Palaeontologia Electronica
http://palaeo-electronica.org

LATE PALEOCENE—EARLY EOCENE CLIMATIC AND BIOTIC EVENTS IN THE MARINE AND TERRESTRIAL RECORDS

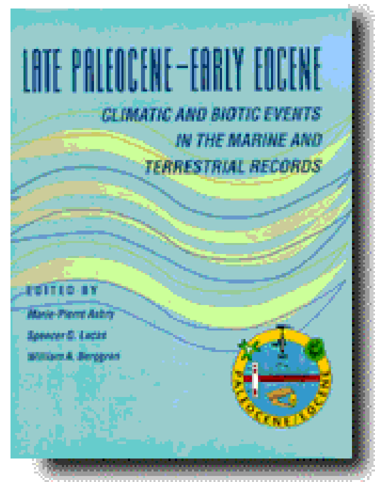
Reviewed by Stephen Schellenberg

Marie-Pierre Aubry, Spencer Lucas, and William Berggren (Editors)
Columbia University Press, New York, NY. 1998, p. 513
ISBN 0-231-10238-0, $105

The Strange Country

While everyone agrees that stasis is data, most would rather not study it. We are drawn to events of change, movement, and action by our animal instincts and hypermorphosed brains. Of course, we cannot observe past events directly, but we can see their resultant patterns. Thus, our challenge as historical scientists is to document these myriad patterns, order them in time and space, hypothesize the responsible processes, and test these hypotheses using the principles of historical science (sensu Simpson, 1963; Chamberlin, 1897). A number of workers have taken up this challenge to focus on a very strange mélange of patterns in the early Paleogene, and report their adventures in **Late Paleocene-Early Eocene Climatic and Biotic Events in the Marine and Terrestrial Records.**

Indeed, the Late Paleocene-Early Eocene (LP-EE) was a strange and pivotal time in Earth history. Climate was the warmest of the Cenozoic, particularly at high-latitudes, and imbedded within this long-term warmth was a rapid, large, and transient increase in global temperatures termed the Late Paleocene Thermal Maximum (LPTM). In the marine realm, planktonic organisms responded to the LPTM through major biogeographic shifts, short-term evolutionary events, and high taxonomic turnover, while the LPTM had a catastrophic impact on deep-ocean benthos, with a global, geologically instantaneous extinction of up to 50% of benthic foraminifera species. In the terrestrial realm, the LPTM coincided with the global extinction of numerous archaic mammal orders, the first North American and Eurasian appearances of many new mammal orders, and major perturbations in floral assemblages.



The title of the book aptly characterizes its coverage of the LP-EE: inclusive and long at 513 pages. The layout is well-produced by the authors and editors: Figures are generally of excellent design and quality, although some complex black-and-white figures would have benefited from coloration wasted on other fairly straightforward figures. Each chapter contains its own bibliography, and indexing is sufficient, with page numbers of entries addressed in appendices, figures, and tables helpfully marked as such by a, f, and t, respectively. The editors provide an introduction and overview chapter, including concise summaries and references on taxonomic groups not discussed elsewhere. The remaining 21 chapters are divisible into three "downstream" categories: chronostratigraphic control, environmental change, and biological response.

Schellenberg, Stephen, 2000. [Review of Aubry, Marie-Pierre, Spencer Lucas, and William Berggren (Editors), 1998. **Late Paleocene—Early Eocene Climatic and Biotic Events in the Marine and Terrestrial Records.** Columbia University Press.] **Palaeontologia Electronica,** vol. 3, issue 2, book review 3: 4pp., 193KB; http://paleo-electronica.org.

In Our Time

An obvious prerequisite for any historical reconstruction is a robust chronostratigraphic framework, without which local studies are the equivalent of a game of chess when the house is a mess. Chronostratigraphic aspects of the LP-EE are examined, warts and all, in three chapters. Bergreen and Aubry provide a detailed review of the tortuous history of the interval's chronostratigraphy, present the operational framework used throughout the book, and summarize the major bio-magnetochronological events and geochronological data upon which it is based. Aubry follows with a chapter on the dangers of wearing magnetochronological blinders to divide-and-conquer lithologic sections into high-resolution temporal records, which assumes these sections are "complete" and biochronological "errors" reflect diachroneity. Although her concerns are valid, Aubry essentially presents a special case of graphic correlation to illustrate a concept most workers appreciate: a total-evidence approach is the best means to discriminate unconformities from diachroneity. Flynn and Tauxe compile the major terrestrial and marine paleomagnetic records of the LP-EE, and apply some simple robustness measures to evaluate the often noisy data from which binary magnetozonations are decided. After reading this chapter, I will forever doubt the phrase "as plain as black and white."The Dangerous SummerA broad examination of LP-EE environmental change begins with chapters by Knox and Beck et al. on the role of tectonics. Knox focuses on North Atlantic tectonic and volcanic events that led to significant regional oceanographic isolation through Euro-American land-bridge formation, concluding that these events produced more regional than global environmental and biological effects. Beck et al. outline the various tectonic-driven processes that can increase or decrease pCO^2 at different temporal and spatial scales, and examine the potential role of the Indo-Asian orogeny in generating LP-EE warmth (i.e., high pCO^2). An intriguing working hypothesis is presented, but is highly dependent upon a collisional timing sequence that remains controversial.

The remaining chapters on environmental change have a more global focus. Rea reviews atmospheric dust records as a proxy for atmospheric circulation, whereas Corfield and Norris review oxygen and carbon isotope records as proxies for oceanographic circulation. Both atmospheric and oceanographic reconstructions of the LP-EE indicate a reduction in latitudinal thermal gradients and, during the LPTM, an even greater reduction accompanied by a shift in bottom-water production from high- to low-latitudes. Sloan and Thomas compare early Eocene "background" and LPTM "event" climates through ocean-atmosphere models. Each model is driven by fixed latitudinal sea-surface temperature gradients (estimated from planktonic foraminifera $\delta^{18}O$ values) to which all other climate parameters are forced to equilibrate. While most equilibrated model values are consistent with climatic principles and geological evidence, the models' results on bottom-water production are confounding to existing climate reconstructions: the early Eocene "background" climate appears more conducive to low-latitude warm saline bottom-water production than the LPTM "event" climate.Thus, something appears wrong with existing climate reconstructions and/or models of the LP-EE. Two possible explanations come to mind: First, tropical end-member sites for thermal gradient reconstructions are few and far between (e.g., limited in this study to only two as stressed by Sloan and Thomas), and recent modeling questions existing LP-EE tropical sea-surface temperature estimates from planktonic foraminifera (Huber and Sloan, 1999, 2000). Thus, reconstruction-model disagreement may reflect model input of overly flat estimates of latitudinal thermal gradients. Second, the two climate models may accurately reflect climate at equilibrium, but not the equilibration process as recorded in the sedimentary record. Higher-resolution stratigraphic studies may show that warm saline bottom-water formation slightly preceded the onset of the LPTM, with subsequent feedbacks during the LPTM eventually returning bottom-water formation to high-latitudes. Such disagreements between climate reconstructions and modeling results highlight the self-testing nature of science, and serve as guides for future research.

A Natural History of the Dead

The remaining bulk of the book examines biotic responses to LP-EE environmental changes. Coverage ranges from marine benthos (foraminifera by Thomas; molluscs by Dockery) and plankton (calcareous nannoplankton by Aubry; foraminifera by Boersma et al.; radiolaria by Sanfilippo and Nigrini; dinoflagellates by Bujak and Brinkhuis) to terrestrial flora (Wing) and fauna (mollusca by Hartman and Roth; vertebrates by Hutchinson, Gunnel, Hooker, and Lucas). Many chapters approach monographic depth and a number contain detailed appendices of stratigraphic and taxonomic data. Most authors move beyond documentation to infer ambient LP-EE environmental conditions from their respective group's biology, ecology, biogeography, and taphonomy. These biotic-based inferences address ocean bottom-water temperature, oxygenation, and corrosivity (Thomas), ocean mixed-layer temperature and nutrient concentration (Aubry, Boersma et al., Bujak and Brinkhuis), and terrestrial temperature and biome change (Wing, Hutchinson, Gunnel, Hooker). Geographic coverage tends to be more global for open-ocean microfossil groups compared to macrofossil groups from near-shore and terrestrial environments — largely an artifact of the relative ease of accessing widespread ocean drilling samples versus the long-term field investments in often regionally-restricted, land-based records. Of the many fossiliferous macroinvertebrate groups, only the molluscs are covered in detailed regional studies by Dockery (North American Gulf Coastal Plain) and Hartman and Roth (North American Western Interior). Other macroinvertebrate groups clearly have a tale to tell about the LP-EE, but one riddled with hiatuses and unconformities in the shallow-marine realm. To address these lithostratigraphic uncertainties, future biostratigraphic, sequence stratigraphic, and paleontological studies will likely capitalize more upon global geochemical patterns (e.g., 87/86Sr, 13C) to better constrain just “which letters, of which words, of which pages” of these groups’ tales are preserved in shallow-marine strata.

To Have and Have Not

The effectiveness of this compilation lies in its utility across a spectrum of interest levels. Specialists will find many chapters’ monographic treatments, well, a treat, whereas generalists can still walk away with the big picture and not get lost in the “X from the Yity of Zeeland” details. The book could even serve as the core of a upper-level undergraduate or graduate student case-study seminar — it covers nearly all aspects of near-surface processes and patterns as focused on a critical time interval in Earth history. Indeed, the chapters collectively epitomize the study of our planet as a complex system, cutting across the strange world of the early Paleogene from so many angles that many aspects integrate to consensus, whereas controversies and mysteries emerge as directives for future research.

After the Storm

This book owes part of its existence to the International Commission on Stratigraphy’s appointment of a working group, including many of the above chapter authors, to recommend a Global Standard Stratotype and Point (GSSP) for the Paleocene-Eocene boundary. Differences of opinion within and outside of this working group have produced more than one fracas in print and meetings, and numerous direct and indirect references to this ongoing controversy are found in the book. The argument arises from the confluence of multiple historical definitions of the base of the Eocene (Ypresian, Sparnacian Stages), the poor correlativity of both type-areas to one another and to other regions, and recent advances in geochronology and chronostratigraphy (including recognition of the powerful correlation potential of the LPTM 13C excursion). From an overly dichotomized, polarized, and simplified view, the issue boils down to what principles should serve to define the boundary: Some workers prefer strict adherence to a principle of historical priority, whereas other workers prefer utility over priority, embracing the distinct and global 13C excursion as a means to define a more universally recognizable boundary. Reviewing these arguments, the Paleogene Subcommission of the International Commission on Stratigraphy has recently reportedly voted in favor of defining the 13C excursion as the boundary for the Paleocene-Eocene Epoch, hence favoring correlative utility over historical priority (as directed by Cowie et al., 1996). The selection of a physical stratotype, however, remains another can of worms altogether.

REFERENCES

Chamberlin, T. C. 1987. The method of multiple working hypotheses. Journal of Geology 5:837-848.

Cowie, J. W., Zeigler, W., Bouchot, A. J., Basset, M. G., and Remane, J. 1986. Guidelines and statutes of the International Commission on Stratigraphy (ICS). Courier Forschungsinstitut Senckenbergiana 83:1-14.

Huber, M. and Sloan, L. C. 1999. Warm climate transitions: A general circulation modeling study of the Late Paleocene Thermal Maximum (~56 Ma). Journal of Geophysical Research 104:16,633-16,655.

Huber, M. and Sloan, L. C. 2000. Climatic responses to tropical sea surface temperature changes on a “greenhouse” Earth. Paleoceanography 15:443-450.Simpson, G. G. 1963. Historical Science. in Albretton, C. A. (ed.). The Fabric of Geology. Freeman, Cooper, and Company, Stanford, CA. pp. 24-48.
