

REMARKS ON MIDDLE TO LATE MIOCENE CHRONOSTRATIGRAPHY

by

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Neogene standard stages, most of which are defined in the Mediterranean stratigraphic record, have not yet been formally defined by the GSSP of their bases. Indeed, Neogene stages are rarely used outside their type region (see, for example, most DSDP and ODP Reports and Scientific Results). This may derive from the fact that, besides lacking a formal definition, most of their stratotype sections have been difficult to position in time and, hence, to correlate worldwide. In particular, the position in time and the mutual relationships of the Langhian, Serravallian and Tortonian stratotype sections, all located in Piemonte region (NW Italy), are not well established (Berggren et al., 1985; Rio et al., 1990a; Rio et al., 1990b).

In order to contribute to the formal definition of the middle and late Miocene stages, we have undertaken high resolution quantitative studies of the calcareous nannofossil contents of the Langhian and Serravallian historical stratotype sections (Fig. 1) and of other mediterranean reference middle Miocene sections (Bossio et al., 1992; Fornaciari, Rio, Iaccarino, Ghibaudo, Massari, in preparation). These studies have resulted in a proposal of a new Mediterranean calcareous nannofossil biostratigraphic scheme for the early and middle Miocene (Fornaciari and Rio, submitted 1994; Fornaciari et al., submitted 1994) which can be correlated with the oceanic stratigraphic record and the Mediterranean planktonic foraminifera zonation of Iaccarino (1985) (Fig. 2). The framing in the calcareous nannofossil biostratigraphy of the stratotype sections of the Langhian, Serravallian and Tortonian (the latter on the base of the published data of Martini, 1975 and Mazzei, 1977) integrated with the available data provided by planktonic foraminifera, allow to evaluate their mutual relationships and, at least grossly, to correlate them on global scale (Fig. 3). The results of these studies suggest that a revision of the middle and late Miocene chronostratigraphy is needed. The latter topic is widely discussed in Rio et al. (submitted 1994). In this report we briefly summarize the most significant results of previous studies and reiterate for a discussion within the Neogene community the chronostratigraphic proposal made by Rio et al. (submitted 1994).

MAIN RESULTS

- Calcareous nannofossils allow a straightforward correlation among the historical stratotypes of the Langhian, Serravallian and Tortonian indicating that the three stratotypes do not overlap each other and time gaps exist between them (Figs. 3 and 5).
- The base of the Langhian, as recognized since long time (Cita and Blow, 1969), is associated with the *Praeorbulina* datum, which occurs however some 100m below the base of the historical stratotype section (Bossio et al., 1992; Fornaciari, Iaccarino et al., submitted 1994; Fig. 3). In terms of calcareous nannofossil biostratigraphy the base of the Langhian is within the overlapping ranges of *Sphenolithus heteromorphus* and *Helicosphaera ampliaperta* (Zone NN4 of Martini, 1971 and Zone CN3 of Okada and Bukry, 1980).
- The base of the Serravallian, which so far was poorly constrained in terms of calcareous plankton biostratigraphy (Berggren et al., 1985), is close to the LO of *S.*

heteromorphus (occurring some 25-30m above the base of the stratotype section, Fig. 1).

- The base of the Tortonian is within the range of *Discoaster hamatus* (Zone NN9/CN7). The presence of *Neogloboquadrina acostaensis* detected in the lower part of the stratotype section (Cita and Blow, 1969) most probably does not represent the first occurrence of the species in the Mediterranean as suggested by calcareous nannofossil correlations reported in Figure 3.

The most interesting finding of previous studies has been the fact that the base of the Serravallian is remarkably close to the LO of *S. heteromorphus*, one of the most easily recognized and widely correlatable calcareous nannofossil biohorizon of the Neogene (Olafsson, 1991; Raffi et al., in press), which virtually coincides with one of the major change in the paeoclimatic-paleoceanographic history of the entire Cenozoic, the so called Mid-Miocene event (Fig. 7). This event consists in a major increase of the $\delta^{18}\text{O}$ of the benthic foraminiferal record, interpreted as related to a combination of increased production of high-latitude cold deep waters and increased east Antarctica ice sheets growth (see, among others, Miller et al., 1991a, 1991b). Miller et al. (1991a) labelled the maximum increase in the $\delta^{18}\text{O}$ as Mi3 event (Fig. 5), and demonstrated its wide correlatability. Concomitant with the Mi3 event is a change in the $\delta^{13}\text{C}$ of benthic and planktic foraminifera recorded worldwide (the end of the "Monterey excursion" of Vincent and Berger, 1988; Fig. 4).

ARE HISTORICAL STRATOTYPE SECTIONS SUITABLE AS GSSPs?

The practice of defining stages by the GSSP of their bases meets with the needs of precision and accuracy in time correlations which can be achieved in modern stratigraphy by integrating various dating tools, especially in the Neogene. The Langhian, Serravallian and Tortonian (as well as virtually all the stages of the standard Geologic Time Scale) have been introduced and stratotypified in a cultural context very different from the present one and often with regional (and not global) scopes. Not surprisingly their stratotypes fail to meet with the requirements of the GSSP. Specifically, because of the unfavourable facies (terrigenous and turbiditic sediments in the Langhian, inner and outer shelf sediments in the Serravallian and Tortonian), the historical stratotype sections are unsuitable for establishing the precise chronology which is necessary in defining the GSSPs of Neogene stages. The search for suitable marine pelagic sequences is required and is under way by members of the Subcommission of the Neogene Stratigraphy (Leader: M. B. Cita) and of the Miocene Columbus Project (MICOP, leaders: G. Odin, A. Montanari, and R. Coccioni).

THE CHRONOSTRATIGRAPHIC PROPOSAL

The most critical point in defining a chronostratigraphic unit is the selection of the boundary point in the lithologic record. Bearing in mind that stages should represent the smallest chronostratigraphic unit in the stratigraphic jargon in prospect applicable all over the world in various facies, it is selfevident that the boundaries between stages should correspond to moments (but intervals are sufficient for most practical needs) of geologic time when significant environmental, life evolutive and physical changes have occurred. During Neogene, steps in the evolution of the global climatic system may represent such moments, and the Miocene Series represents a key interval in the global climatic evolution of the Cenozoic Era. It would be tempting to revise the traditional chronostratigraphy "adjusting" stages to major climatic steps in order to

in order to establish a sort of "natural" chronostratigraphy. However, chronostratigraphic units are being used since last century, although with regional scopes and often in contradictory ways, and they are deeply entrenched in geological literature. Elemental reasons of stability of the stratigraphic nomenclature suggest that in defining stages by means of the GSSPs of their bases a compromise is to be done among 1) the real position in time of the stratotype, which is the only definition of the unit; 2) the use which stratigraphers have done of it, i. e. the criteria which have been practically used for its recognition outside the type area; 3) the potential of worldwide correlatability. In line with these reasonings, Rio et al. (submitted 1994) proposed to subdivide the middle and late Miocene as follows (see Fig. 4):

- the base of the Langhian be defined closed to (not necessarily coincident with) the *Praeorbulina* datum;
- the base of the Serravallian be defined close to the LO of *S. heteromorphus*;
- the base of the Tortonian be defined close to the FO of *N. acostaensis*.

This proposal does not violate the position in time of the historical stratotypes and results in a balanced subdivision of the Miocene Series (Fig. 4). The bases of the Serravallian and the Tortonian are positioned in times of high climatic instability (Fig. 5), which should facilitate their global recognition. The Langhian, which is deeply entrenched in the stratigraphic literature, corresponds with the Miocene maximum of the sea-level stand (Fig. 5), but its base apparently does not correspond with a major climatic threshold.

References

- Berggren W.A., Kent D.V. & Van Couvering J.A., 1985 - The Neogene: Part 2. Neogene geochronology and chronostratigraphy. In Snelling N.J. Ed.: The Chronology of the Geological Record. Mem. Soc. Geol., London, 211-259.
- Bossio A. Fornaciari E., Iaccarino S., Mazzei R., Monteforti B., Rio D., & Salvatorini G., 1992 - Integrated calcareous plankton biostratigraphy from the Langhian stratotype section (Piedmont Tertiary Basin, Italy). Interdisc. Geol. Confer. on the Miocene Epoch, Ancona, (abstract).
- Cande S.C. & Kent D.V., 1992 - A new geomagnetic Polarity Time Scale for Late Cretaceous and Cenozoic. J. Geoph. Res., v.97, 13.917-13.951.
- Cita M.B. & Blow W.H., 1969 - The biostratigraphy of the Langhian, Serravallian and Tortonian stages in the type-sections in Italy. Riv. Ital. Paleont., v.75, 549-603.
- Fornaciari E., Iaccarino S., Mazzei R., Rio D., Salvatorini G., Bossio A., & Monteforti B., 1994 submitted- Calcareous plankton biostratigraphy of the Langhian historical stratotype. In: Montanari A., Odin G. and Coccioni R. (Eds.). Miocene Integrated Stratigraphy.
- Fornaciari E., Rio D., Ghibaudo G., Iaccarino S., Massari F. - Calcareous plankton biostratigraphy of the Serravallian (middle Miocene) stratotype section (Piedmont Tertiary basin NW Italy). In preparation
- Fornaciari E. and Rio D., 1994 submitted - Latest Oligocene to Early Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean Region. Micropaleontology.
- Fornaciari E., Di Stefano A., Rio D. and Negri A., 1994 submitted - Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean Region. Micropaleontology.
- Iaccarino S., 1985 - Mediterranean Miocene and Pliocene planktic foraminifera. In Plankton stratigraphy, Bolli H.M., Saunders J.B. & Perch Nielsen K. (Eds), 283-314.
- Martini E., 1971 - Standards tertiary and quaternary calcareous nannoplankton zonation. Proc. II Plankt. Confer., Roma, 1970, 739-786.

- Martini E., 1975 - Calcareous nannoplankton from the type Tortonian (upper Micene). C.M.N.S., Proc. VI Congress Regional Bratislava, 1975, 53-56.
- Mazzei R., 1977 - Biostratigraphy of the Rio Mazzapiedi-Castellania section (type section of the Tortonian) based on calcareous nannoplankton. Atti Soc. Tosc. Sc. Nat. Mem., v.84, 15-24.
- Miller, K. G., Wright, J. D., and Fairbanks, R. G., 1991a - Unlocking the Ice House: Oligocene-Miocene Oxygen Isotopes, Eustasy, and Marginal Erosion. Journ. Geophys. Res., 96, 6829-6848.
- Miller K.G., Feigenson M.D., Wright J.D & Clement B.M., 1991b - Miocene isotope reference section, Deep Sea drilling Project Site 608: An evaluation of isotope and biostratigraphic resolution. Paleoceanogr., v.6, 33-52.
- Okada H. & Bukry D., 1980 - Supplementary modification and introduction of code numbers to the low latitude coccolith biostratigraphic zonation. Marine Micropal., v.5, 321-325.
- Olafsson G., 1991 - Quantitative calcareous nannofossil biostratigraphy and biocronology of early through late Miocene sediments from DSDP 608. Medd.Stockholm Univ. Inst. Geol. Geok., 203 (4), 28 pp.
- Raffi I., Rio D., d'Atri A, Fornaciari E. and Rocchetti S. - Quantitative distribution patterns and biomagnetostatigraphy of middle and late Miocene calcareous nannofossils from equatorial Indian and Pacific oceans (Legs 115, 130 and 138). In Press.
- Rio, D., Fornaciari, E., and Raffi, I., 1990a. - Late Oligocene through early Pleistocene calcareous nannofossils from western equatorial Indian Ocean (Leg 115). In Duncan R.A. Backman J et al. Proc. ODP Sci. Results, v. 115, 175-221.
- Rio D., Sprovieri R., & Fornaciari E., 1990b - Remarks on the middle-late Miocene boundary. IX Congr. C.R.M.N.S., Barcelona, 1990, (abstract).
- Rio D., Cita M.B., Gelati R., and Gnaccolini M., 1994 submitted - Langhian, Serravallian and Tortonian historical stratotypes. In: Montanari A., Odin G. and Coccioni R. (Eds.). Miocene Integrated Stratigraphy.
- Vincent, E and Berger, W. H., 1988 - Carbon Dioxide and Polar Cooling in the Miocene: the Monterey Hypothesis. In: Sundquist, E. t., and Broecker, W., S. (eds): The Carbon Cycle and Atmospheric CO₂: Natural Variations Archean to Present. AGU Geophysical Monograph 32, 455-468.

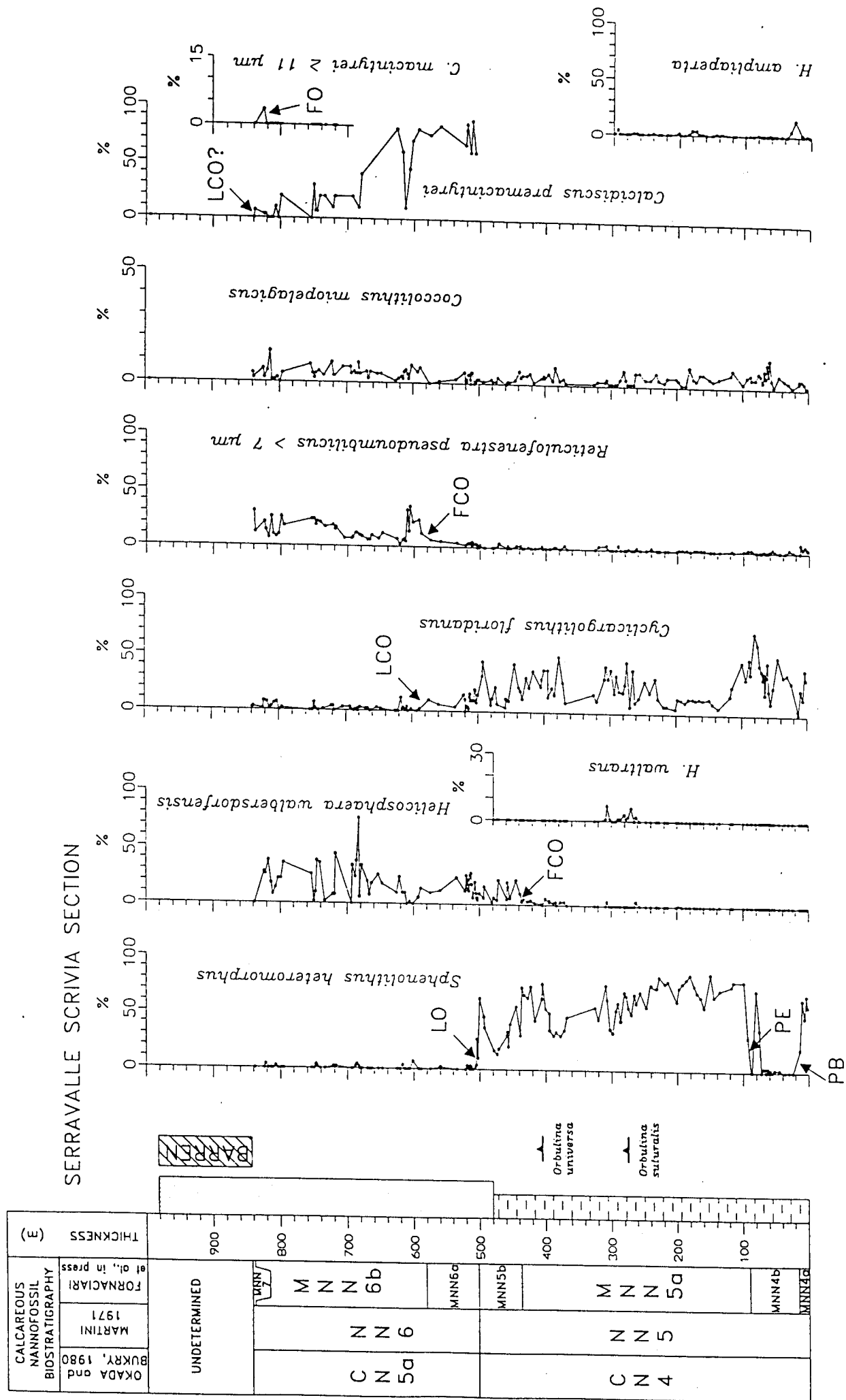


Fig. 1. Quantitative distribution patterns of index calcareous nannofossils in the Serravallo stratotype section at Serravallo Scriva. After Fornaciari, Rio, Ghibaud, Iaccarino, Massari, in preparation.

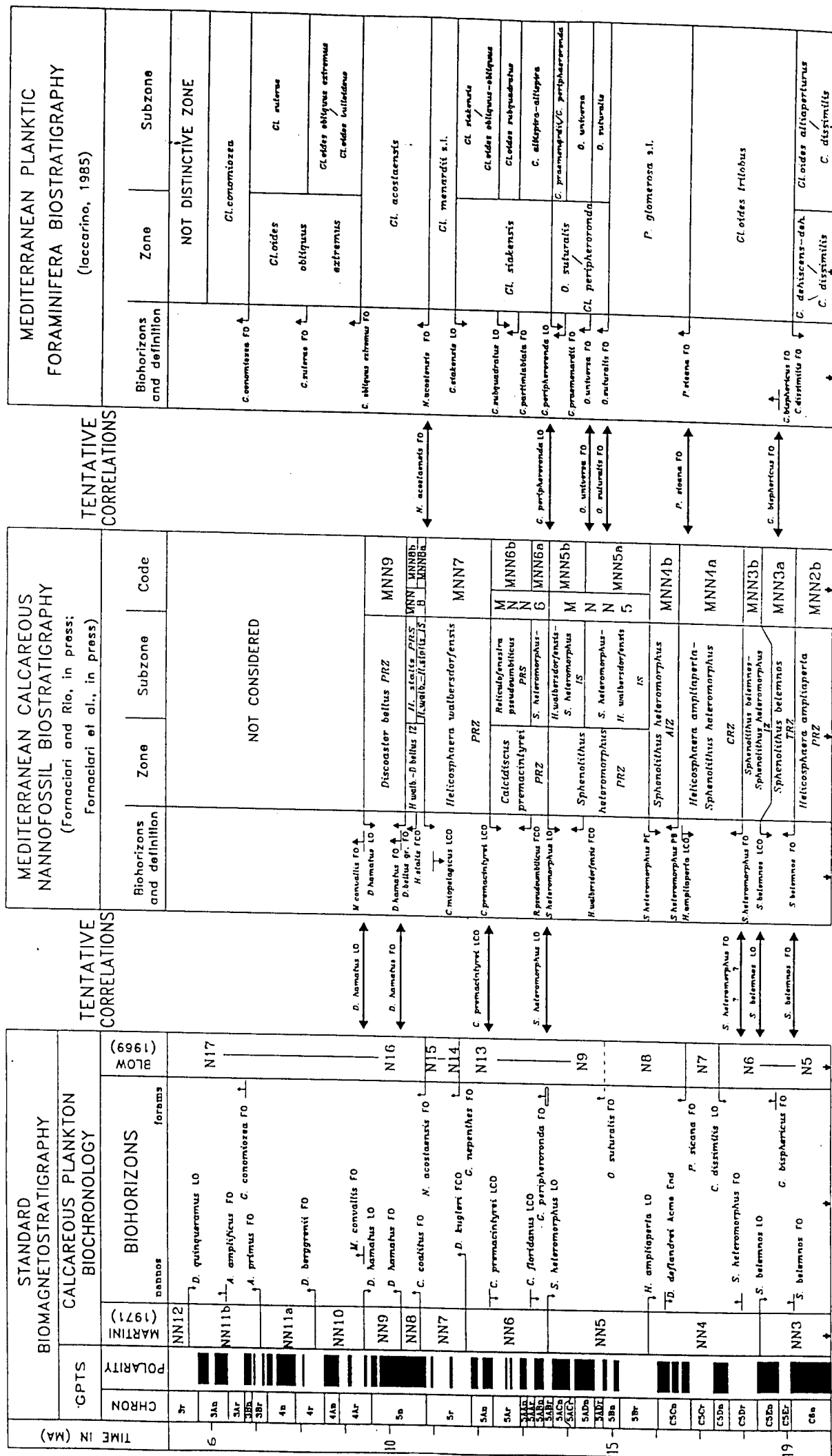


Fig. 2. Correlation of Mediterranean calcareous plankton biostratigraphic schemes to oceanic standard biomagnetostратigraphy.

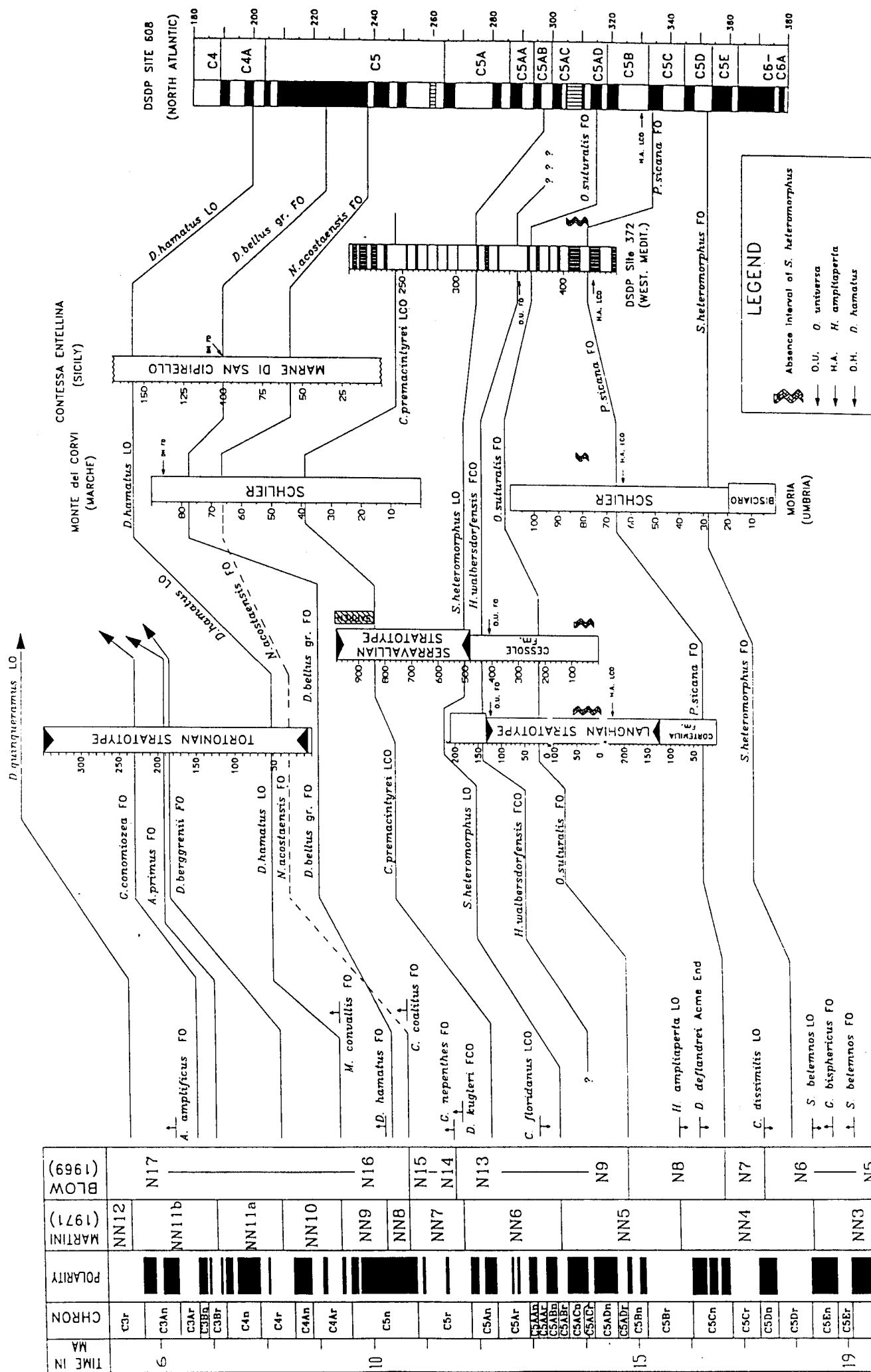


Fig. 3. Mediterranean reference and stratotype sections correlated to DSDP Site 608 (North Atlantic) and to standard biomagnetostratigraphy.

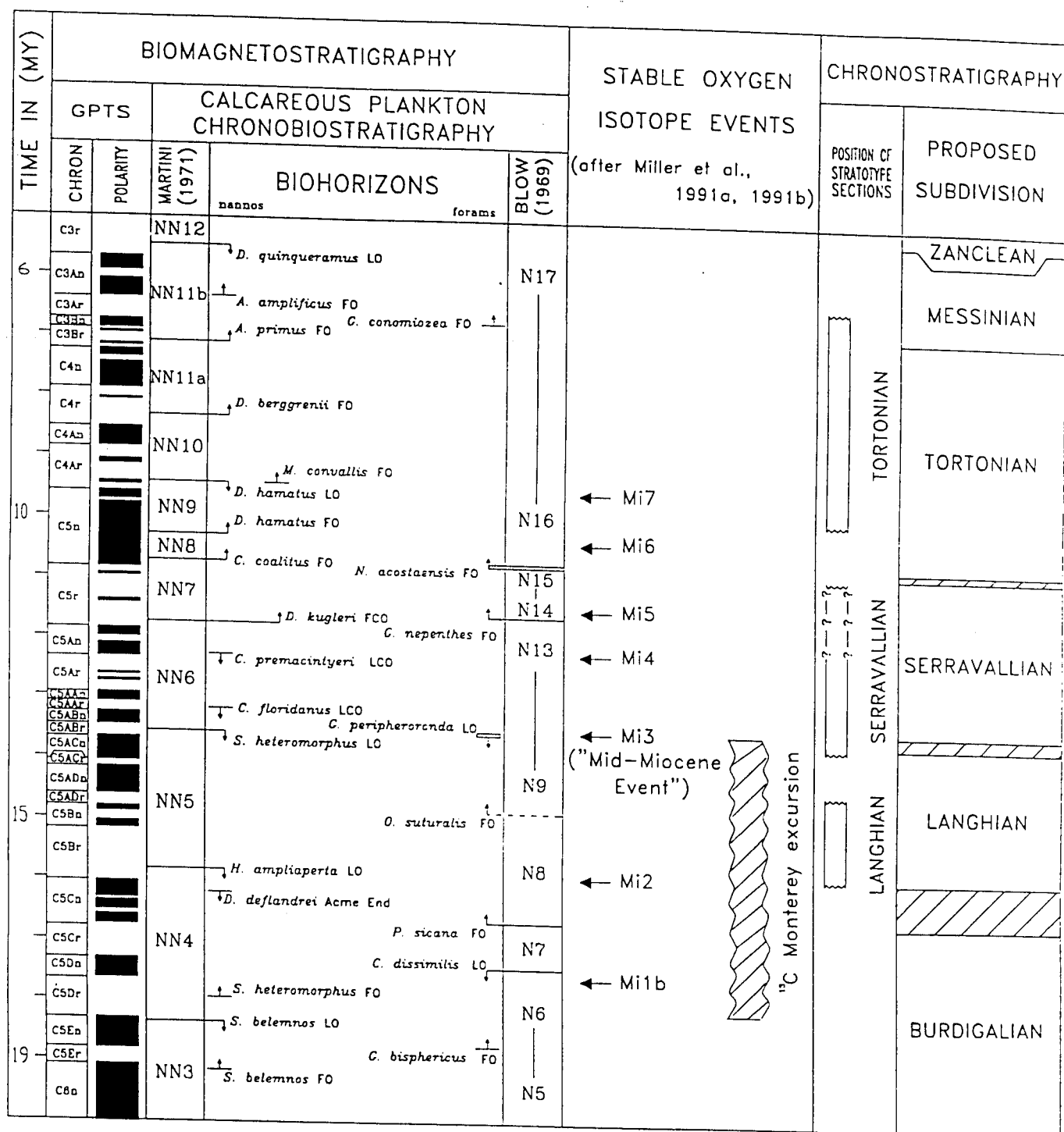


Fig. 4. Proposed chronostratigraphic subdivision of the middle Miocene. After Rio et al., submitted 1994.

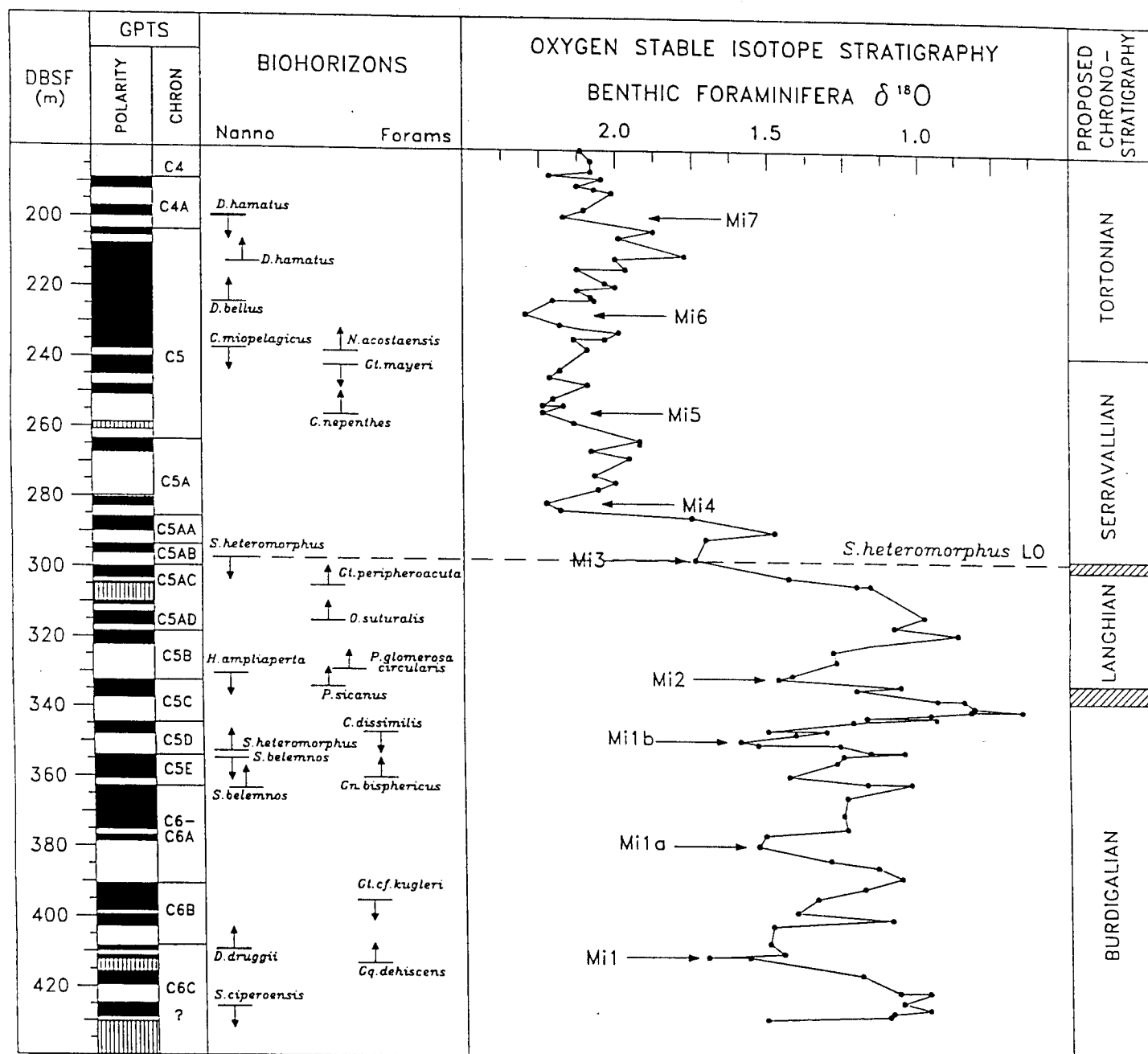


Fig. 5. The proposed middle Miocene chronostratigraphy applied in DSDP Site 608 core, proposed as a deep sea reference Miocene section by Miller et al. (1991b).