nannofossil Zone NP 9), a relatively short-term increase in the intensity of weathering of continental source areas occurred in middle latitudes on both sides of the North Atlantic Ocean and in equatorial latitudes of the Indian Ocean. The intensified weathering involved warmer temperatures and/or a more year-round distribution of precipitation, which also may have involved an increase in total annual precipitation. The intensified weathering caused a large increase in the proportion of kaolinite in the clay mineral suite in soil profiles and thereby resulted in a large increase in the kaolinite proportion occurring in marine sediments derived from these source areas. Although kaolinite usually comprises a relatively small proportion (<5%) of the clay mineral suite in upper Paleocene deposits of the northeastern U.S. and Pakistan (usually considered essentially equatorial in the Indian Ocean at this time), kaolinite increases to as much as 60% of the suite near the end of the Paleocene before returning to 5% or less in the latest Paleocene–earliest Eocene.

The large kaolinite increase is present in uppermost Paleocene marine strata extending along the U.S. Atlantic Coastal Plain from New Jersey (Gibson et al. 1993) to southern Virginia. These deposits reflect influx via several river drainage systems and they suggest a widespread kaolinite-rich source area across the northeastern U.S. at this time. A large kaolinite increase also is present at similar latitudes in northwestern Europe (the North Sea and Spain) at this time (Knox 1998). The geographic extent in Pakistan of source areas with abundant kaolinite is uncertain. A kaolinite increase of lesser magnitude is present at or near this time interval in the Southern Ocean (Robert & Kennett 1994).

Kaolinite proportions are low in upper Paleocene strata located below the highly kaolinitic beds, and no enriched kaolinite-bearing sediment pulses are known from upper Paleocene strata prior to the large increase near the very end of the Paleocene. If long-term weathering over several million years had formed the kaolinite-rich soils, localized erosion of some of these kaolinite-rich deposits likely would have produced some earlier kaolinite-enriched sedimentary pulses in upper Paleocene marine strata. The absence of earlier significant increases in kaolinite, combined with the similar pattern and timing of the large increase and decrease of kaolinite on three widely separated continents, strongly suggests that both the formation of the kaolinitic-rich soil profile and its erosion were short-term events caused by the relatively short-lived intensive weathering and erosion in the upper part of Zone NP 9. Mixed-layer illite-smectite dominates clay mineral suites in the northeastern U.S. both before and after the high-kaolinite period, suggesting that more wet and dry seasonal climates prevailed here during much of the late Paleocene and early Eocene.

In shallow marine strata of the northeastern U.S., the beginning of the rapid kaolinite increase coincides with a large carbon isotope excursion (CIE), the benthic foraminiferal extinction, and substantial changes in the terrestrial and the marine flora, indicating that climatic conditions and events affecting land areas changed at approximately the same time as the events that affected the oceans and their biota. As at Site 690 in the Southern Ocean, all of these changes take place well below the lowest occurrence of *Rhomboaster bramlettei* (including *R. cuspis*); this relationship places the CIE and associated events in the upper part of Zone NP 9. The exact position of the CIE is uncertain in Pakistan because of probable diagenetic overprint on the calcareous microfossils, but the rapid kaolinite increase here coincides with other biotic and lithologic events typically associated with the CIE and the onset of the late Paleocene thermal maximum.

The pattern of a short-term kaolinite increase and subsequent decrease can be used for high-resolution stratigraphic correlation through the northeastern U.S. sections. The portion of the kaolinite pattern that is absent at some localities can be used to approximate the amount of the record removed by erosion. In many upbasin sections, only beds recording the increase in kaolinite are present; the disconformities present at the top of these truncated sections show that the higher beds that would record the peak kaolinite and subsequent declining values have been erosionally removed. The disconformities are common at or near the top of Zone NP 9 in the shallower water, more upbasin sections, and probably result from subaerial erosion during times of lowered sea level. These disconformities usually are overlain by lowermost Eocene strata placed in the lower to middle parts of Zone NP 10; this relationship illustrates a rapid erosional removal of the upper Zone NP 9 beds shortly after their deposition followed very soon by new marine deposition in Zone NP 10. The more downbasin sections, however, which represent deeper water, outer neritic to slope deposits, exhibit a different pattern. Uppermost Paleocene strata documenting the earlier part of the kaolinite pattern, the portion containing the increase from low to peak values, are absent at all downbasin localities. However, much of the record of the kaolinite decrease from peak values to subsequent low values is present in some of the downbasin sections. The beds containing the kaolinite increase were deposited during a time of rising sea level that would have ponded much of the incoming sediment in shallow water environments, resulting in condensed downbasin sections. The pervasive absence of all parts of these lower beds in downbasin sections, however, suggests that, in addition, submarine erosion was active on the outer shelf and slope during this time. The erosion presumably was by ocean currents active during this period of unusual warmth of high-latitude waters. The inference of active submarine current erosion during the late Paleocene thermal maximum contrasts with the common idea of sluggish deep-sea circulation during warm climate periods.

References

Gibson, T.G., Bybell, L.M. & Owens, J.P., 1993: Latest Paleocene lithologic and biotic events in neritic deposits from southwestern New Jersey. *Paleoceanography 8*, 495–514.

Knox, R.W.O'B., 1998: Kaolinite influx within Paleocene-Eocene boundary strata of western Europe (Extended abstract). *Newsletters on Stratigraphy 36*, 49–53.

Robert, C. & Kennett, J.P., 1994: Antarctic subtropical humid episode at the Paleocene-Eocene boundary: clay-mineral evidence. *Geology 22*, 211–214.

T.G. Gibson, Department of Paleobiology, National Museum of Natural History, MRC 121, Smithsonian Institution, Washington, DC 20560-0121 USA, fax +1-202-786-2832, gibson.thomas@nmnh.si.edu

L.M. Bybell, MS 926, U.S. Geological Survey, Reston, VA 20192 USA

E. Thomas, Department of Earth and Environmental Sciences, Wesleyan University, Middletown, CT 06457 USA

J.C. Zachos, Earth Sciences Department, University of California, Santa Cruz, CA 95064 USA