The Zumaya section in Spain: A possible global stratotype section for the Selandian and Thanetian stages

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Introduction

In September 1993 the Paleocene Working Group was established, aiming at defining Global Stratotype Sections and Points (GSSP's) for the Selandian and Thanetian stages (see Schmitz, 1994; and accompanying symposium proceedings in GFF, v. 116, p. 39-67). Multiparameter stratigraphical records through sections in the historical stratotype areas in Denmark (Selandian) and England (Thanetian) as well as in Spain, Israel, Egypt, and Tunisia are being prepared by various groups.

One of the most promising sections for providing GSSP's for the upper Paleocene stages is the Zumaya section in the Basque region, northern Spain (see Molina, 1994). This section is easily accessible and consists of an expanded about 160 m thick and biostratigraphically complete Paleocene record. The historical Paleocene stage boundaries in the North Sea area were defined at unconformities corresponding to modern sequence boundaries (Hardenbol, 1994; Knox, 1994a). In the Basque region there are many Paleocene sections, that were deposited at a variety of sea-floor conditions and depths (carbonate platform to outer slope). Studies of these sections and the Zumaya section have established a sequence stratigraphic framework (Pujalte et al., 1994), which can be used for further correlations with the original stratotype sections in the North Sea region. The Zumaya section is also an important link between the historical stratotype sections and the expanded Paleocene sections at low latitudes in the Tethys.

The base of the Selandian

The original basal Selandian in Denmark was defined at a major lithological shift, from greyish white, oxic limestone/chalk to suboxic greensand overlain by grey marl and clay (Rosenkrantz, 1924). The limestone/chalk deposition had prevailed throughout the entire Maastrichtian and Danian. After the Danian-Selandian transition, grey marls and clays dominated sedimentation in Denmark for several million years. In terms of calcareous nannoplankton zonations, the basal Selandian in Denmark falls in the upper part of Zone NP4 or lower NP5 (Thomsen, 1994).

Our preliminary results indicate that at Zumaya the base of the Selandian corresponds to a package of red marls forming a 3.4 m thick transition interval from reddish limestone-marl couplets below to grey marls above, about 55-60 m above the Cretaceous-Tertiary (K-T) boundary (Fig. 1-2). This lithological shift is one of the most prominent in the Zumaya section. Thick reddish limestones with some marl layers dominate the lower 45 m of the Danian. They are followed by some 10 m of reddish limestone-marl couplets. The overlying 3.4 m of red marls change abruptly into grey marls, which thereafter persist for some 25 m. A varied grey marl-limestone lithology characterizes the remainder of the Paleocene. Turbidites are rare in the Danian reddish limestones and marls, but become more common in the grey marls and continue to be important higher up in the sequence.

The calcareous nannofossils at Zumaya were studied in smear slides with the light microscope. The first representatives of the genera *Sphenolithus* and *Fasciculithus* were found in the red limestone-marl couplets, that also include occassional *Ellipsolithus macellus,* and thus can be assigned to the upper part of NP4. The lowermost *Fasciculithus tympaniformis,* the marker for the base of NP 5, was observed 75 cm above the lithologic change to the red marls (Fig. 2), while the lowermost occurrence of typical *Neochiastozygus perfectus* was noted at the very base of the red marls. A sharp decrease in *Braarudosphaera bigelowi* s. ampl. accompanies the lithologic shift from the reddish limestone-marl couplets to the red marl. No major change in nannofossil flora was found at the shift from red to-grey marl, however, a sharp increase in the abundance of microscopic dolomite rhombs was observed.

Planktonic foraminifera were studied in disaggregated marl samples (Arenillas & Molina, 1996). Near or at the base of the red marls four species have their last appearance (*Eoglobigerina trivialis, Acarinina hansbolli, Acarinina kubaensis* and *Morozovella tadjikistanensis*), and two species have their first occurrence (*Morozovella crosswickensis* and *Chiloguembelina crinita*). In the red marls, or just above these, *Subbotina velascoensis* has its first appearance.

We have also analyzed whole-rock samples (0.25 to 0.5 m spacings) across the entire Paleocene part of the Zumaya section for stable isotopes. In the interval in which the basal Selandian may be defined, there is a negative $\delta^{13}C$ shift of about 1‰. Similar, but more prominent, $\delta^{13}C$ anomalies are found at the K-T boundary and the benthic extinction event (BEE; see Schmitz et al., 1996) around the end of the Paleocene (Fig. 1-2).

There are a number of arguments in favor of that the transitions from dominantly oxic limestones to grey suboxic marls or clays in Denmark and Spain reflect the same event. The nannofossil data show that at both sites the lithological shifts occur near or at the transition from Zone NP4 to NP5. Moreover, the finding of *Neochiastozygus perfectus* at the base of the red marls at Zumaya concurs with its first appearance in Denmark in the uppermost metres of the Danian (Thomsen, 1994). Pujalte et al. (1994) suggest that one of the most important sequence boundaries in the Zumaya section occurs in the interval in which we think that the basal Selandian occurs. This is the boundary between depositional sequences (DS) 4 and 5 according to their sequence stratigraphic framework (Fig. 1). This may be the same sequence boundary as the one marking the unconformity at the Danian-Selandian boundary in Denmark, and which represents the Se-1 sequence boundary in the chart of Hardenbol (1994). The sequence boundaries in this chart and other general charts have been established mainly based on studies of sections in northwestern Europe. Although these sequence boundaries may not be correlatable worldwide, it is likely that at least regionally, along the northeastern Atlantic coast the same sea-level changes are registered by the strata. Magnetostratigraphy shows that the upper part of the limestone-clay couplets at Zumaya belongs to the Chron C26r (Roggenthen, 1976), which is the same chron preliminarily assigned for the basal Selandian in Denmark (see Ali et al., 1994). It is noteworthy that the basal Selandian interval at Zumaya is situated about 10 m above the boundary between the *P. uncinata* - *M. angulata* (P2-P3a) planktonic foraminiferal zones, which in the general stratigraphic scheme of Berggren et al. (1996) is considered to correspond to the Danian-Selandian boundary.

Because the $\delta^{13}C$ anomaly in the basal Selandian at Zumaya has been measured on bulk samples it is uncertain whether a real change in the chemistry of the Paleocene ocean is registered. Diagenesis or reworking of extraneous calcite may explain the origin of the $\delta^{13}C$ anomaly. One fact speaking in favor of a "real" carbon isotopic event, however, is that the whole-rock $\delta^{13}C$ trend through the entire Zumaya section is very similar to that measured on other Paleocene sections, including well-preserved deep-sea sections (see Charisi & Schmitz, 1995).

The base of the Thanetian

In its original type area the unconformity-related base of the Thanetian has been dated to the upper part of Zone NP6 (Aubry, 1994; Knox, 1994b). Our preliminary nannofossil data suggest that the NP6 zone corresponds approximately to the interval from 80 to 100 m above the K-T boundary. There is no important sequence boundary near or within this interval (Fig. 1; Pujalte et al., 1994). The closest sequence boundaries are the abovementioned DS4-DS5 boundary and the DS5-DS6 boundary at about 140 m above the K-T boundary. The DS5-DS6 boundary occurs in NP9 well above the level corresponding to the basal Thanetian in England. According to the stratigraphic scheme of Berggren et al. (1996) the Selandian-Thanetian boundary correlates with the base of the C26n polarity chron, which may occur near or within the +80 m to +100 m interval at Zumaya, based on correlations with the magnetostratigraphy for the nearby Trabakua section (Pujalte et al., 1995).

Dividing the Paleocene in stages/ages

After studies of the Zumaya section, the question can be restated (see Schmitz, 1994), whether there really are good reasons for dividing the Paleocene into three stages and not two?

The base of the Selandian appears to coincide with an important rapid event leading to a long-term conspicuous shift in depositional conditions at least over large areas of the eastern Atlantic region. Our data show that the event may coincide with a perturbation of the carbon cycle. No similar prominent event with significant long-term consequences is found registered in the Zumaya section until at the BEE at 163 m above the K-T boundary. Thus if focus is on dividing the Paleocene into ages/stages that reflect global change, a two-fold division appears more appropriate. The decision of how to divide the upper Paleocene into stages must, however, await the decision of where the Paleocene-Eocene (P-E) boundary, or the base of the Ypresian, will be placed. Within the framework of IGCP Project 308 it has been suggested that the P-E boundary may be defined at the BEE (e.g. Molina, 1994). The BEE occurs in the middle-upper part of Zone NP9 (Schmitz et al., 1996), which is substantially lower than the originally defined P-E boundary at the base of the Oldhaven Beds (England), corresponding to the middle or upper part of Zone NP10 (Aubry et al., 1988). The interval between the Danian-Selandian boundary and the BEE is characterized by the rise and fall in global oceanic productivity, as shown by the development of the global $\delta^{13}C$ maximum (Fig. 1). This is the period with the most abundant productivity in the oceans during the entire Cenozoic. It appears attractive to let this unusual oceanic event define one stage, in particular if the BEE is chosen as the P-E boundary marker.

Acknowledgements

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Fig. 1 Multiparameter stratigraphy for the Zumaya section, after Molina (1994), revised in this study. Dashed lines at boundaries between P, NP and DS zones indicate that the exact placements of the boundaries are preliminary. Full lines reflect boundaries that have been studied with a higher resolution. P-zonation after Molina (1994) with revisions based on our new studies. NP-zonation, this work. Magnetostratigraphy after Roggenthen (1976) and Pujalte et al. (1995). Depositional sequences after Pujalte et al. (1994). Carbon isotopic curve, this work. Two different possibilities how the Paleocene can be divided in stages are shown in the far right column. Hatched areas indicate intervals in which Global Stratotype Points may be defined.

Fig. 2 The uppermost Danian and basal Selandian at Zumaya. The base of the Selandian occurs in the 3.4 m red marl interval, however, its exact placement is still a matter of investigation. The 0 level in this profile corresponds to the level 56.5 m above the K-T boundary in Fig. 1.

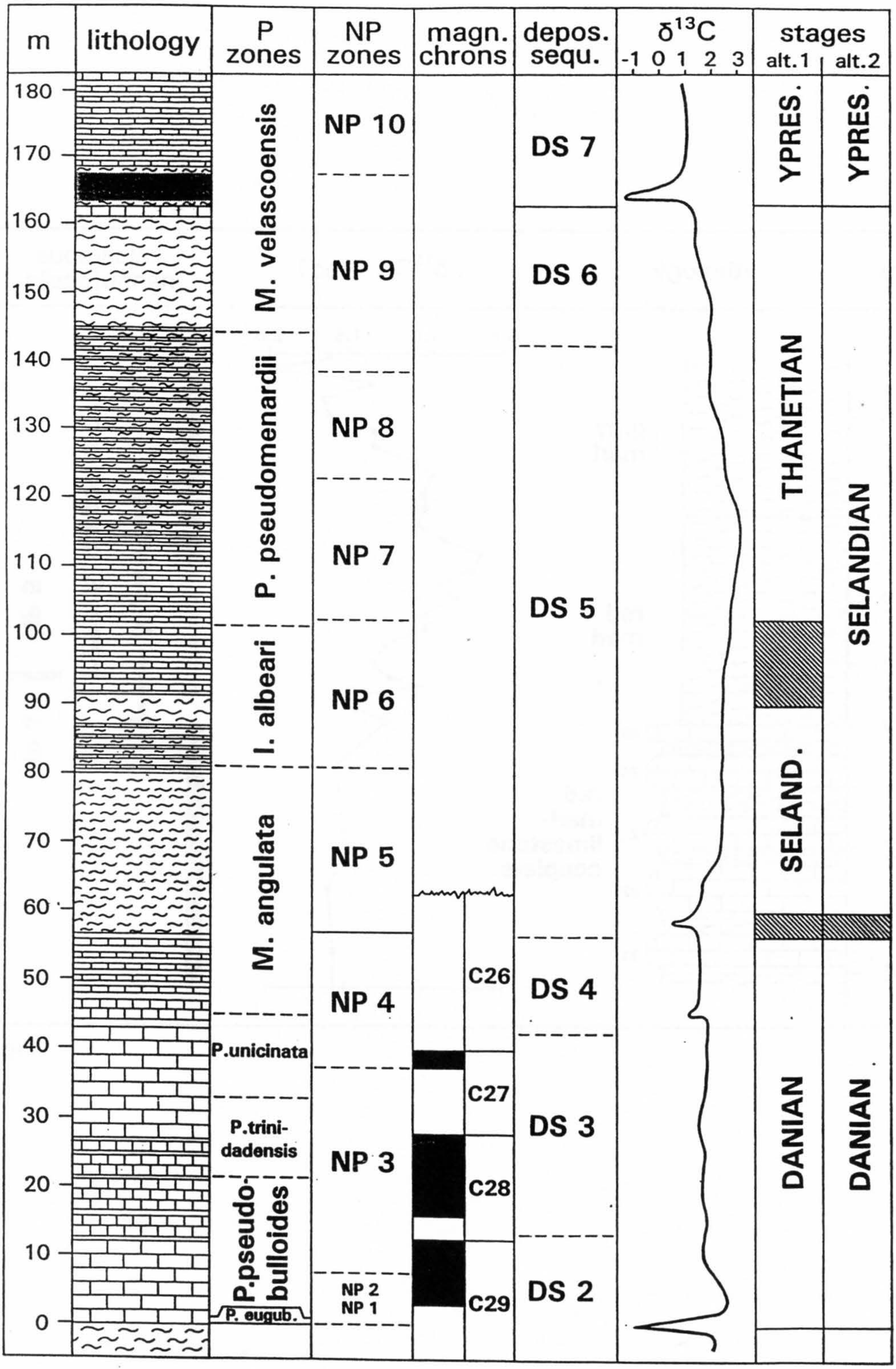
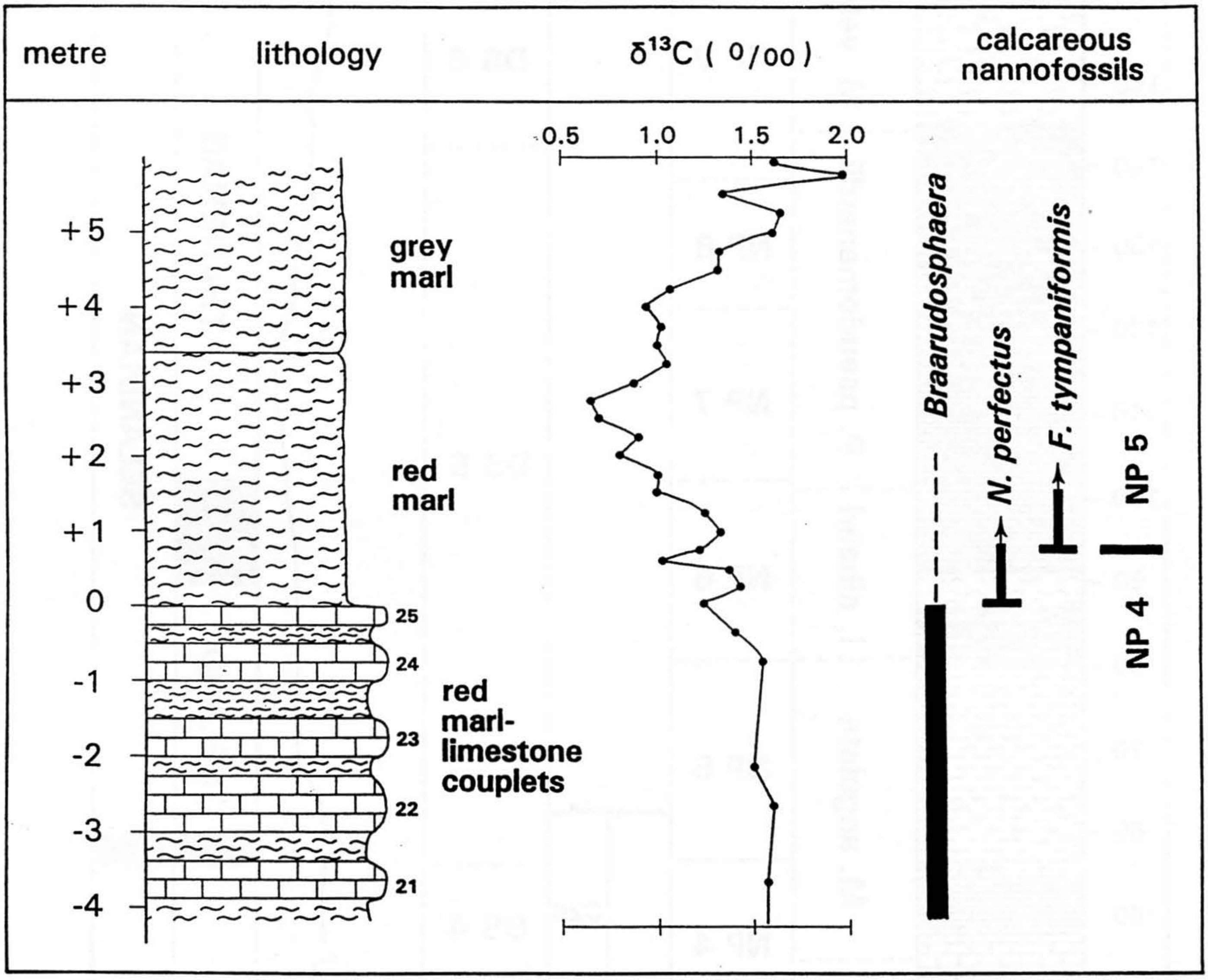

m
lithology
P zones
NP zones
magn. chrons
depos. sequ.
δ13C
-1 0 1 2 3
stages
alt.1
alt.2
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
M. velascoensis
P. pseudomenardii
I. albeari
M. angulata
P.unicinata
P.trini-dadensis
P.pseudo-bulloides
P. eugub.
NP 10
NP 9
NP 8
NP 7
NP 6
NP 5
NP 4
NP 3
NP 2
NP 1
C26
C27
C28
C29
DS 7
DS 6
DS 5
DS 4
DS 3
DS 2
YPRES.
THANETIAN
SELAND.
DANIAN
YPRES.
SELANDIAN
DANIAN

Fig. 1



metre
lithology
δ13C (0/00)
calcareous nannofossils
0.5
1.0
1.5
2.0
+5
+4
+3
+2
+1
0
-1
-2
-3
-4
grey marl
red marl
red marl-limestone couplets
25
24
23
22
21
Braarudosphaera
N. perfectus
F. tympaniformis
NP 5
NP 4

Fig. 2