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The Global Standard Stratotype-section and Point (GSSP) of the Piacenzian Stage (Middle Pliocene)

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The base of the Piacenzian Stage, representing the Lower Pliocene-Middle Pliocene boundary, has been recently defined and ratified by IUGS. The boundary-stratotype is located in the Punta Piccola section (Sicily, Italy).

Introduction

The aim of this report is to announce the ratification of the Global Standard Stratotype-section and Point of the Piacenzian Stage (Middle Pliocene). Together with the Gelasian (Upper Pliocene; reported on in this same issue) and the Zanclean (Lower Pliocene) Stages, the Piacenzian represents the threefold subdivision of the Pliocene Series in the Global Standard Chronostratigraphic Scale.

A brief description of the stratotype-section, of the boundary itself ("golden spike") and of the different stratigraphic tools available for the worldwide correlation of the boundary will be provided. More information can be found in the proposal (Cita et al., 1996) voted by the Subcommittee on Neogene Stratigraphy (SNS) and the International Commission on Stratigraphy (ICS) reported in Neogene Newsletter no 3 and in the literature referred to in this paper.

A postal ballot on the proposal by Cita et al. (1996) was forwarded to all voting members of the Subcommittee on Neogene Stratigraphy (SNS) in 1996 and unanimously accepted. Following the results of the postal ballot, a formal recommendation of SNS was submitted to the Secretary General of the International Commission on Stratigraphy (ICS) in October 1996. Official acceptance by ICS and ratification by the Executive Committee of IUGS were obtained in January 1997.

Background and motivation

The erection of the Gelasian as third (and uppermost) Stage of the Pliocene Series (published in this issue), formally settled the controversies concerning the upward extension of the Piacenzian Stage. As a consequence, the Piacenzian now represents the (entire) Middle Pliocene because its top is automatically defined by the base of the overlying Gelasian Stage in the Monte San Nicola section (also in Sicily), a point in the rock with an approximate age of 2.588 Ma, close to the Gauss/Matuyama magnetic reversal.

Immediately after having reached an agreement on the Gelasian Stage, the Subcommittee on Neogene Stratigraphy was faced with the problem of defining the base of the Piacenzian Stage. According to the guidelines for defining chronostratigraphic boundaries (see Remane et al., 1996 for detailed information), a unit stratotype, as

the one defined by Barbieri (1967; see below) for the Piacenzian, is no longer appropriate for the definition of a Stage. The only (formally) acceptable way to define the Piacenzian Stage was to select and approve a boundary stratotype for its base.

Since in the type-area of the Piacenzian (near Castell'Arquato, Northern Apennines, Italy) a hiatus was proved to be present right at the base of this chronostratigraphic unit (see further on), the attention focused on Sicily, where a continuous succession of hemipelagic limestones and marls, or marls and sapropelic layers, is exposed along the southern coast.

At first sight, it seems arbitrary to have a Piacenzian Stage defined on Sicily (Piacenza is a town on the Emilian side of the Po river in Northern Italy); however, move outside the type-area for the selection of the most suitable section to define the base of a chronostratigraphic unit is common in modern stratigraphy. This allows for preserving name and approximate time-significance of widely used chronostratigraphic units and maintaining, as far as possible, the stability of stratigraphic nomenclature.

In the following paragraph, we will briefly introduce the historical Piacenzian Stage to document how the ratified GSSP is respective of its original definition.

The Piacenzian Stage

Since its introduction (Mayer-Eymar, 1858), the Piacenzian Stage has been quite popular in the geologic literature. It was soon adopted by Pareto (1865), who clearly indicated the fossiliferous sediments ("blue clays") outcropping between Castell'Arquato and Lugagnano (Northern Apennine) as typical of the unit. He ascribed the Piacenzian to the (upper) Tortonian which at that time was considered a Pliocene unit. Afterwards, the term Piacenzian has been widely used, although with rather different meanings. Reviewing the literature, one may gain the impression that the term was more often used as a lithostratigraphic than a chronostratigraphic term, indicating the "Argille azzurre" of the Italian Pliocene (see Gignoux, 1950).

The designation of a unit-stratotype in the Castell'Arquato section by Barbieri (1967) was an important step towards the clarification of the Piacenzian Stage. The base was defined at the lithofacies change from slope-basin to outer-shelf sediments coincident with the local disappearance of the planktonic foraminifer *Globorotalia margaritae*. The latter bioevent was subsequently used in most geologic time scales to mark the base of the Piacenzian (e.g., Cita, 1973; Berggren and Van Couvering, 1974; Berggren et al., 1985, 1995b; Haq and Van Eysinga, 1987; Haq et al., 1988; Harland et al., 1982, 1990).

As already mentioned, an integrated calcareous plankton biostratigraphic study carried out by Rio et al. (1988) and Raffi et al. (1989) clearly demonstrated that a hiatus is present right at the base of the type-Piacenzian and that the local disappearance of *G. mar-*

garitae does not correspond to its extinction datum. According to these Authors, the Piacenzian base lies at an undetermined point in between the last occurrence (LO) of *Reticulofenestra pseudumbilicus* (dated at 3.89 Ma, according to the time scale of Lourens et al., 1996a) and the temporary disappearance in the Mediterranean of *Globorotalia puncticulata* (3.57 Ma). The outcome of this investigation was twofold. In the first place, the LO of *G. margaritae* could not be used to export the base of the Piacenzian away from the type-area; secondly, the type-area is not suitable to formally define the base of the Piacenzian Stage and a suitable continuous section had to be found elsewhere.

The GSSP of the Piacenzian Stage

Having to move away from the Castell'Arquato section, our attention focused immediately on the Punta Piccola section for two obvious reasons. In the first place, the Italian stratigraphic record is considered as the type of the Pliocene Series and, secondly, the Rossello Composite Section (of which the Punta Piccola is the upper segment) has recently become a reference standard for Pliocene Time Scales (Langereis & Hilgen, 1991; Hilgen, 1991b; Berggren et al., 1995a; Lourens et al., 1996a). The superior quality of the selected section is discussed below.

The section

Location

The Punta Piccola section is located along the road from Porto Empedocle to Realmonte, 4 km to the east of Capo Rossello, and

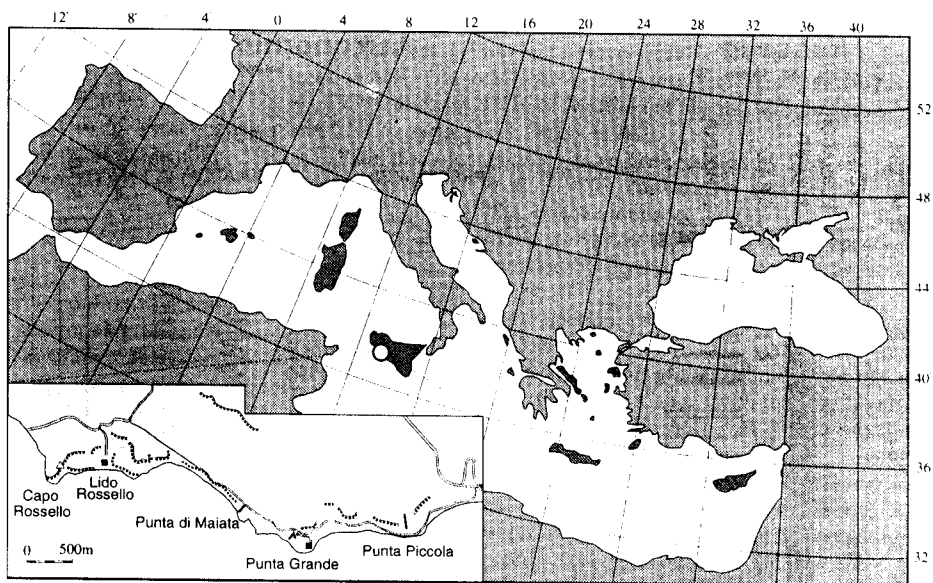


Figure 1 Location of the Punta Piccola section.

about 3 km to the W-NW of Porto Empedocle (Agrigento province, Sicily, Italy), at a latitude of $37^{\circ}17'20''$ N and a longitude of $13^{\circ}29'36''$ E of Greenwich ($1^{\circ}02'25''$ E of Monte Mario). The area is represented on the Carta Topografica d'Italia at 1:25,000 Foglio 271, IV NO (Porto Empedocle) (Figures 1 and 2).

The stratigraphic succession

The Punta Piccola section is situated in the Caltanissetta Basin; from a structural point of view, the section belongs to a major tectonic element known as Gela nappe or Gela thrust system (Ogniben, 1969; Butler et al., 1995). The Rossello Composite Section is made up by about 100 m of alternating limestones and marls of the Trubi Formation gradually passing upwards into the more marly Monte Narbone Formation, characterized by the cyclical occurrence of laminated (sapropelic) layers (Figures 2 and 3). The transition from the

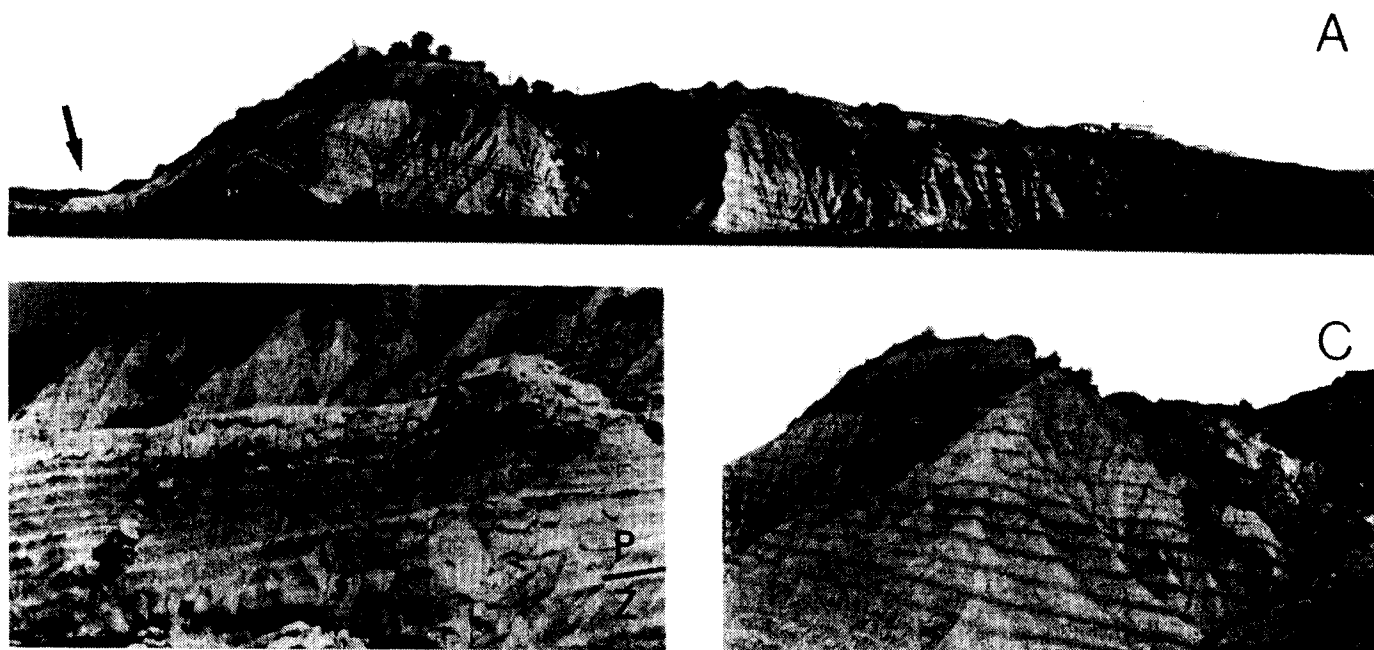


Figure 2 (a) Punta Piccola section, showing the topmost Trubi beds at the left and the overlying Monte Narbone marls and sapropels, strike and dip: 330° and 10° (photo courtesy after M J Brolsma, 1978), (b) Close-up of the Zanclean/Piacenzian boundary (solid line) interval of the Trubi marls at Punta Piccola, (c) Close-up of the Trubi-Monte Narbone boundary interval. Dark colored ferromanganese and organic enriched beds are indicated with A to L after Brolsma (1978).

Rossello

Langereis and Hilgen, 1991

Astronomical Time Scale

Lourens et al., 1996

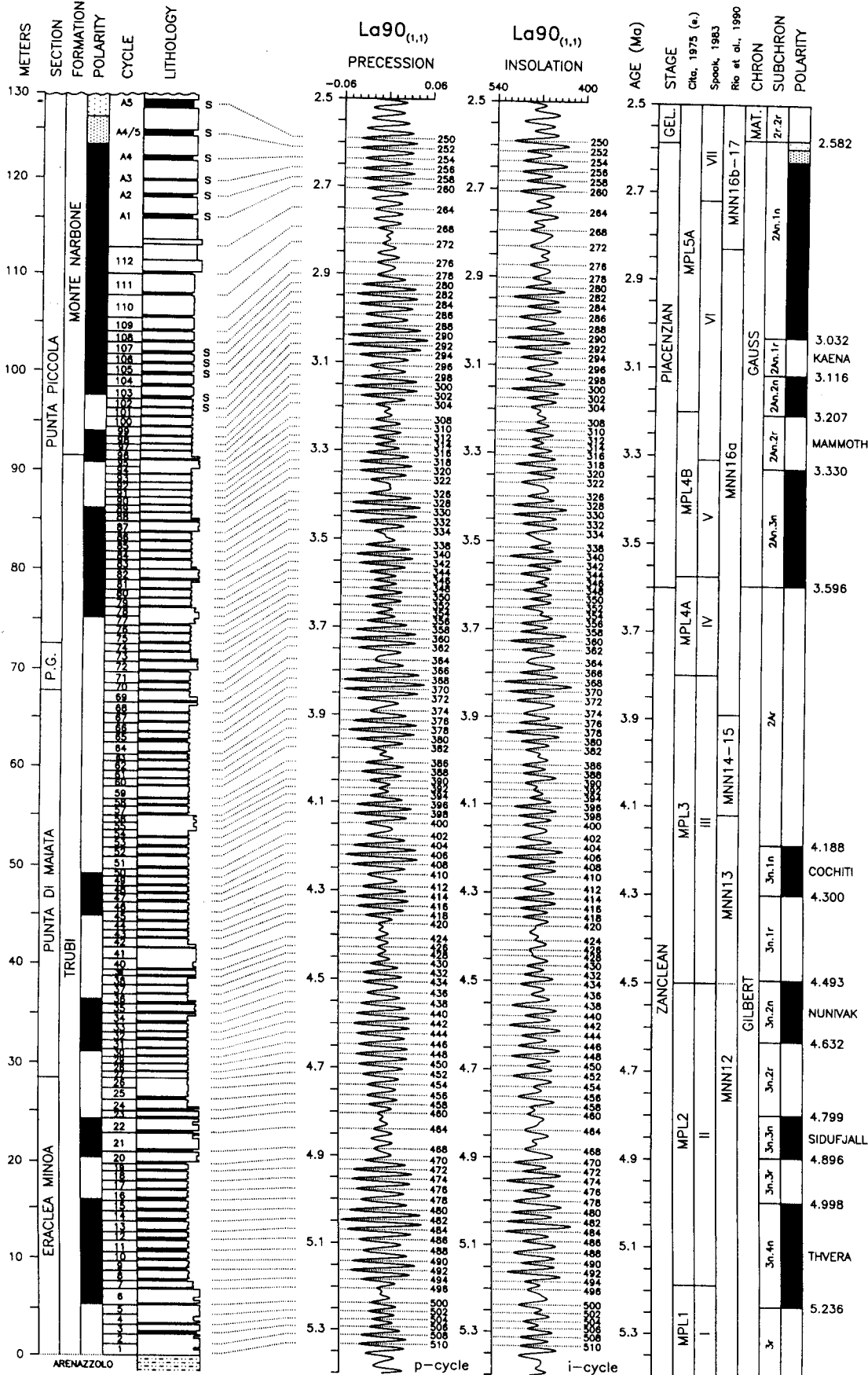


Figure 3 Chronology of the Rossello composite section based on the correlation of small-scale carbonate cycle patterns to the $La90_{(1,1)}$ (Laskar, 1990; Laskar et al., 1993) precession and $65^\circ N$ summer insolation curves (Hilgen, 1991b; Lourens et al., 1996a).

Trubi to the Monte Narbone formations actually occurs in the Punta Piccola segment of the Rossello Composite, at about 20 m from its base. The depositional environment is inferred to be an open marine slope-basin setting (Brolsma, 1978; Sprovieri & Barone, 1982). According to the abundance of planktonic foraminifers, the presence of rare psychrospheric ostracods and the composition of the benthic assemblage, the water depth is estimated to range from 800 to 1,000 m.

Biomagnetostratigraphy, astrocyclostratigraphy, and isotope stratigraphy

During the last decade, detailed field work carried out on rhythmically bedded sedimentary successions widely outcropping in Sicily and Calabria led to the reconstruction of an ideal stratigraphic composite section which ranges from the base of the Pliocene to the middle Pleistocene (e.g. Hilgen, 1987, 1990, 1991a, b; Langereis & Hilgen, 1991; Zijdeveld et al., 1991; Lourens et al., 1996a, b; Lourens et al., 1997). The cyclic limestone-marl and marl-sapropel alternations in this succession were tightly linked to every single fluctuation of the Earth's precessional parameter (in turn modulated by orbital eccentricity), resulting in a continuous astrochronology of the lithostratigraphic record (Hilgen, 1991a, b). Later on, the influence of obliquity was also recognized in the lithologic record and the astronomical calibration slightly adjusted and improved (Lourens et al., 1996a).

This astrocyclostratigraphy, intimately linked to an integrated biostratigraphy (nanofossils and foraminifers) (among many others, Rio et al., 1990; Sprovieri, 1992, 1993) and magnetostratigraphy (e.g. Zachariasse et al., 1989, 1990; Zijdeveld et al., 1991; Langereis & Hilgen, 1991), resulted in a stratigraphic framework for the Mediterranean Pliocene and Pleistocene with unprecedented accuracy and resolution. This framework allows for a bed-by-bed correlation of stratigraphic sections hundreds of kilometers apart, testing stratigraphic continuity of specific intervals.

In the Punta Piccola section calcareous nanofossils were studied by Rio et al. (1984) and Driever (1988). The section is referable to Zone MNN16a to MNN16b/17 (in terms of the zonation by Rio et al., 1990), to Zone NN16 of Martini (1971) and to Subzones CN12a and CN12b of Okada & Bukry (1980).

Planktonic foraminifers have been studied by Brolsma (1978), Spaak (1983), Rio et al. (1984), Zachariasse et al. (1989, 1990), Sprovieri (1992, 1993), and Lourens et al. (1996a). The section ranges from Zone MPI4a to MPI5a (according to the zonation by Cita, 1973, 1975b, emended by Sprovieri, 1992) and from Interval IV to VII of Spaak (1983).

The Punta Piccola section provided an excellent magnetostratigraphy (Zachariasse et al., 1989, 1990) which was straightforwardly correlated to the upper part of the Gilbert (C2Ar of Cande & Kent, 1992, 1995), to the entire Gauss (with the Mammoth and Kaena Subchrons), and to the lowermost part of the Matuyama chrons.

Sprovieri (1992) used the percentage of *Globigerinoides ruber* to reconstruct temporal variations in sea surface temperature (SST). In addition, high-resolution quantitative planktonic foraminiferal and stable isotope records have been established by Lourens et al. (1996a) for the entire Rossello Composite Section (Figure 4). These authors recognized the influence of both precession and obliquity in these records. Obliquity controlled variations could be correlated in detail to ODP Site 659 (eastern tropical Atlantic) and Site 846 (eastern equatorial Pacific).

All the analytical data reported above clearly indicate that the Punta Piccola section is basically continuous, possible hiatuses having a duration below the resolution provided by astrocyclostratigraphy (few kyrs). The sedimentation rate ranges between 4.5 to 5.5 cm/kyr, increasing to 12 cm/kyr towards the top of the section.

In the upper part of the Punta Piccola section the base of the newly defined Gelasian Stage (see this issue) can be easily recog-

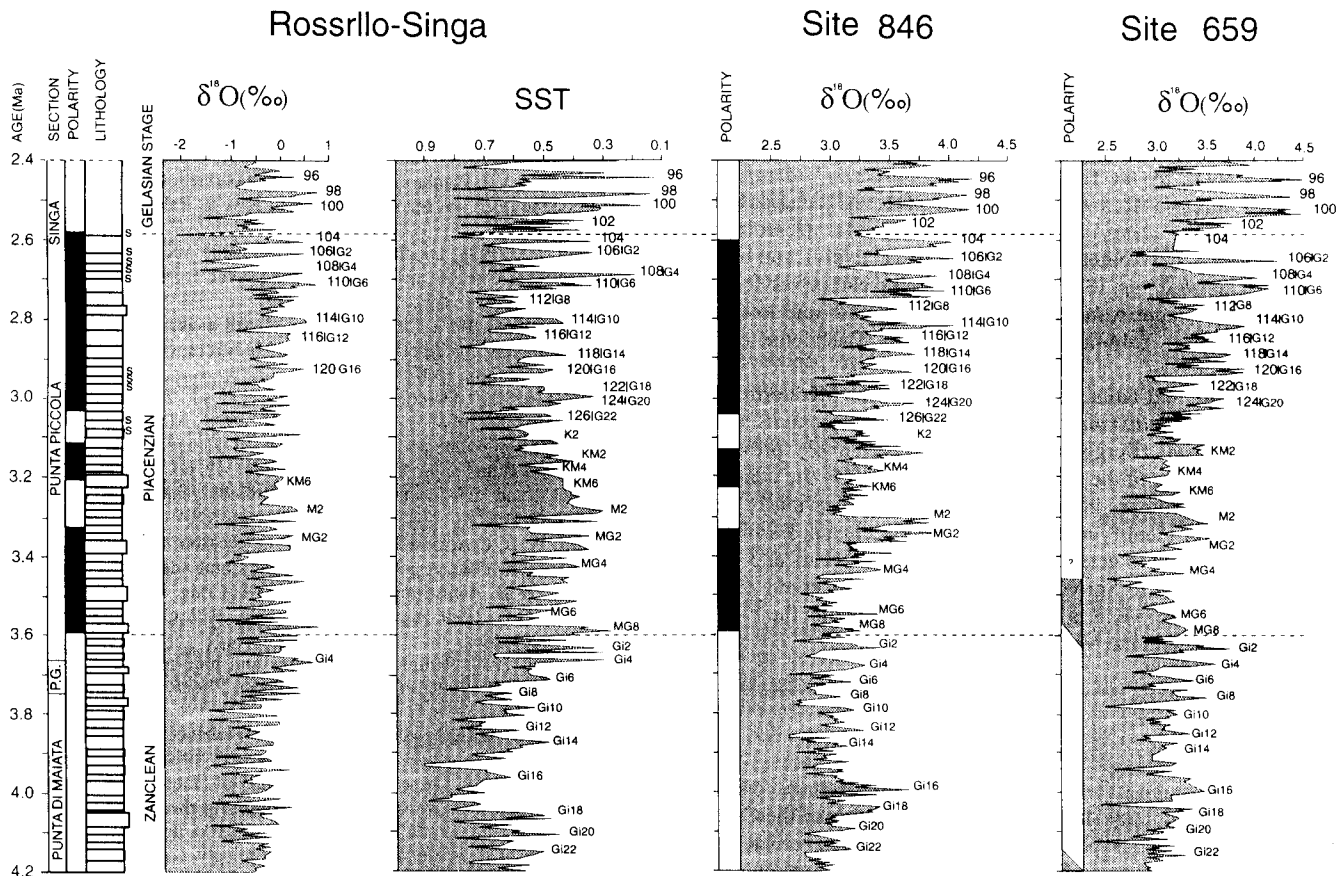


Figure 4 Stable isotope stratigraphy of the Punta Piccola section (Lourens et al., 1996a), ODP Site 659 (Tiedemann et al., 1994), and ODP Site 846 (Shackleton et al., 1995b)

nized by means of magneto-, bio-, and cyclostratigraphy (Hilgen, 1991b; Rio et al., 1994). Therefore, the entire Piacenzian Stage is exposed in the Punta Piccola section which may be regarded as a sort of unit-stratotype.

The boundary ("golden spike")

Definition and age

The base of the beige marl bed of the small-scale carbonate cycle 77 (sensu Hilgen, 1991b) is the approved base of the Piacenzian Stage (that is the Lower Pliocene-Middle Pliocene boundary). It corresponds to precessional excursion 347 as numbered from the present with an astrochronological age estimate of 3.600 Ma (Lourens et al., 1996a).

Correlation tools

The Gilbert-Gauss magnetic reversal can be considered as the primary tool for the worldwide recognition of the base of the Piacenzian Stage. In the Punta Piccola section the reversal is recorded immediately above the "golden spike", within the same precessional cycle, having an astrochronological age of 3.596 Ma (Lourens et al., 1996a).

From a stable isotope point of view, the boundary is located in obliquity-related $\delta^{18}\text{O}$ stage MG8 (Shackleton et al., 1995b; Tiedemann et al., 1994), labelled O-176 by Lourens et al. (1996a; 1997). The correlative $\delta^{18}\text{O}$ minimum is clearly recognizable in the isotopic record of ODP Site 659 (eastern tropical Atlantic) and Site 846 (eastern equatorial Pacific), where it closely corresponds to the Gilbert/Gauss boundary.

Most Pliocene biostratigraphic events are somewhat diachronous on a global scale (Dowsett, 1988; Hills and Thierstein, 1989) and, therefore, the time-significance of a single biohorizon in a specific region must be ascertained before using it as a chronostratigraphic correlation tool. However, numerous bioevents can be used in different regions to approximate the base of the Piacenzian Stage. In the Mediterranean region the base of the Piacenzian can be accurately approximated by the temporary disappearance of *Globorotalia puncticulata* (3.57 Ma according to Lourens et al., 1996a, and Sprovieri, 1993), by the first influx of *Globorotalia crassaformis* (3.60 Ma; Lourens et al., 1996a), by the end of the paracme interval of *Discoaster pentaradiatus* (3.56 or 3.61 Ma, according to Sprovieri, 1993, and Lourens et al., 1996a, respectively), and by the LO of *Sphenolithus* spp. (3.73 or 3.70 Ma, same authors as above). The last event is approximately synchronous in mid- and low-latitudes, having been calibrated at 3.66 (0.04 by Shackleton et al., 1995a).

In low- and mid-latitudes sediments outside the Mediterranean, the LO of *Globorotalia margaritae* and *Pulleniatina primalis*, dated at 3.58 and 3.65 Ma (Berggren et al., 1995a) respectively, provide a good approximation of the base of the Piacenzian. On the contrary, the LO of *G. margaritae* in the Mediterranean (the previously most used criterion for identifying the base of the Piacenzian; Barbieri et al., 1967) is difficult to determine consistently and occurs at 3.75 or 3.81 Ma (according to Sprovieri, 1993, and Lourens et al., 1996a, respectively). Therefore, it is a poor tool for recognizing the base of the Piacenzian within the Mediterranean.

Conclusion

The formal definition of the base of the Piacenzian Stage (Middle Pliocene) is an important step towards the completion of the Global Standard Chronostratigraphic Scale of the Neogene, which now include a tripartite Pliocene Series. In this issue, we also report on the introduction of a new Stage, the Gelasian, to represent the Upper Pliocene and on the formalization of its base which constitutes, by definition, the top of the Piacenzian Stage.

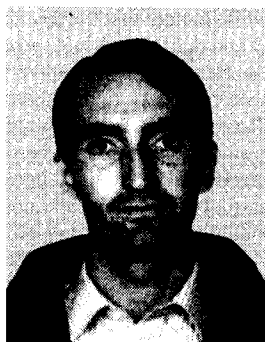
The definition of the base of the Zanclean Stage (Lower Pliocene) is not yet achieved. SNS plans to work hard in that direction in the next few months.

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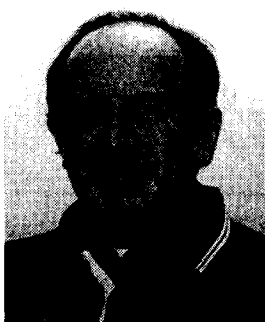
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