Appendix I:

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

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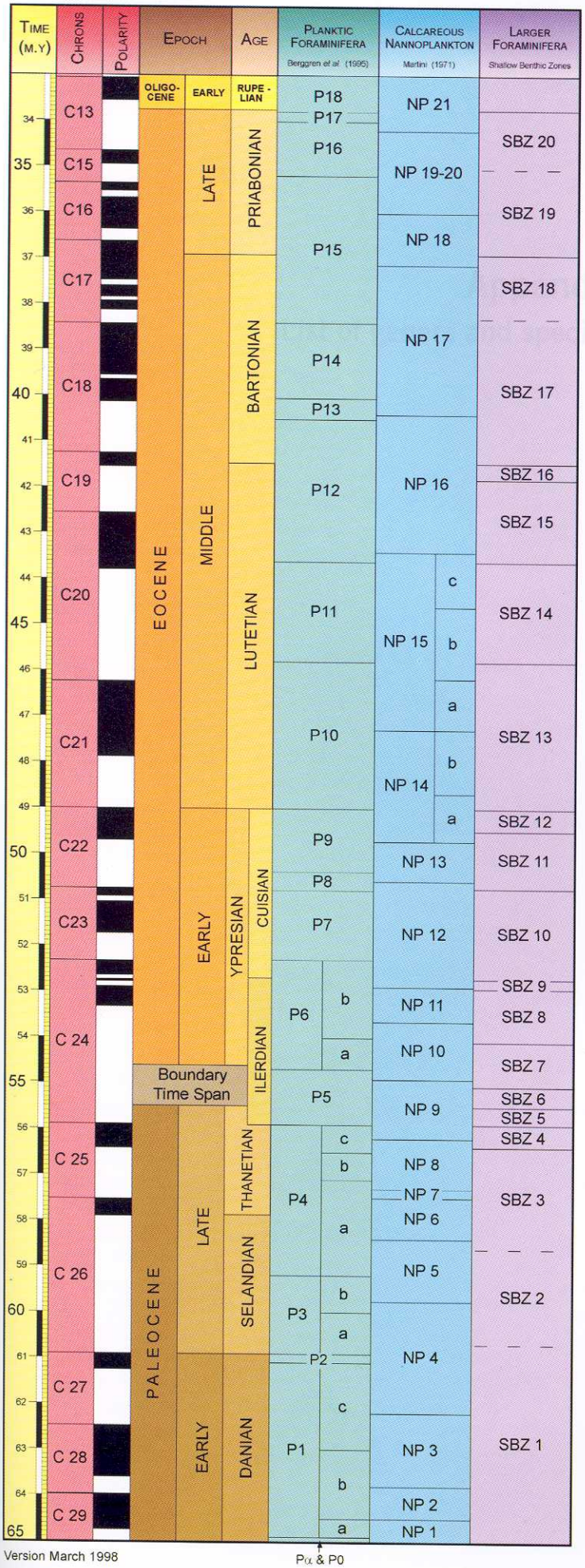

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The Shallow Benthic foraminiferal biozones (SBZ) presented here are, in part, the results of the IGCP Projects No. 286 *Early Paleogene Benthos*, and No. 393 *Neritic Events at the Middle-Upper Eocene boundary*, and have been published in a previous 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 lithostratigraphic sections in the Pyrenean realm, Swiss and Austrian Alps (Schlieren and Gurnigelflysch, various sequences in the Helvetic units), Northern Italy (Verona, Vicenza), Adriatic and Gargano platforms, Crimean Peninsula, Hoymana Basin (Central Anatolia), Nammal Gorge (Pakistan) and Therria (India).

The SBZ foraminiferal biozonation is the outcome of a revision of the classical biozonation based on Paleocene-Eocene alveolinids, *Assilina* and *Nummulites*, established in the early 1960's by Lukas Hottinger and posteriorly updated by Hans Schaub, Lukas Hottinger, and Katica Drobne. Their typologically-defined biozones, which are in principle oppelzones, are composite (or concurrent-range) zones, based on faunal assemblages of both concurring 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 non-contiguous, 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 oppelzones, they are not simple biostratigraphic zones, but possess chronostratigraphic value.

In addition to nummulitids and alveolinids, in the last decades much interest has focused on the taxonomy and biostratigraphy of other Paleogene larger foraminifera from various neritic facies, among which are orthophragminiform, rotaliiform, larger miliolid, 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 neo-Tethyan 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 foraminifera taxa, and is defined using integrated evidence on multiple first appearances (FA's) and last occurrences (LO's) of taxa from all available neritic paleoenvironments, correlated to magnetostratigraphy, which are in turn correlated to standard planktic microfossil biozonations. This correlation is based on data from the authors 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 Spec. Pub., 54), including the Ilerdian and Cuisian stages, and the Span Time Boundary for the Paleocene-Eocene boundary according to Molina *et al.* (1992· Rev. Micropal., 35).

Shallow Benthic Zones (SBZ)

SBZ 1 (Danian) Defined by the biostratigraphic range of: *Laffitteina bibensis* and *Bangiana hanseni*. The lower boundary corresponds to the Cretaceous-Tertiary boundary.

SBZ 2 (Selandian) Defined by the biostratigraphic range of: *Miscellanea globularis, Ornatononion minutus, Paralockhartia eos* and *Lockhartia akbari*.

SBZ 3 (Early Thanetian) Defined by the biostratigraphic range of: *Glomalveolina primaeva, Periloculina slovenica, Coskinon rajkae, Fallotella alavensis, Cribrobulimina carniolica, Vania anatalica, Miscellanea yvettae, Pseudomiscellanea primitiva, Ranikothalia bermudezi, Nummulites heberti* and *Discocyclina seunesi*.

SBZ 4 (Late Thanetian) Defined by the biostratigraphic range of: *Glomalveolina levis, Hottingerina lukasi, Miscellanea meandrina, Daviesina garumnensis, Dictyokathina simplex, Nummulites catari, Assilina azilensis* and *Ass. yvettae*.

SBZ 5 (Early Ilerdian 1) Defined by the biostratigraphic range of: *Orbitolites gracilis, Daviesina tenuis, Alveolina vredenburgi, A. avellana avellana, A. aramaea aramaea, A. varians, Nummulites gamardensis, Assilina dandotica* and *Ass. prisca*.

SBZ 6 (Early Ilerdian 2) Defined by the biostratigraphic range of: *Alveolina ellipsoidalis, A. daniensis, A. posticillata, A. solida* and *Nummulites minervensis*.

SBZ 7 (Middle Ilerdian 1) Defined by the biostratigraphic range of: *Alveolina moussoulensis, A. subpyrenaica, A. dedolia, A. laxa, Nummulites robustiformis, N. carcasonensis, N. praecursor, N. obliticus, Assilina arenensis* and *Orbitoclypeus schopeni neumannae*.

SBZ 8 (Middle Ilerdian 2) Defined by the biostratigraphic range of: *Alveolina corbarica, A. recondita, A. brassica, Nummulites exilis, N. atacicus, N. globulus nanus, N. globulus latior, Assilina leymeriei* and *Ass. canalifera*.

SBZ 9 (Late Ilerdian) Defined by the biostratigraphic range of: *Alveolina trempina, A. citrea, A. polatliensis, Nummulites involutus, Assilina adrianensis* and *Ass. pomeroli*.

SBZ 10 (Early Cuisian) Defined by the biostratigraphic range of: *Alveolina schwageri, A. indicatrix, A. canavarii, A. haymanensis, A. cosinensis cosinensis, A. minuta, Nummulites planulatus, N. aquitanicus, N. burdigalensis burdigalensis, N. subramondi thalmanni, N. rotularius, N. pavloveci, N. subdistans, Assilina plana, Ass. placentula, Ass. aspensis, Ass. karreri, Ass. escheri* and *Discocyclina archiaci archiaci*.

SBZ 11 (Middle Cuisian) Defined by the biostratigraphic range of: *Alveolina dainelli, A. aff. canavarii, A. histrica histrica, A. decastroi, A. cremae, Nummulites praelaevigatus, N. burdigalensis cantabricus, N. kapellosi, N. escheri, N. nitidus, N. archiaci, Assilina laxispira* and *Discocyclina tortisi simteropolensis*.

SBZ 12 (Late Cuisian) Defined by the biostratigraphic range of: *Alveolina vialae, A. rakoveci, A. azzarolii, A. cuspidata, Nummulites manfredi, N. angularis, N. campesinus, N. quasilaevigatus, N. formosus, N. caupennensis, Assilina maior* and *Ass. cuvillieri*.

SBZ 13 (Early Lutetian) Defined by the biostratigraphic range of: *Alveolina stipes, A. colloso, A. cayrasi, A. hottingeri, Nummulites laevigatus, N. obesus, N. verneuili, N. uranensis, N. lehneri, N. messinae, Assilina parva, Ass. tenuimarginata, Ass. praespira* and *Ass. spira obrardi*.

SBZ 14 (Middle Lutetian 1) Defined by the biostratigraphic range of: *Alveolina munieri, Nummulites beneharnensis, N. gratus, N. aspermontis, N. hilarionis, N. stephani, N. boussaci* and *Assilina spira spira*.

SBZ 15 (Middle Lutetian 2) Defined by the biostratigraphic range of: *Alveolina prorrecta, Nummulites sordensis, N. crassus, N. millecaput, N. tavertetensis, N. crusafonti* and *Orbitoclypeus douvillei chudeaui*.

SBZ 16 (Late Lutetian) Defined by the biostratigraphic range of: *Nummulites herbi, N. deshayesi, N. praepuschi, N. aturicus, N. carpenteri, N. puigsecensis, Assilina gigantea* and *Discocyclina pulcra balatonica*

SBZ 17 (Early Bartonian) Defined by the biostratigraphic range of: *Alveolina elongata, A. fragilis, A. fusiformis, Nummulites brongniarti, N. perforatus, N. hottingeri, N. puschi, N. biarritzensis, N. lyelli* and *Discocyclina pulcra baconica*.

SBZ 18 (Late Bartonian) Defined by the biostratigraphic range of: *Nummulites biedai, N. cyrenaicus, N. vicaryi* and *N. boulangeri*.

SBZ 19 (Early Priabonian) Defined by the biostratigraphic range of: *Nummulites fabianii, N. garnieri garnieri, N. cunialensis, Discocyclina pratti minor* and *Asterocyclina alticostata donubica*.

SBZ 20 (Late Priabonian) Defined by the biostratigraphic range of: *Nummulites retiatus, N. garnieri inaequalis* and *Heterostegina gracilis*.

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