reverse faults must still be considered both as significant hazards and partial sources of the observed geodetic and geological discrepancy.

Fortunately, these outstanding problems are tractable. Continued geodetic measurements using the SCIGN array will refine and reduce errors in estimates of fault motion. Palaeoseismic investigations may show whether the critical strike-slip faults move at the proposed high rates and whether past earthquakes have been clustered in time. Moreover, a wealth of new subsurface data recently made available by the petroleum industry is helping to define additional blind thrust faults and sources of hazard[8,10]. These advances in characterizing seismic sources are complemented by better methods of forecasting ground shaking and of planning emergency responses. It seems inevitable that, sooner or later, a large earthquake will occur in the Los Angeles area. Taken together, however, all of these approaches offer ways of mitigating the consequences. □

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1. Walls, C. *et al. Nature* **394,** 356–360 (1998).
2. Bock, Y. *et al. J. Geophys. Res.* **102,** 18013–18033 (1997).
3. Rubin, C. M., Lindvall, S. C. & Rockwell, T. K. *Science* **281,** 398–401 (1998).
4. Tapponnier, P. P., Peltzer, G., Le Bain, A. Y., Armijo, R. & Cobbold, P. *Geology* **10,** 611–616 (1982).
5. Dolan, J. *et al. Science* **267,** 199–205 (1995).
6. Stein, R. & Yeats, R. F. *Sci. Am.* **260** (6), 48–57 (1989).
7. Davis, T. L., Namson, J. & Yerkes, R. F. *J. Geophys. Res.* **94,** 9644–9664 (1989).
8. Shaw, J. H. & Suppe, J. *J. Geophys. Res.* **101/B4,** 8623–8642 (1996).
9. US Geologic Survey and SCEC Scientists *Science* **266,** 389–397 (1994).
10. Schneider, C. L., Hummon, C., Yeats, R. S. & Huftile, G. L. *Tectonics* **15,** 341–355 (1996).

Palaeontology

An Asian *Grande Coupure*

Jean-Louis Hartenberger

The more palaeontologists know about mammals from the Cenozoic era (65 million years, Myr BP, to present), the more convinced they are that these fauna have undergone two major turning points in the Northern Hemisphere. The first is marked by the dispersal and subsequent radiation of most modern orders of mammals, within continents, at the Palaeocene/Eocene boundary, 55 Myr BP. The second happened 20 Myr later, around 34 Myr BP, at the Eocene/Oligocene boundary (EOB). This second event has been documented on a much more global scale than the first and, on page 364 of this issue, Meng and McKenna[1] add a new cornerstone for understanding it. They give an overview of successive mammalian faunas in Mongolia, from the Palaeocene to the end of the Oligocene, and identify a large-scale extinction — the Mongolian remodelling — which occurred at roughly the same time as the EOB.

The story starts at the beginning of the century when Hans Georg Stehlin[2], a Swiss palaeontologist, tried to convince his colleagues at the Société Géologique de France that the EOB, as observed in the marine realm, could also be recognized on land. From his studies of European Palaeogene faunas, he showed that the large herbivores suffered a big break at about the same time as the EOB. This event — which he named the *Grande Coupure* (the big cut) — corresponds to an extinction/origination event whereby new immigrants of Asian origin replaced most of the (old) endemic Eocene genera of Europe.

In 1966, Louis Thaler[3] emphasized the point by showing that, at around the time of the EOB, rodent biotas in Europe were enriched by Asian forms. A few years later, I proposed[4] that the shift from a warm to a cooler climate at the end of the Eocene must have been a factor in this European event. Then, as debates about mass extinctions expanded after Alvarez and colleagues[5] published their paper on the iridium and mass-extinction events at the Cretaceous/Tertiary boundary, those who studied the EOB decided to ask exactly what happened at the end of the Eocene. Most of them thought — and still think — that the boundary corresponds more to a transition than to a single catastrophic event. Nevertheless, at a symposium[6] held in 1985 it was proposed that the EOB should be labelled the 'terminal Eocene event' (TEE), a name suggestive of a single event.

On a global scale, the TEE is marked by a climatic crisis that probably started with glaciation in the Antarctic Ocean and led to climate change in the Northern Hemisphere. In 1989, North American mammalian faunas were recalibrated and it was shown[7] that important changes also occurred in this area, with a stepwise pattern near the EOB. So, Central Asian invaders were thought to have played a big part in the reworking of European and North American faunas, allowing many Asian families and genera to reach a cosmopolitan status.

With the synthesis of Meng and McKenna[1], which embraces a review of the available fossil record and recalibration of Mongolian formations, we can now appreciate what consequences the misnamed TEE had for the evolution of Central Asian faunas. The authors find that after the many sizes of mammal that existed in the warm Eocene, small rodents and lagomorphs (hares and rabbits) predominated in the Oligocene. These mammals were more adapted to the arid and cool environment of the Oligocene and, in many ways, these changes were very like the European ones[8].

Many questions remain. For example, how quickly did these species evolve, and what units of evolution are most influenced by climatic change? In Europe, there was a considerable change in the structuring of mammalian communities at the time of the TEE, so the *Grande Coupure* is not only a consequence of an Asian invasion[8]. In North America, there is much debate as to whether the climatic changes of the TEE have any influence on how long mammalian species existed, and whether evolutionary changes showed a bimodal pattern — long periods of stability interrupted by rapid evolutionary restructuring[9,10].

In my opinion, the most interesting question about the EOB lies in Africa and concerns our own family, Anthropoidea. The best fossil record that we have of its early radiation comes from the Palaeogene Fayoum deposits in Egypt[11]. But what is the precise age of this rock formation? Were our early relatives born before or after the TEE? And did the climatic events of the TEE affect our origins? Because the position of the EOB is controversial in the Fayoum deposits[12,13], the best way to resolve this debate would be to look at other places in the southern margin of Tethys (which includes all of the countries from Morocco to Egypt, and part of Arabia). To work out when and why our very old ancestors emerged, we need more information on the Eocene-to-Oligocene history of mammals in Africa — only then should we know if the TEE had some influence on our evolution. □

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1. Meng, J. & McKenna, M. C. *Nature* **394,** 364–367 (1998).
2. Stehlin, H. G. *Bull. Soc. Géol. Fr.* **9,** 488–520 (1909).
3. Thaler, L. *Mém. Mus. Hist. Nat. 3e sér. Sciences de la Terre* **17,** 1–295 (1966).
4. Hartenberger, J.-L. *Bull. Mus. Hist. Nat. Paris, 3e sér. Sciences de la Terre* **24,** 49–70 (1973).
5. Alvarez, L. W., Alvarez, W., Asaro, F. & Michel, H. V. *Science* **208,** 1095–1108 (1980).
6. Pomerol, C. & Premoli-Silva, I. R. (eds) *Terminal Eocene Event* (Elsevier, Amsterdam, 1986).
7. Prothero, D. R. in *Mass Extinctions: Processes and Evidence* (ed. Donovan, S. K.) (Columbia Univ. Press, New York, 1989).
8. Legendre, S. *Münchner. Geowiss. Abh.* **16,** 1–110 (1989).
9. Prothero, D. R. & Heaton, T. H. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **127,** 257–283 (1996).
10. Alroy, J. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **127,** 285–311 (1996).
11. Gagnon, M. *J. Hum. Evol.* **32,** 133–160 (1997).
12. Kappelman, J., Simons, E. L. & Swisher, C. C. I. *J. Hum. Evol.* **22,** 495–503 (1992).
13. Gingerich, P. D. *J. Hum. Evol.* **24,** 207–218 (1993).