
Climate and Biota of the Early Paleogene: recent advances and new perspectives

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The Paleogene is a period of the Earth History in which the close interaction between global climate and biological evolution can be clearly perceived. For one thing, it was the most recent period when a warm “greenhouse” climate prevailed on Earth. The warm climate climaxed in the early Eocene, when subtropical forests spread up to latitudes above 60°. A gradual cooling followed that led to the first appearance of continental ice sheets in Antarctica around the Eocene-Oligocene transition. Superimposed on this general trend, there occurred several short-lived, transient climatic perturbations called hyperthermal events. The most prominent of them, so-called the Paleocene/Eocene thermal maximum (PETM), was a comparatively short episode (ca. 200 kyr) of extreme global warming characterized by a 2-6‰ negative carbon isotope excursion in terrestrial and marine records indicative of a rapid addition of large amounts of isotopically light carbon to the ocean-atmosphere carbon reservoir. The concurrence of this transient event with major faunal and floral turnovers in continental, shallow-marine and deep-marine realms suggests that short-term climatic perturbations may have been of fundamental importance in the evolution of the biosphere, and this fact has fostered a renewed interest in the study of the climate and biota interactions. Indeed, the PETM is regarded as a natural experiment that can be used to predict the long-term effects on global climate of the present-day anthropogenic carbon input to the atmosphere, and its effects on the modern biota.

The Paleogene was also a time of profound reorganization in the biosphere, following the important Cretaceous-Paleocene (K-P) catastrophic extinction. On land,

the demise of large dinosaurs and the warm climate prompted a radiation of mammals, which evolved from small and relatively primitive forms to large and complex animals that colonized a wide range of ecological niches, including aquatic and aerial environments (Rose and Archibald, 2005). Also on land, the warm climate allowed the expansion of subtropical flora to 60°N. In the seas, the recovery of the biota was slow during Danian times (with some exceptions, such as corals; see Baceta et al., 2005), but it accelerated after the mid-Paleocene in parallel to global warming and overall transgressions. Planktonic foraminifera and calcareous nannoplankton, which were nearly extinguished at the K-P boundary, again diversified and expanded in the oceans (Berggren and Norris, 1997; Aubry, 1998; Berggren and Pearson, 2005). In shallow seas, larger foraminifera multiplied, increased in size and extended their geographic range to middle latitudes from mid-Paleocene to early Lutetian, and then declined owing to cooling temperatures (Hottinger, 1998).

Recent advances in the understanding of the above-mentioned interactions were presented and discussed in the International Meeting “Climate and Biota of the Early Paleogene 2006” (CBEP2006), held in Bilbao in June 2006, and in a follow-up International Workshop of the Paleocene Working Group of the International Subcommittee on Paleogene Stratigraphy (ISPS) held in Zumaia in June 2007. The scientific sessions of the CBEP2006 were attended by 148 scientists from 26 countries of all continents (Fig. 1). Such participation was larger than in any of the earlier Meetings on the same theme celebrated

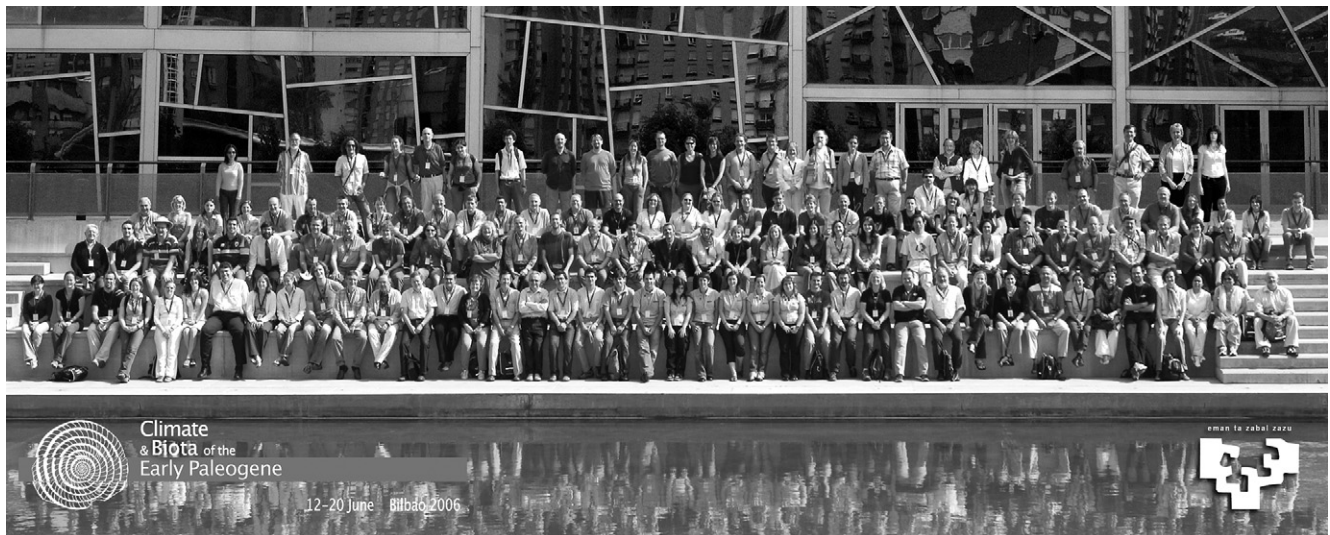


FIGURE 1 | Group photo of the participants in the Climate and Biota of the Early Paleogene International Meeting (CBEP2006), celebrated in Bilbao in June 2006.

since 1989 in Albuquerque (USA), Zaragoza (Spain), Paris (France), Goteborg (Sweden), Powell (Wyoming, USA) and Luxor (Egypt), and attests to the increasing interest of the scientific community in the Paleogene climate and biota. The scientific sessions included 64 oral presentations and 92 poster presentations (Caballero et al., 2006).

More than half of the oral presentations, and several poster presentations, focused on the so-called hyperthermal events (Fig. 2), particularly on the important floral and faunal turnovers and/or migrations associated with the PETM. For instance, Jaramillo et al. (2006) demonstrated that its impact on the tropical flora was particularly severe while Wing et al. (2006) documented important floral changes in the middle-latitude Bighorn Basin coeval to the event; Gibbs et al. (2006), Petrizzo (2006), and Pujalte et al. (2006) discussed its effects in the marine realm, as respectively recorded by the calcareous nannoplankton, the planktonic foraminifera and the larger foraminifera. Other presentations addressed physical consequences of the PETM, such as the possible increase in storm activity brought about by the rapid warming (Huber, 2006), the sea-level changes associated with the event (Speijer, 2006), or its influence on the evolution of carbonate platforms (Scheibner et al., 2006); further, Collinson et al. (2006) provided strong evidence of extensive wildfires in Britain at the onset of the PETM, and Pujalte and Schmitz (2006) presented empirical evidence from the Pyrenees indicative of a coeval dramatic increase in the intensity of the hydrological cycle. Roelh et al. (2006) finally gave an improved estimate of the duration of the PETM. The remainder Paleogene hyperthermals were discussed in several other talks and posters, including Bernaola et al.

(2006), Clyde et al. (2006), Coccioni et al. (2006), Galeotti et al. (2006), and Quillevère et al. (2006), among others.

Many other aspects of Paleogene Climate and Biota were treated during the Meeting. For instance, Dinarès-Turell et al. (2006) and Westerhold et al. (2006) presented improved astronomical calibrations of the Paleocene time scale; other authors focussed on the analysis or definition of specific boundaries, particularly on the Cretaceous-Paleogene (Alegret and Thomas, 2006;), the Danian-Selandian (Rodríguez and Aubry, 2006; Sprong et al., 2006), the Ypresian-Lutetian (Orue-Etxebarria et al., 2006), the Bartonian-Priabonian (Río et al., 2006) and the Eocene-Oligocene (De Man et al., 2006). A sizable number of papers were based on deep-sea drilling boreholes and the rest provided data from outcrops of Spain, France, Italy, North America, but also from Argentina, Armenia, Bulgaria, the Caucasus, Egypt, India, Iraq, Tunisia, New Zealand and western Siberia, between other areas. The final oral session of the Meeting included six talks centred on the northern high-latitude Paleogene record: three of them (Eldrett et al., 2006; Tripathi et al., 2006; Heilmann-Clausen et al., 2006) presented evidence for a late Eocene glaciation, and the other three were based on data from a deep-sea borehole recently completed in the Lomonosov ridge, in the Arctic Ocean (Brinkhuis et al., 2006; Pagani et al., 2006; Sluijs et al., 2006). Despite the wide variety of topics treated during the Meeting, and of its single-session format, both the oral and the poster sessions were fully attended. Indeed, the Meeting was an efficient forum to promote cooperation and expertise exchange among different specialists.

Three field trips were organized in connection with the CBEP 2006, including one to the classical Zumaia

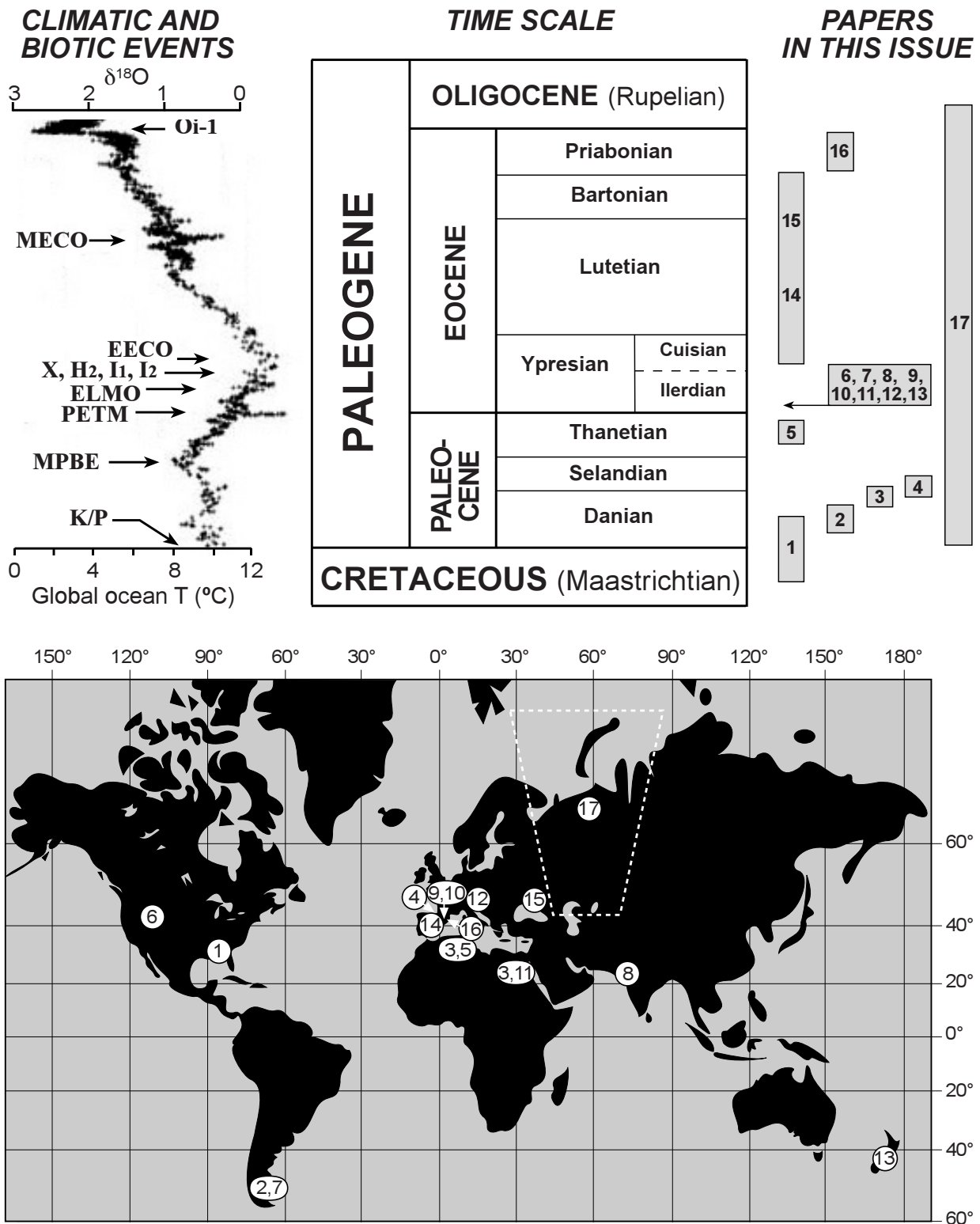


FIGURE 2 | Chronostratigraphical and geographical distribution of the papers included in this special issue: 1) Schulte et al. 2) Scafati et al. 3) Sprong et al. 4) Bernaola et al. 5) Stassen et al. 6) Anemone and Dirks 7) Raigemborn et al. 8) Tripathi et al. 9) Pujalte, Schmitz et al. 10) Pujalte, Baceta et al. 11) Scheibner and Speijer 12) Egger et al. 13) Villasante-Marcos et al. 14) Badiola et al. 15) Zakrevskaya et al. 16) Cascella and Dinarès-Turell 17) Akhmetiev and Beniamovski. Paleogene global ocean temperature curve after Zachos et al. (2001). KEY: K-P, Cretaceous-Paleogene boundary; MPBE, Mid-Paleocene biotic event (after Bernaola et al., 2008). PETM, ELMO, X, H₂, I₁ and I₂, Eocene hyperthermals (mainly after Zachos et al., 2001, and Nicolo et al., 2007); EECO, Early Eocene Climatic Optimum; MECO, Middle Eocene Climatic Optimum; Oi-1, Oligocene isotopic event.

section, which started with the official inauguration of the Algorri Interpretation and Research Centre, a facility of the Zumaia Town Council to assist and promote research in the section. The field trip itself included an inspection of the Cretaceous–Paleogene and the Paleocene–Eocene boundaries, and also a discussion of the possible placement of the Danian–Selandian and Selandian–Thanetian global stratotype boundaries, for which Zumaia was the leading candidate. That candidature was formally presented in the International Workshop of the Paleocene Working Group organized at Zumaia in June 2007 by B. Schmitz, X. Orue-Etxebarria and V. Pujalte. After two days of constructive discussions the workshop participants held a vote with the unanimous result to place the Global Stratotype Section and Point (GSSP) of the Selandian and Thanetian stages in the Zumaia section (see front cover of this issue). [The proposal (Schmitz et al., 2008) was then successively approved by the ISPS in April 2008, by the International Commission on Stratigraphy in June 2008, and was ratified by the International Union of Geological Sciences in September 23, 2008].

Several of the presentations in the CBEP2006 were based on papers published, just before or after the Meeting, in highly rated periodicals, including *Nature*, *Science*, *Geology* or *Earth and Planetary Science Letters* (e.g., Wing et al., 2005; Brinkhuis et al., 2006; Jaramillo et al., 2006; Pagani et al., 2006; Sluijs et al., 2006; Bernaola et al., 2007; Collinson et al., 2007; Dinarès-Turell et al., 2007; Eldrett et al., 2007; Gibbs et al., 2007; Roehl et al., 2007; Schmitz and Pujalte, 2007; Quillevère et al., 2008; Westerhold et al., 2008). Another twenty-six presentations were submitted to *Geologica Acta*, of which 17 passed the peer-reviewing process and are included in this special issue in, approximately, “stratigraphic” order (Fig. 2).

The first 6 papers of this volume mainly deal with Paleocene deposits: Schulte et al. (this issue) investigate, in a core in central Alabama, Danian (and Maastrichtian) paleoenvironmental and sea level changes in the Gulf of Mexico margin, by means of a multi-proxy approach involving benthic foraminifera and major and trace element data. Scafati et al. (this issue) describe a rich, freshwater Danian palynological assemblage from northern Patagonia, Argentina, indicative of humid, warm climatic conditions. Sprong et al. (this issue) attempt to clarify the taxonomy of the planktic foraminifera *Igorina albeari*, using its lower occurrence as a correlation tool in Mid-Paleocene sections from Tunisia and Egypt. Bernaola et al. (this issue) discuss the calcareous nannofossil biostratigraphy of the Danian/Selandian transition at Zumaia, a study that greatly contributed to the decision to place the GSSP for the

Selandian Stage in this section. Stassen et al. (this issue) unravel the late Paleocene paleoenvironmental conditions in shallow marine settings of Central Tunisia through analysis of calcareous nannofossils, ostracods, benthic foraminifera and stable isotopes. Lastly, Anemone and Dirks (this issue) report a new Clarkforkian (i.e. Thanetian) mammalian fauna from the Great Divide Basin (S Wyoming) that differs from coeval assemblages of the Bighorn Basin (N Wyoming), and discuss possible reasons for such differences.

The following 7 papers of the volume are focused on the study of records of the Paleocene–Eocene transition, including the PETM: Raigemborn et al. (this issue) present clay mineral and paleobotanical data from a non-marine succession of central Patagonia, Argentina, indicative of a shift in climatic conditions across the Paleocene–Eocene boundary. Tripathi et al. (this issue) report palynofloral assemblages of a 32-m thick Paleocene–Eocene succession of Rajasthan (India) dominated by angiospermic and *Nypa*-like pollen indicative of a coastal swamp environment surrounded by mangroves. The two papers by Pujalte et al. (this issue) are based on field and stable isotopic data from carbonate soil nodules of continental and transitional settings of the southern Pyrenees. These papers respectively discuss the correlation between the PETM and the Ilerdian turnover of larger foraminifera, and the implication of such correlation on the definition of the base of the Ilerdian Stage. Scheibner and Speijer (this issue) use data from a platform-to-basin transect in the Galala Mountains to demonstrate that, also in Egypt, the Ilerdian turnover of larger foraminifera coincides with the PETM. Egger et al. (this issue) compare Paleocene–Eocene boundary sections from different marine depths in Austria and show that the PETM event was preceded by a prominent sea-level fall. Finally, Villasante-Marcos et al. (this issue) provide data from New Zealand. They explain the rock magnetic properties of three PETM outcrop sections by an increase in terrigenous discharge linked to an acceleration of the hydrological and weathering cycles during the PETM.

Eocene biotas are discussed in 3 papers: Badiola et al. (this issue) summarize new Eocene mammalian discoveries in western and northeastern Iberia and suggest that the Iberian Peninsula was one of the dispersal routes for some Eocene mammal faunas that appeared in Central Europe during the Middle and Late Eocene. Zakrevskaya et al. (this issue) use planktic and larger foraminifera from two sections in the Western Caucasus to refine the intercalibration of the biostratigraphic scales of both types of organisms in the late Ypresian–middle Lutetian interval. And Cascella and Dinarès-Turell (this issue) for the first time report unambiguous Priabonian marine

deposits on the southeastern Pyrenean basin based on magnetostratigraphic and unprecedented calcareous nanofossil data.

In the last paper, Akhmetiev and Beniamovski (this issue) document the entire Paleogene paleoflora evolution in northern Central Eurasia and explore the impact caused by the closure of a N-S trending early Cenozoic epicontinental seaway, which connected Tethyan and Paleoarctic water masses, on climatic conditions in north Eurasia.

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