PLANKTIC FORAMINIFERAL BIOSTRATIGRAPHY ACROSS THE PALEOCENE/EOCENE BOUNDARY : EVENTS AND CORRELATIONS

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A study of planktic foraminiferal assemblages of different sections in the Tethys and North Atlantic realms allows us to to revise the biostratigraphical zonations and to establish the correlation among biozones, sections and the geochronological time scale of Berggren *et al.* (1995). Many sections were studied in Belgium, Bay of Biscay, France, Israel, Italy, Kazakstan, Spain and Tunisia in order to search for the Paleocene/Eocene (P/E) Boundary Stratotype. The best ten sections were studied at high resolution and their results are summarized in this synthesis. Other sections, such as the Ypresian stratotype in Belgium (Pardo *et al.*, 1994) and the Aïn Settara section in Tunisia, have low planktic foraminiferal richness and were not included in this synthesis, although their results were taken into consideration. The best studied sections are located in Spain (Alamedilla and Caravaca in the Betic Cordillera and Zumaya, Campo and Tremp in the Pyrenees), the Bay of Biscay (DSDP Site 401), Italy (Bottaccione and Possagno), Israel (Ben Gurion) and Kazakstan (Kaurtakapy).

The quantitative study of the planktic foraminifera in all these sections allows us to identify several datum events along the P/E transition. These events are: first occurrence (FO) of *Muricoglobigerina soldadoensis*, last occurrence (LO) of *Luterbacheria pseudomenardii*, LO *of Igorina laevigata*, FO of *Acarinina berggreni*, *Acarinina sibaiyaensis* and *Acarinina africana* apparently simultaneous. LO of *Morozovella velascoensis* and FO of *Morozovella formosa*. These events have been used to recognize the biozonation of Berggren *et al.* (1995) that have been modified by Pardo *et al.* (in press) subdividing the P5 zone in two subzones: P5a of *Luterbacheria pseudomenardii-Acarinina sibaiyaensis* and P5b of *Acarinina sibaiyaensis/Morozovella velascoensis*. Some of these events have been used to establish the biozonation of Arenillas and Molina (1996) that have been slightly modified in this paper subdividing the *Luterbacheria pseudomenardii* in two biozones: *Luterbacheria pseudomenardii* Biozone and *Muricoglobigerina soldadoensis* Biozone. These subdivisions are useful in order to have a more detailed biostratigraphical scale for correlation between different regions and basins.

The planktic foraminiferal faunal turnover across the P/E boundary is quite gradual except at the benthic foraminiferal extinction event (BFEE) horizon. This extinction of the bathyal and abyssal small benthic foraminifera has been found in all deep sea sections just below a dissolution clay interval. This relevant extinction event and the concomitant lithological change from marls to clay constitutes an apparently very isochronous datum, which would be very suitable for the definition of the P/E Boundary Stratotype (Molina, 1996). The BFEE coincides with the LO *of Igorina laevigata* and the beginning of the increase of acarininids. In this interval, coincindent with the BFEE, an acarininid extra-tropical excursion is observed in middle and high latitudes. This excursion indicates increased sea waters temperatures coincident with the dissolution interval. The FO of the new acarininids (*A. africana, A. berggreni* and *A. sibaiyaensis*) is found just above the dissolution clay. An increase of the chiloguembelinid population has been found also above the dissolution clay, indicating hypoxic conditions in intermidiate waters.

The Caravaca section consists of marls at the P/E transition and it is not well exposed. Its foraminiferal assemblages were first studied by Von Hillebrandt (1974) establishing the correlation between planktic and large benthic. Later on, this section was evaluated as a potential P/E boundary stratotype by Molina *et al.* (1994) based on a high resolution and integrated stratigraphical study. Planktic foraminifera are very abundant and quite well preserved but this section is not optimal as potential stratotype for the P/E boundary, mainly because the likely presence of a short hiatus 2.5 m below the BFEE.

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The Alamedilla section is probably the best exposed and most continuos section in Spain. The preservation is not as good as in Caravaca, but planktic foraminifera are abundant (Arenillas and Molina, 1996) and have been correlated with the isotopic and sediment compositional changes (Arenillas *et al.*, 1996; Lu *et al.*, 1996). All the biozones from *M. soldadoensis* to *M. formosa* are present and there is no evidence of hiatuses in the P/E transition. A very distinctive red clay interval marks the BFEE at the bottom and the extra-tropical excursion at the top. Nannofossils and magnetostratigraphy are currently under study.

The Zumaya section is a quite expanded section especially from the *M. subbotinae* Biozone which consists of about 120 m of marl and calcarenitic sediments. Nevertheless, the P/E transition is not so calcarenitic and expanded. Von Hillebrandt (1965) first published the biostratigraphy of the whole section based on planktic foraminifera. Planktic foraminiferal faunal turnovers and bio-chronostratigraphy of the P/E transition were studied by Canudo and Molina (1992) and Canudo *et al.* (1994). The high-resolution iridium, isotopic, nannofossil and foraminifera correlations have been establish by Schmitz *et al.* (1997).

The Campo section constitutes the parastratotype of the Ilerdian stage and consists of platform facies at the base. The section is extremely expanded with a 70 m thick *M. velascoensis* Biozone (Arenillas and Molina, 1995). Although planktic foraminifera are scarce their assemblages were studied by several authors (Von Hillebrandt, 1965; Molina *et al.*, 1989; Canudo *et al.*, 1989). Many other microfossil groups are abundant (e.g., alveolinids, nummulitids, ostracodes, dinoflagellates, etc.) and the integrated stratigraphy across the P/E boundary have been revised and refined by Molina *et al.* (1992).

The Tremp section is the stratotype of the Ilerdian stage and consists of a shallow marine transgressive-regressive megasequence intercalated within terrestrial facies. Scarce planktic foraminifera are only present just in the middle part of the section, which represents the P-E transition. Planktic foraminiferal assemblages were studied by Gartner and Hay (1962), Von Hillebrandt (1965), Blow (1979) and Molina *et al.* (1992; 1995). The Tremp and Campo are very good reference sections for correlation between shallow environments and the deep see sections.

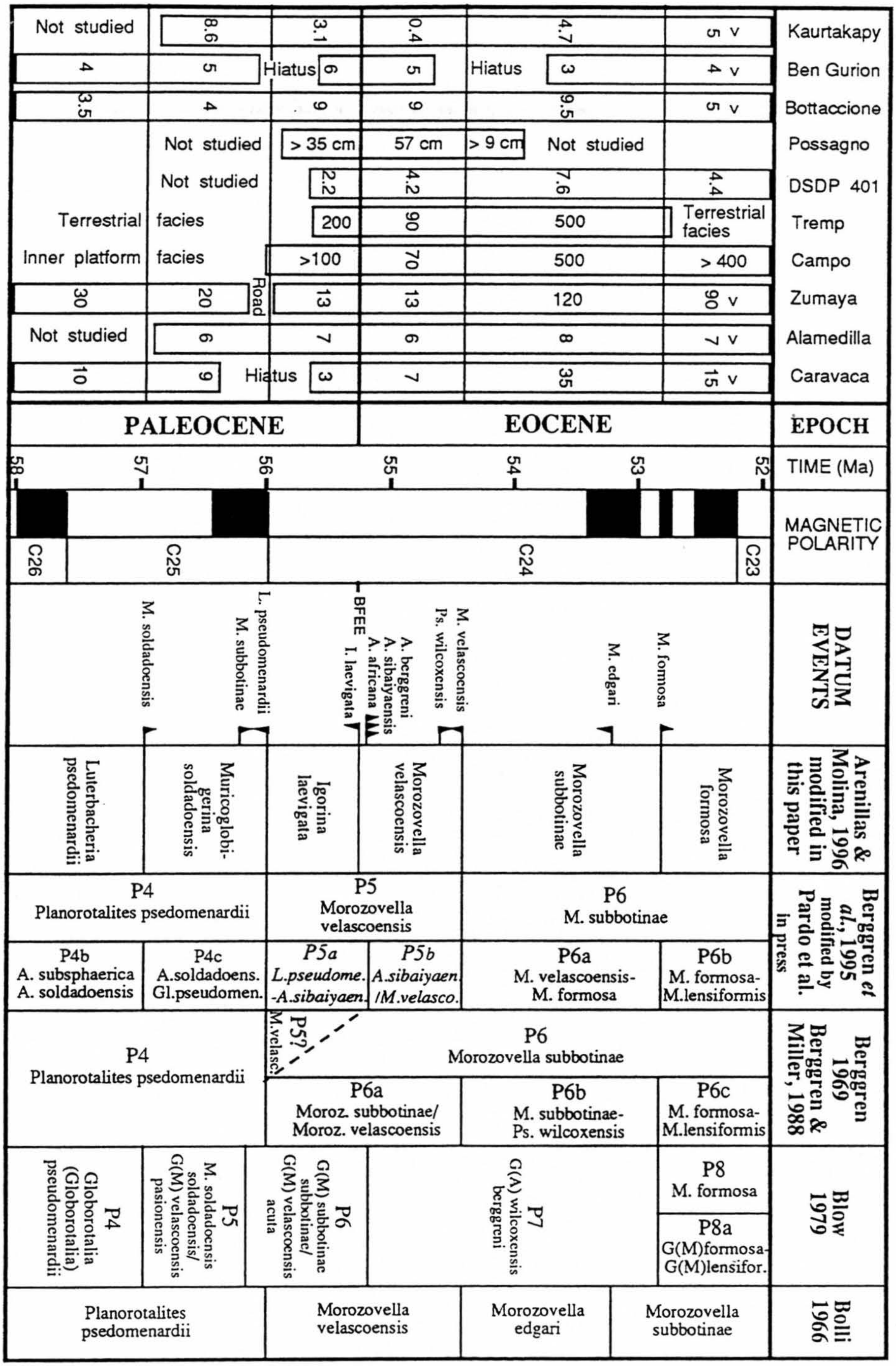
The DSDP Site 401 is located in the western abyssal plain of the Bay of Biscay. The P-E transition ranges from Zone P5 to P8, with some artificial hiatuses due to core recovery. Planktic foraminiferal assemblages show good preservation and diagenetic alteration is low. $\partial^{13}C$ analysis shows a shift coincident with a $\partial^{18}O$ shift, the BFEE and an increase in relative abundance of warm water acarininids and morozovellids. After the BFEE and the isotopic shift, chiloguembelinid population shows an increase, suggesting the onset of hypoxic conditions in intermediate waters (Pardo *et al.*, 1997).

The Possagno section micropaleontological studies were summarized in a monograph edited by Bolli (1975). This classical Italian section is located in a quarry, which is a major problem to consider it as a good candidate for the P/E boundary stratotype. Furthermore, the section is very condensed with a 4 cm thick red dark clay and a 57 cm thick *Morozovella velascoensis* Biozone. Nevertheless, we have identified the acarininids extra-tropical excursion in coincidence with the $\partial^{13}C$ shift.

The Bottaccione section, located in Gubbio, is another classical Italian section. Planktic foraminiferal assemblages from the Paleocene and lower Eocene were first studied by Luterbacher (1964). Preservation of planktic foraminifera is poor since the lithology is very calcareous, but nevertheless this section allows correlation between biostratigraphy and magnetostratigraphy.

The Ben Gurion is one of the best Israeli sections. Planktic foraminifera are frequent and were first studied by Benjamini (1980). Several dissolution levels are present across the P-E transition and two hiatuses have been recognized. Nevertheless, all the biozones from the *M. soldadoensis* to *M. formosa* Biozone have been identified.

The Kaurtakapy section, located in the boreal Paratethys, is a composite of two outcrops which are correlated by means of a 10 cm thick clay layer with marcasite nodules. Planktic foraminiferal assemblages are well preserved and characterized by a sharp increase in relative abundance and species richness of tropical acarininids, morozovellids and igorinids during the P-E transition. The maximum diversity of subtropical species, and the FO of *Acarinina sibaiyaensis* and *A. africana* coincides with a $\partial^{13}C$ shift and the onset of the clay layer. Prior to the main $\partial^{13}C$ shift a long term gradual decrease characterizes the upper Paleocene (Pardo et al., *in press*). The P5b Zone is only 0.4 m thick and suggests the presence of a hiatus.


Kaurtakapy
Ben Gurion
Bottaccione
Possagno
DSDP 401
Tremp
Campo
Zumaya
Alamedilla
Caravaca
Not studied
Hiatus
> 35 cm
57 cm
> 9 cm
Terrestrial facies
Inner platform facies
Road
200
500
>100
> 400
120
PALEOCENE
EOCENE
EPOCH
TIME (Ma)
58
57
56
55
54
53
52
MAGNETIC POLARITY
C26
C25
C24
C23
DATUM EVENTS
M. soldadoensis
L. pseudomenardii
M. subbotinae
BFEE
I. laevigata
A. africana
A. sibaiyaensis
A. berggreni
Ps. wilcoxensis
M. velascoensis
M. edgari
M. formosa
Arenillas & Molina, 1996 modified in this paper
Luterbacheria psedomenardii
Muricoglobigerina soldadoensis
Igorina laevigata
Morozovella velascoensis
Morozovella subbotinae
Morozovella formosa
Berggren et al., 1995 modified by Pardo et al. In press
P4 Planorotalites psedomenardii
P5 Morozovella velascoensis
P6 M. subbotinae
P4b A. subsphaerica A. soldadoensis
P4c A.soldadoens. Gl.pseudomen.
P5a L.pseudome. -A.sibaiyaen.
P5b A.sibaiyaen /M.velasco.
P6a M. velascoensis- M. formosa
P6b M. formosa- M.lensiformis
Berggren 1969 Berggren & Miller, 1988
P4 Planorotalites psedomenardii
P5? M.velasc.
P6 Morozovella subbotinae
P6a Moroz. subbotinae/ Moroz. velascoensis
P6b M. subbotinae- Ps. wilcoxensis
P6c M. formosa- M.lensiformis
Blow 1979
P4 Globorotalia (Globorotalia) pseudomenardii
P5 M. soldadoensis soldadoensis/ G(M) velascoensis pasionensis
P6 G(M) subbotinae subbotinae/ G(M) velascoensis acuta
P7 G(A) wilcoxensis berggreni
P8 M. formosa
P8a G(M)formosa- G(M)lensifor.
Bolli 1966
Planorotalites psedomenardii
Morozovella velascoensis
Morozovella edgari
Morozovella subbotinae

REFERENCES

ARENILLAS, I. & MOLINA, E. (1995). El límite Paleoceno/Eoceno en el corte de Campo (Paraestratotipo del Ilerdiense) con foraminíferos planctónicos. *Actas XI Jornadas de Paleontología*. 29-33.

ARENILLAS, I. & MOLINA, E. (1996). Bioestratigrafía y evolución de las asociaciones de foraminíferos planctónicos del tránsito Paleoceno-Eoceno en Alamedilla (Cordilleras Béticas). *Revista Española de Micropaleontología*. 18(1). 75-96.

ARENILLAS, I., MOLINA, E. & PARDO, A. (1996). Correlación cuantitativa con foraminíferos planctónicos del tránsito Paleoceno-Eoceno en Alamedilla (Béticas), Zumaya (Pirineos) y Site 401 (Golfo de Vizcaya): implicaciones paleoceanográficas. *Geogaceta*. 20(1), 187-190.

BENJAMINI, CH. (1980). Planktonic foraminifera of the Avedat Group (Eocene) in the northern Negev, Israel. *Journal of Paleontology*. 54 (2), 325-358.

BERGGREN, W.A., KENT, D.V., SWISHER. C.C. & AUBRY, M.P. (1995). A revised Cenozoic Geochronology and Chronostratigraphy. *In* Berggren *et al.* eds. *Geochronology, time scales and global stratigraphic correlation.* SEPM Special Pulication. 54, 130-212.

BLOW, W.A. (1979). *The Cainozoic globigerinida.* Leiden, E.J. Brill. 3 vols. 1-1413.

BOLLI, H.M. ed. (1975). Monografia micropaleontologica sul Paleocene e L'Eocene di Possagno, Provincia di Treviso, Italia. *Mem. svezzere Paleontol.* 97, 1-223.

CANUDO, J.I, KELLER, G., MOLINA, E. & ORTIZ, N. (1995). Planktic foraminiferal turnover and $\partial^{13}C$ isotopes across the Paleocene-Eocene transition at Caravaca and Zumaya, Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 114. 75-100.

CANUDO, J.I. & MOLINA, E. (1992). Planktic foraminiferal faunal turnover and bio - chronostratigraphy of the Paleocene-Eocene boundary at Zumaya (Northern Spain). *Revista de la Sociedad Geológica de España*. 5 (1-2), 145-157.

CANUDO, J.I., MOLINA, E. & SUCUNZA, M. (1989). Bioestratigrafía con foraminíferos planctónicos y nanoplancton calcáreo de la sección de Campo (Paraestratotypo del Ilerdiense). *Geogaceta*. 5, 81-84.

GARTNER, S. Jr. & HAY, W.W. (1962). Planktonic foraminifera from the Type Ilerdian. *Eclogae geologicae Helvetiae*. 55, 560-571.

LU, G., KELLER, G., ADATTE, T., ORTIZ, N. & MOLINA, E. (1996). Long-term (10^5) or short-term (10^3) $\partial^{13}C$ excursion near the Paleocene-Eocene transition: evidence from the Tethys. *Terra Nova*. 8. 347-355.

LUTERBACHER, H.P. (1964). Studies in some Globorotalia from the Paleocene and lower Eocene of the central Apennines. *Eclogae geologicae Helvetiae*. 57 (2), 631-730.

MOLINA, E. (1996). El límite Paleoceno/Eoceno en España: características y posibilidades. *Geogaceta*. 20(7), 1668-1671.

MOLINA, E., CANUDO, J.I., GUERNET, C., McDOUGALL, K., ORTIZ, N., PASCUAL, O., PARES, J.M. SANSO, J.M., SERRA-KIEL, J. & TOSQUELLA, J. (1992). The stratotypic Ilerdian revisited: integrated stratigraphy across the Paleocene/Eocene boundary. *Revue de Micropaléontologie*. 35 (2). 143-156.

MOLINA, E., CANUDO, J.I., MARTINEZ, F. & ORTIZ, N. (1994). Integrated Stratigraphy across the Paleocene/Eocene boundary at Caravaca, Southern Spain. *Eclogae Geologicae Helvetiae*. 87(1). 47-61.

MOLINA, E., DE RENZI, M. & ALVAREZ, G. (1995). El estratotipo del Ilerdiense y su registro fósil. *Actas XI Jornadas de Paleontología*. 211-220.

PARDO, A., CANUDO, J.I. & MOLINA, E. (1994). Bioestratigrafía con foraminíferos planctónicos de la parte inferior de la Formación Ieper (Ypresiense estratotípico) en el sondeo Knokke (Bélgica). *Revista Española de Micropaleontología*. 26. 109-125.

PARDO, A., KELLER, G. & OBERHANSLI, H. (in press). Paleoecologic and paleoceanographic evolution of the Thetyan realm during the Paleocene- Eocene transition. *Palaios*.

PARDO, A., KELLER, G., MOLINA, E. & CANUDO, J.I. (1997). Planktic foraminifera turnover across the Paleocene/Eocene boundary at the DSDP site 401 (Bay of Biscay, North Atlantic). *Marine Micropaleontology*. 29. 129-158.

SCHMITZ, B., ASARO, F., MOLINA, E. MONECHI, S. von SALIS, K. & SPEIJER, R.P. (1997). High-resolution iridium, ∂13C, ∂18O, foraminifera and nannofossil profiles across the latest Paleocene benthic extinction event at Zumaya, Spain. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 133 (1-2). 49-68.

VON HILLEBRANDT, A. (1965). Foraminiferen-Stratigraphie im Alttertiar von Zumaya (Prov. Guipuzcoa, NW Spanien) und ein Vergleich mit anderen Tethys-Gebienten. *Bayer. Akad. Wiss., mat., nat., Kl. Abh.* 123, 1-62.