

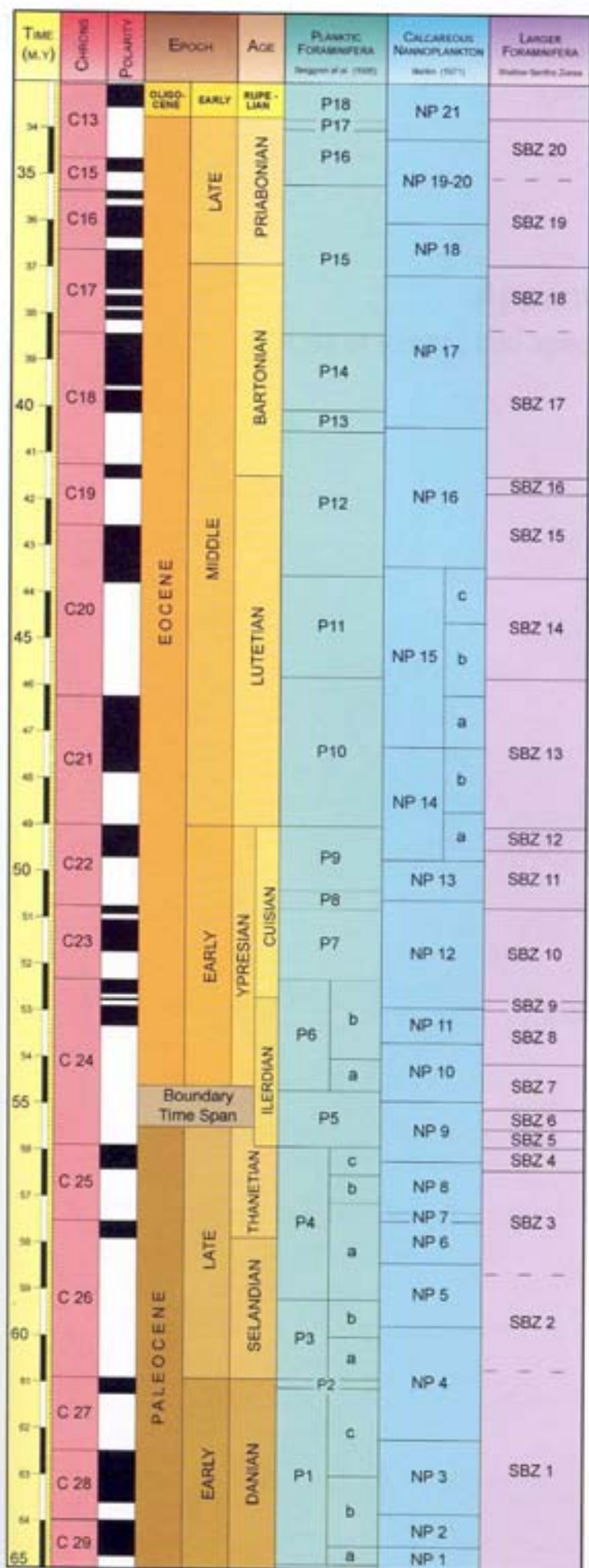
Appendix I:

**Tethyan Paleocene-Eocene Larger Foraminifera Biostratigraphy:
Shallow Benthic Zones (SBZ)**



Tethyan Paleocene-Eocene Larger Foraminifera Biostratigraphy: Shallow Benthic Zones

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The Shallow Benthic foraminiferal biozones (SBZ) presented here are, in part, the results of the IODP Project No. 280 Early Paleogene Benthos, and No. 393 Navajo Events at the Middle Upper Eocene boundary, and have been published in a previous paper (Serra-Kiel et al., 1998: *Bull. Soc. Géol. Fr.*, vol. 169, no. 2).

These SBZ biozones cover the Paleocene and Eocene time span from the eastern shores of the Atlantic (Paris and Pyrenean basins) to the central part of the Tethys (India). Basically, they are derived from species ranges observed in many micropaleontological sections in the Pyrenean region, Swiss and Austrian Alps (Schlatter and Gungl, various sequences in the Helvetic units), Northern Italy (Verona, Vicenza), Adriatic and Gargano plateaus, Cretaceous-Northern Tethyan Basin (Central Anatolia), Hormuz Gorge (Pakistan) and Thana (India).

The SBZ foraminiferal biozonation is the outcome of a revision of the classical biozonation based on Paleocene-Eocene alveolines, *Assulinia* and *Nannulites*, established in the early 1940's by Lukás Hattinger and posteriorly updated by Hans Schaub, Lukás Hattinger, and Katka Drobek. Their typologically defined biozones, which are in principle open zones, are composite (or concurred) zones, based on faunal assemblages of both occurring and mutually exclusive species from key-localities and key-levels, each of which occupies a definitive chronostratigraphic position. In the resulting discrete biozonation, these biozones are noncontiguous, separated by intervals and not by boundaries, the key-locality assemblages represent the central point of each biozone. They must reflect objective, repeatedly observed breaks in faunal assemblages since many deposits rich in larger foraminifera are often formed in a transgressive context and are separated by relatively long sedimentary hiatuses. Due to their integrated nature

and their ties with the stratotypes of several Paleogene stages, these typologically defined biozones proved to be quite stable. Various correlations allowed them to be linked to standard zonations based on planktic microfossils. Moreover, because these biozones are in fact open zones, they are not single biostratigraphic zones, but process chronostratigraphic values.

In addition to sunnited and alveolines, in the last decades much interest has focused on the taxonomy and biostratigraphy of other Paleogene larger foraminifera from various tethyan facies, among which are orthogonulines, rotulines, larger miliolids, and conical and discoidal agglutinated species.

In the light of the impressive body of evidence on the Paleogene larger foraminifera, it seemed to proceed feasible one step further in their biozonation, through a critical survey of their first and last occurrences in various sea-level basins. The present attempt fully incorporates the past twenty years of research into its methodology. Each SBZ biozone corresponds to the total range zone of some larger foraminiferal taxa, and is defined using integrated evidence on multiple first appearances (FA's) and last occurrences (LO's) of taxa from all available tethyan paleoenvironments, correlated to magnetostratigraphy, which are in turn correlated to standard planktic microfossil biozonations. This correlation is based on data from the outcrops and from the literature, and is susceptible to be modified as new data will be available.

This chart corresponds to the correlation of the SBZ with the Paleocene-Eocene Time Scale elaborated by Berggren, Kent, Swisher and Aubry (1995: *SEPM Special. Pub.*, 54), including the Lenton and Cusack stages, and the Span Time Boundary for the Paleocene-Eocene boundary according to Molina et al. (1990: *Rev. Micropal.*, 35).

Shallow Benthic Zones (SBZ)

- SBZ 1** (Danian) Defined by the biostratigraphic range of *Coffinitina bilobata* and *Bergina ferretii*. The lower boundary corresponds to the Cretaceous-Tertiary boundary.
- SBZ 2** (Selandian) Defined by the biostratigraphic range of *Micralina globulata*, *Ornatostoma minutum*, *Parabocheria asi* and *Lochertia aberti*.
- SBZ 3** (Early Bartonian) Defined by the biostratigraphic range of *Chlorovalva pinnae*, *Pericollina alveolata*, *Cochlidium rotulae*, *Falsella alveolata*, *Cribrodinium carinifera*, *Verrucanatica*, *Micralina yvettei*, *Perforinocollaria pinnae*, *Evastitella ferretii*, *Nannulites helvi* and *Diacyclops sereni*.
- SBZ 4** (Late Bartonian) Defined by the biostratigraphic range of *Glyptovalva lerici*, *Hattingerina lerici*, *Micralina meandrina*, *Daviesina gummensis*, *Diacyclops simplex*, *Nannulites sereni*, *Assulinia asiensis* and *Ass. yvettei*.
- SBZ 5** (Early Lenton 1) Defined by the biostratigraphic range of *Orbitolites gracilis*, *Daviesina lerici*, *Alveolina virensburgi*, *A. ovalina ovalina*, *A. serotona armata*, *A. varians*, *Nannulites gamoderai*, *Assulinia subrotata* and *Ass. pinna*.
- SBZ 6** (Early Lenton 2) Defined by the biostratigraphic range of *Alveolina alveolata*, *A. danensis*, *A. yvetensis*, *A. solida* and *Nannulites moerensis*.
- SBZ 7** (Middle Lenton 1) Defined by the biostratigraphic range of *Alveolina moerensis*, *A. subyvetensis*, *A. obdita*, *A. laxa*, *Nannulites subrotata*, *N. carinifera*, *N. serotona*, *N. aberti*, *Assulinia asiensis* and *Orbitolites sereni*.
- SBZ 8** (Middle Lenton 2) Defined by the biostratigraphic range of *Alveolina rotulata*, *A. serotula*, *A. serotona*, *Nannulites helvi*, *N. aberti*, *N. globulosa sereni*, *N. globulosa latera*, *Assulinia lymeri* and *Ass. conifera*.
- SBZ 9** (Late Lenton) Defined by the biostratigraphic range of *Alveolina yvetensis*, *A. citata*, *A. polita lerici*, *Nannulites involuta*, *Assulinia adriatica* and *Ass. gamoderai*.
- SBZ 10** (Early Cuisian) Defined by the biostratigraphic range of *Alveolina schwageri*, *A. indistincta*, *A. conseri*, *A. keymanensis*, *A. conseri*, *A. minutula*, *Nannulites pilosulata*, *N. oviformis*, *N. burgalensis burgalensis*, *N. subrotata*, *Assulinia*, *N. subrotata*, *N. parvifera*, *N. subrotata*, *Assulinia pinna*, *Ass. pinnae*, *Ass. ferretii*, *Ass. sereni*, *Ass. echeri* and *Diacyclops sereni*.
- SBZ 11** (Middle Cuisian) Defined by the biostratigraphic range of *Alveolina danica*, *A. olli conseri*, *A. kistritz hantoni*, *A. detersi*, *A. conseri*, *Nannulites pinnae*, *N. burgalensis burgalensis*, *N. subrotata*, *N. sereni*, *N. globulosa sereni*, *N. globulosa latera*, *Assulinia lymeri* and *Ass. conifera*.
- SBZ 12** (Late Cuisian) Defined by the biostratigraphic range of *Alveolina rotulae*, *A. rotulata*, *A. ozzaroli*, *A. cuspidata*, *Nannulites moerensis*, *N. angulata*, *N. compressus*, *N. quadrifidus*, *N. limeri*, *N. compressus*, *Assulinia moerensis* and *Ass. conifera*.
- SBZ 13** (Early Lutetian) Defined by the biostratigraphic range of *Alveolina etipes*, *A. cylindrica*, *A. yvetensis*, *A. hattingeri*, *Nannulites lerici*, *N. aberti*, *N. virensis*, *N. helvi*, *N. moerensis*, *Assulinia pinna*, *Ass. neumarginata*, *Ass. pinnae* and *Ass. spinosa*.
- SBZ 14** (Middle Lutetian 1) Defined by the biostratigraphic range of *Alveolina moerensis*, *Nannulites benehensis*, *N. graeca*, *N. virensis*, *N. limeri*, *N. sereni*, *N. bozasi* and *Assulinia spinosa*.
- SBZ 15** (Middle Lutetian 2) Defined by the biostratigraphic range of *Alveolina conseri*, *Nannulites conseri*, *N. conseri*, *N. moerensis*, *N. limeri*, *N. conseri* and *Orbitolites sereni*.
- SBZ 16** (Late Lutetian) Defined by the biostratigraphic range of *Nannulites helvi*, *N. detersi*, *N. pinnae*, *N. sereni*, *N. conseri*, *N. yvetensis*, *Assulinia pinnae* and *Diacyclops sereni*.
- SBZ 17** (Early Bartonian) Defined by the biostratigraphic range of *Alveolina elongata*, *A. fragilis*, *A. kistritz hantoni*, *Nannulites moerensis*, *N. parvifera*, *N. pinnae*, *N. bozasi* and *Diacyclops pinnae*.
- SBZ 18** (Late Bartonian) Defined by the biostratigraphic range of *Nannulites helvi*, *N. yvetensis*, *N. virensis* and *N. bozasi*.
- SBZ 19** (Early Priabonian) Defined by the biostratigraphic range of *Nannulites helvi*, *N. gamoderai*, *N. conseri*, *Diacyclops pinnae* and *Assulinia pinnae*.
- SBZ 20** (Late Priabonian) Defined by the biostratigraphic range of *Nannulites helvi*, *N. gamoderai*, *Assulinia pinnae* and *Assulinia pinnae*.