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THE GELASIAN STAGE: A PROPOSAL OF A NEW CHRONOSTRATIGRAPHIC UNIT OF THE PLIOCENE SERIES

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Key-words: Chronostratigraphy, Pliocene.

Riassunto. Viene proposto un nuovo piano, il Gelasiano, inteso come terza (e superiore) unità crono-stratigrafica del Pliocene. La base del Gelasiano (e il limite Pliocene medio - Pliocene superiore) coincide con un livello laminato rossastro che affiora nella sezione di Monte San Nicola, presso Gela (Sicilia meridionale). Questo livello corrisponde al "Mediterranean Precessional Related Sapropel" 250 di Hilgen (1991) ed ha una età, valutata su basi astronomiche, di 2.589 Ma. Esso corrisponde allo Stage isotopico 103 di Raymo et al. (1989) e nella sezione stratotipica affiora solo 1 metro al di sopra del limite paleomagnetico Gauss-Matuyama. Vengono presentati gli elementi astrocronologici, magnetostratigrafici, biostratigrafici e climatostratigrafici per approssimare al meglio la base del Gelasiano al di fuori della sua sezione stratotipica.

Abstract. A new Stage, the Gelasian, is proposed as the third upper subdivision of the Pliocene Series. The GSSP of the base of the Gelasian Stage and of the Middle Pliocene - Upper Pliocene boundary is coincident with a "sapropel" level which outcrops in the Monte San Nicola section, near Gela (Southern Sicily, Italy). This level corresponds to the Mediterranean Precessional Related Sapropel 250 of Hilgen (1991) and has an astrochronological age of 2.589 Ma. It correspondes to the oxygen isotopic Stage 103 of Raymo et al. (1989) and in the boundary stratotype section it outcrops 1 meter above the Gauss-Matuyama paleomagnetic boundary. Astrochronologic, magnetostratigraphic, biostratigraphic and climatostratigraphic elements to approximate the GSSP of the Gelasian outside the stratotype section are presented.

Foreword.

Chronostratigraphy, the subdivision and classification of the Earth geologic record on the base of time (Hedberg, 1976), does represent the most widely used "common language" of communication in Earth Science. The development of a Standard Global Chronostratigraphic Scale, based on rigorous agreement upon stratigraphic principles, terminology and classificatory procedure is one of the long-standing objective of the International Commission of Stratigraphy (ICS). A fundamental step toward this goal is the elaboration of a standard Series and Stage division within each Geologic System, together with the precise definition of boundaries between them

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(Basset, 1985). With regard to the latter effort, the principle has become firmly accepted that the base of each division be defined at a unique point in a rock sequence, representing a unique point in time to serve as a standard against which other sequences can be correlated by the different available time correlation tools. The standard section and point of the definition are referred to as the Global Boundary Stratotype Section and Point (GSSP) of the designated stratigraphic boundary.

In this paper we face the problem of the Stage level subdivision of the Pliocene Series, reiterating the proposal of its three fold subdivision (Rio et al., 1991) and formally proposing to the ICS the introduction of a new Stage for indicating the Upper Pliocene. We designate this new stage as "Gelasian" and we offer here to the scientific community the motivations for introducing this chronostratigraphic unit and the documentations concerning the section we propose as the GSSP of the Gelasian. This proposal has been discussed with and approved by the Italian Commission of Stratigraphy of the Italian Geological Society, leaded by Maria Bianca Cita (University of Milan).

Motivations.

It is beyond the scope of the present paper to review the historical development of the Pliocene chronostratigraphy. The reader is referred to the detailed reviews of Berggren (1971), Berggren & Van Couvering (1974) and Cita (1975a). We recall here only that the base of the Pleistocene System, and then the top of the Pliocene Series, has been formally defined by the ICS in Vrica section (Calabria, Southern Italy; Aguirre & Pasini, 1985) in a point close to the top of Olduvai Subchron, with an age of 1.83 Ma in the recently developed chronologies of Hilgen (1991) and Shackleton et al. (1990). The base of the Pliocene Series, traditionally considered to be coincident with the restoration of open marine conditions in the Mediterranean basin, following the Messinian "salinity crisis" (Cita, 1975b), has not been formally defined, and different contrasting proposals have been made (Cita, 1975b; Benson et al., 1991; Rio et al., 1991; Hilgen & Langereis, 1993). The age of the restoration of open marine conditions in the Mediterranean, the criterion so far used in the Mediterranean for recognizing the Miocene-Pliocene boundary, has been recently quite accurately determined as being 5.32 Ma in terms of the astronomical chronology of Hilgen (1991) and 5.16 Ma in terms of the chronology of Cande & Kent (1992).

Numerous Stages (Astian, Piacenzian, Zanclean, Fossanian, etc..) have been proposed for subdividing the some 3.5 Ma long Pliocene Series (Berggren, 1971; Carloni et al., 1971) and interpretation of its subdivision has varied over the years. A general two fold subdivision into a Lower (Zanclean) and an Upper (Piacenzian) stages appears to be the most generally accepted procedure to day (i.e. Berggren et al., 1985; Haq & Van Eysinga, 1987), although an informal threefold subdivision is still widely used by Italian geologists following Ruggieri & Selli (1950). Although not formally defined, stratotype sections have been proposed for the most widely used Pliocene chronostratigraphic units, the Tabianian (Iaccarino, 1967), the Piacenzian (Barbieri, 1967) and the

Zanclean (Cita & Gartner, 1973) (Fig. 1). Rio et al. (1990b, 1991) have positioned these proposed stratotype sections in the Pliocene biomagnetostratigraphic time framework as reported in Fig. 1. The major results of this work were: 1) the interval of time between the top of the Piacenzian stratotype and the GSSP of the Pliocene-Pleistocene boundary at Vrica section is not represented in any of the previously proposed stratotype sections; 2) the top of the Piacenzian stratotype falls in a critical point of the evolution of Earth climatic system, i.e. close to the final build-up of the Northern Hemisphere Glaciation, at the Gauss Chron-Matuyama Chron transition. Since around the Gauss-Matuyama boundary plenty of signals are present in both the continental and marine stratigraphic records (see ahead for details) which make the top of the Piacenzian in prospect correlatable on global base, Rio et al. (1991) argued against the practice of extending the top of the Piacenzian to the Pliocene-Pleistocene boundary. They, instead, proposed that the Piacenzian Stage be limited only to that stratigraphic interval present in the stratotype section and that a new Stage be introduced to cover the time-interval between the top of the Piacenzian and the Pliocene-Pleistocene boundary. Resulting is a threefold subdivision of the Pliocene easily recognizable on global base which will enhance the chronostratigraphic resolution.

Definition of the Gelasian Stage.

In the following we formally propose to the ICS the introduction in the Standard Chronostratigraphic Scale of the Gelasian Stage as the third upper subdivision of the Pliocene Series on the base of the procedures suggested by the ICS (Hedberg, 1976).

1) Name.

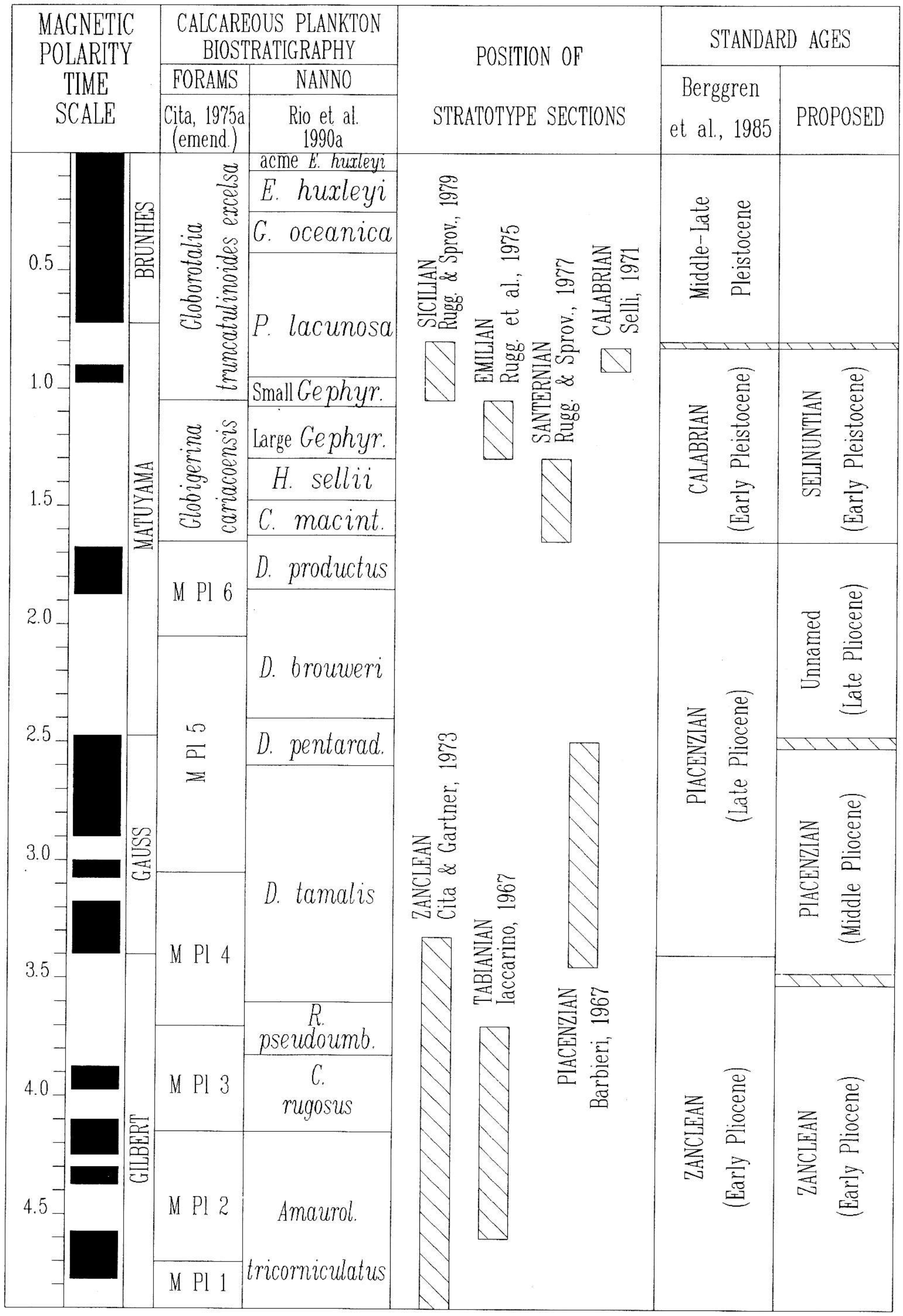
Since no suitable traditional chronostratigraphic term is available in the stratigraphic literature for indicating the rocks of the time interval we intend to distinguish at the Stage rank within the Pliocene Series, we propose the name Gelasian derived from the greek name of the town of Gela (Γελα, Γελασ), in Southern Sicily, nearby the section we propose as GSSP.

2) Kind and rank of Unit.

We ascribe to the Gelasian the Stage rank. The Stage is considered as "one of the smallest units in the standard chronostratigraphic hierarchy that in prospect may be recognized worldwide" (Hedberg, 1976, p. 71). We will show that the Gelasian meets with this requirement.

3) Historical background.

The Gelasian Stage is first introduced here to classify rocks of the Pliocene Series on the base of the intents commented previously. The Gelasian time interval is not represented presently in any proposed stratotype of the Pliocene Series (Rio et al.,


MAGNETIC POLARITY TIME SCALE
CALCAREOUS PLANKTON BIOSTRATIGRAPHY
FORAMS
NANNO
Cita, 1975a (emend.)
Rio et al. 1990a
POSITION OF STRATOTYPE SECTIONS
STANDARD AGES
Berggren et al., 1985
PROPOSED
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
BRUNHES
MATUYAMA
GAUSS
GILBERT
Globorotalia truncatulinoides excelsa
Globigerina cariacoensis
M Pl 6
M Pl 5
M Pl 4
M Pl 3
M Pl 2
M Pl 1
acme E. huxleyi
E. huxleyi
G. oceanica
P. lacunosa
Small Gephyr.
Large Gephyr.
H. sellii
C. macint.
D. productus
D. brouweri
D. pentarad.
D. tamalis
R. pseudoumb.
C. rugosus
Amaurol. tricorniculatus
SICILIAN Rugg. & Sprov., 1979
EMILIAN Rugg. et al., 1975
SANTERNIAN Rugg. & Sprov., 1977
CALABRIAN Selli, 1971
ZANCLEAN Cita & Gartner, 1973
TABIANIAN Iaccarino, 1967
PIACENZIAN Barbieri, 1967
Middle-Late Pleistocene
CALABRIAN (Early Pleistocene)
PIACENZIAN (Late Pliocene)
ZANCLEAN (Early Pliocene)
SELINUNTIAN (Early Pleistocene)
Unnamed (Late Pliocene)
PIACENZIAN (Middle Pliocene)
ZANCLEAN (Early Pliocene)

1991 and Fig. 1). On the base of the principle that the top of a chronostratigraphic unit is defined by the base of the overlying unit, Gelasian rocks are presently ascribed to the Piacenzian in most of the current Standard Time Scale (Haq & Van Eysinga, 1987). Rocks belonging to the Gelasian Stage have been often ascribed in the past to the Astian. For example, in the type area of the Piacenzian Stage at Castell'Arquato (Piacenza Province, Northern Italy) yellowish sandy sediments, outcropping above the Piacenzian stratotype section and below the local appearance of *Arctica islandica*, have been ascribed in the past to the Astian (Pareto, 1865). However, the type Astian, located in Piedmont region (Mayer, 1868; Ferrero, 1971), has been abandoned because represented by shallow water sandy sediments, difficult to frame in time, and most probably correlative to the Zanclean or to the lower Piacenzian (Sampò et al., 1968). The sediments ("Astian" Auctt.) in the Castell'Arquato area we propose to ascribe to the Gelasian Stage were indicated by Ruggieri & Selli (1950) as the type for defining their Late Pliocene.

Sediments corresponding more or less in time to the Gelasian have been recognized as distinct chronostratigraphic units (regional stages) in different regions and/or different facies sediments. Specifically, the Nukumaruan Stage in New Zealand marine record (Edwards, 1987), the Tiglian Stage in the North Western Europe continental record (Zagwijn, 1974), the "Middle Villafranchian" of Mediterranean continental record (Masini & Torre, 1990) seem to have been introduced for indicating grossly the time interval we propose to ascribe to the Gelasian Stage.

Selection of the GSSP.

Since Italy is the type region of the Pliocene Series (Berggren & Van Couvering, 1974), we have considered only Italian marine sections for defining the GSSP of the base of the Gelasian Stage, i.e. the GSSP of the Middle Pliocene - Upper Pliocene Boundary. The critical time interval for defining the boundary is widely represented in the region. However, two sections, at Monte San Nicola in southern Sicily and at Singa in Calabria (Fig. 2), have been thoroughly studied and well constrained in time (Channell et al., 1992; Sprovieri, 1992, 1993; Zijderveld et al., 1991; Lourens et al., 1992). Both sections meet with the requirements for serving as GSSP. However, outcropping and accessibility conditions are better at Monte San Nicola section, which is preferred for defining the Piacenzian (Middle Pliocene)-Gelasian (Upper Pliocene) boundary. The main criterion in selecting the GSSP will be its amenability to worldwide correlations in different facies sediments by available methods, besides being historically sound.

Fig. 1 - Stratigraphic position of the stratotype sections of the Pliocene and lower Pleistocene stages after Rio et al. (1991). Note that the adopted Geomagnetic Polarity Time Scale is that of Beggren et al. (1985). The commonly used Chronostratigraphy of Berggren et al. (1985) is indicated along with the chronostratigraphic proposal of Rio et al. (1991).

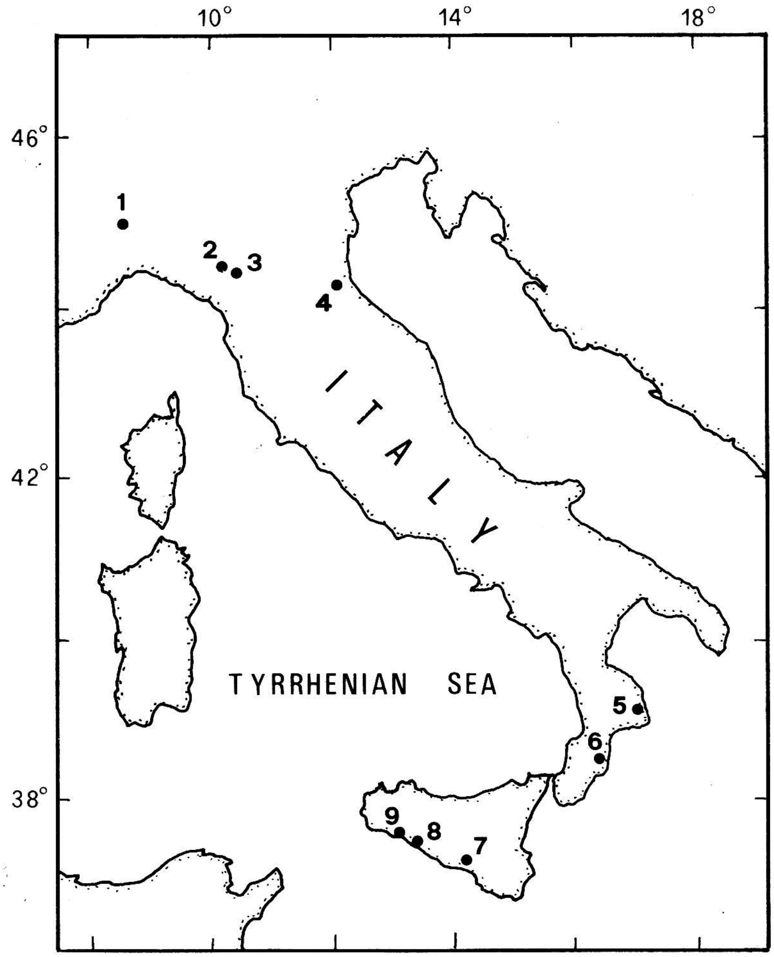


Fig. 2 - Location of the sections discussed in this paper. 1) Valleandona (Asti), Astian stratotype; 2) Tabiano Bagni (Parma), Tabianian stratotype; 3) Castell'Arquato (Piacenza), Piacenzian stratotype; 4) Val Marecchia (Forlì); 5) Vrica (Crotone); 6) Singa (Riace Marina); 7) Monte San Nicola (Gela); 8) Capo Rossello and Punta Piccola (Agrigento), Zanclean stratotype; 9) Eraclea Minoa.

The Monte San Nicola section.

Geographic location.

The section spectacularly outcrops in the badlands ("calanchi") on the southern slope of the San Nicola Mountain, about 10 km N-NW of Gela town, Agrigento Province (Fig. 3). The area is represented on the "Carta topografica d'Italia" at 1:25000 Foglio 272, II NO (Ponte Olivo) (Fig. 3). The section can be easily reached following, also by car, a path which starts from the main road 191 between km 19 and 20 and

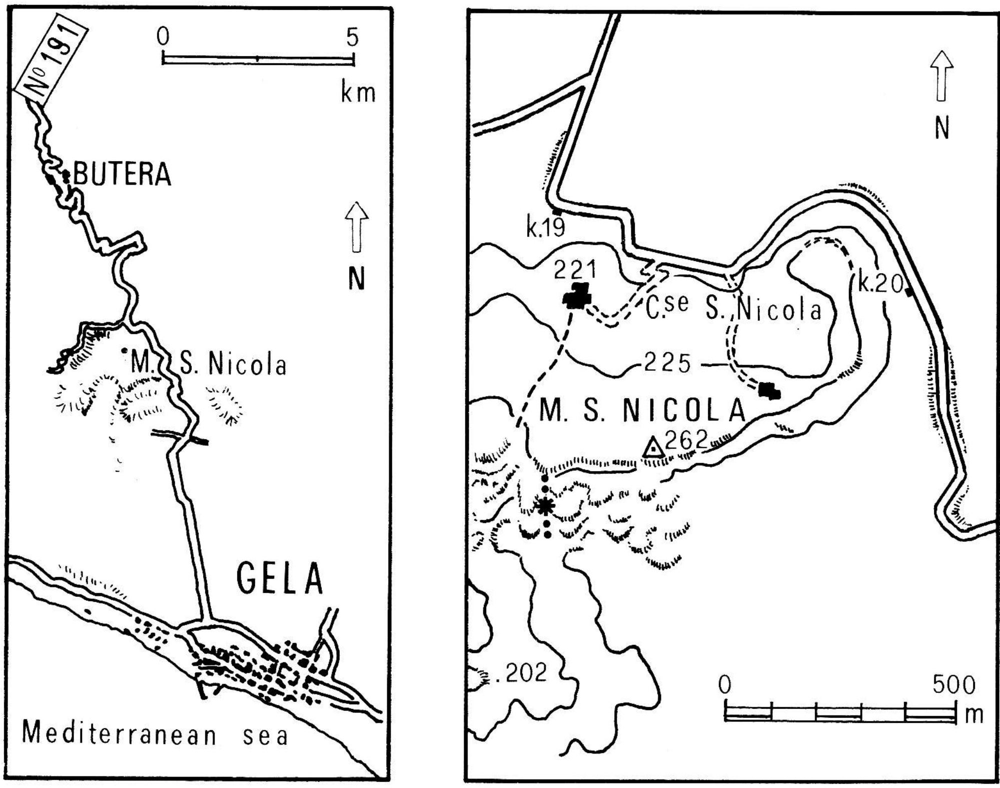


Fig. 3 - Sketch topographic map of the area of Monte San Nicola, showing the access and the location of the Monte San Nicola section and the position of the proposed GSSP of the base of the Gelasian (asterisk).

ends in coincidence of an old, little farm. From this point, a small field must be crossed by feet, till to the top of the section (Fig. 3, 4 and 5).

Previous studies.

The Monte San Nicola section was first described by Spaak (1983), who studied its contents in planktonic foraminifera. Successively, Bonaducè & Sprovieri (1984) and Driever (1988) studied ostracodes and calcareous nannofossils, respectively. Recently, Channell et al. (1992) carried out an high resolution biomagnetostratigraphic and paleoclimatic study. Other studies referring specific stratigraphic, paleoenvironmental and cyclostratigraphic aspects of Monte San Nicola section are those of Sprovieri et al. (1986), Bertoldi et al. (1989) and Sprovieri (1992, 1993).

Geologic setting.

The Plio-Pleistocene sediments of the Monte San Nicola section were deposited piggy-back on the so-called "Gela Nappe" (Fig. 6) during its southward movement

Fig. 4 - Aerial photograph of the Monte San Nicola area. The track of the section and the position of the "Nicola bed", the proposed GSSP of the base of the Gelasian GSSP are indicated. The paved road on the upper right corner is "Road n. 191" (Gela-Butera).

toward the Magrebian foredeep of Sicily (Argnani, 1987). The strata dip at 5-10 degrees to the east. Several reversed faults with essentially East-West direction are present in the basal part of the section. The critical interval for defining the GSSP of the Middle-Upper boundary of the Pliocene is un-affected by any tectonic disturbance, and without detectable sedimentary discontinuities as documented ahead. On the base of paleontological contents, the depositional environment of the Monte San Nicola section is inferred to be a slope-basin setting, with water depth in the range of 500-1000 m, as documented by the presence of the autochthonous benthic foraminifera. Specifically, in the interval in which the GSSP is located, the presence of *Cibicides wuellestorfi*, *Parrelloides bradyi*, *P. robertsonianus*, *Dimorphina tuberosa*, *Eggerella bradyi*, *Ramulina globulifera* point to an upper depth limit of about 500-700 m (Parker, 1958; Wright, 1978). The dominance of lagenids and the presence of *Siphonina reticulata* and *Planulina ariminensis* suggests a lower depth limit of about 1000-1300 m (Parker, 1958; Blanc-Vernet, 1965).

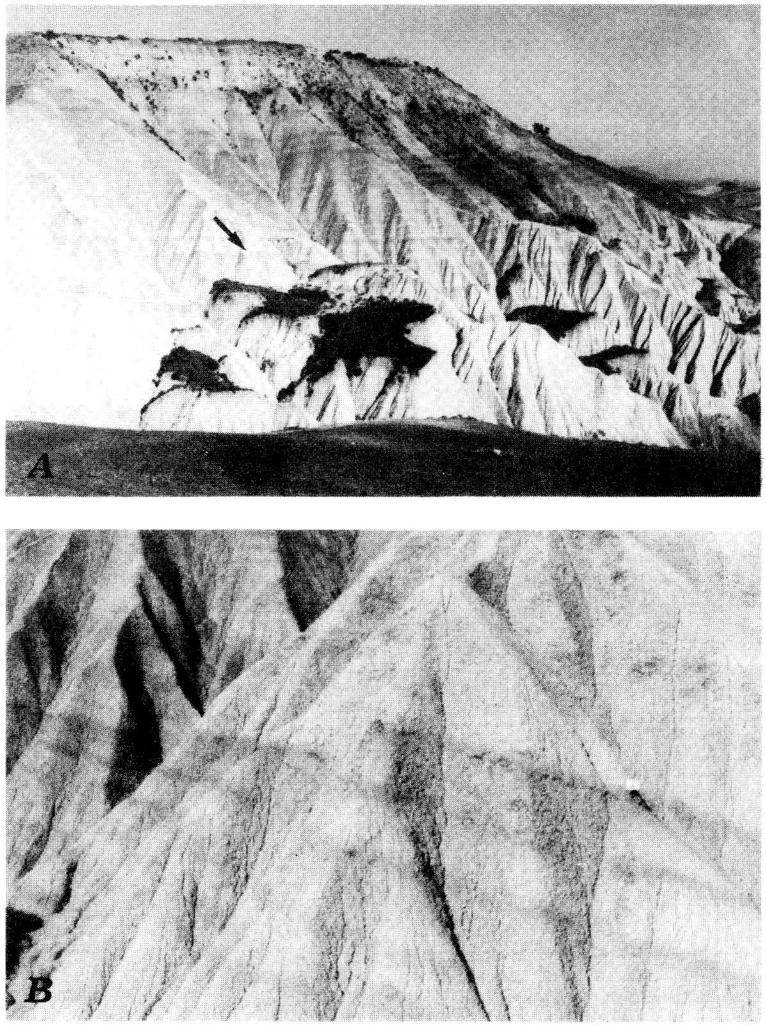


Fig. 5 - A) General view of the southern slope of Monte San Nicola. The arrow indicates the "Nicola bed". B) Detail of "Nicola bed" ("sapropel" MPRS 250 in the terminology of Hilgen, 1991).

The stratigraphic succession.

The lithologic column of the Monte San Nicola section is reported in Fig. 7. The total thickness of the entire Pliocene-Pleistocene succession, resting on sediments of the Numidian Flysch Formation included in the "Gela nappe", is 161 m. The lower part of the section is constituted by about 36 m of rhythmically bedded marly limestones and marlstone of varying colours, belonging to the "Trubi" (Cita & Gartner, 1973). The "Trubi" are overlain by the marly-silty "Monte Narbone Formation" (total thickness 125 m). The passage between the two lithostratigraphic units is transitional

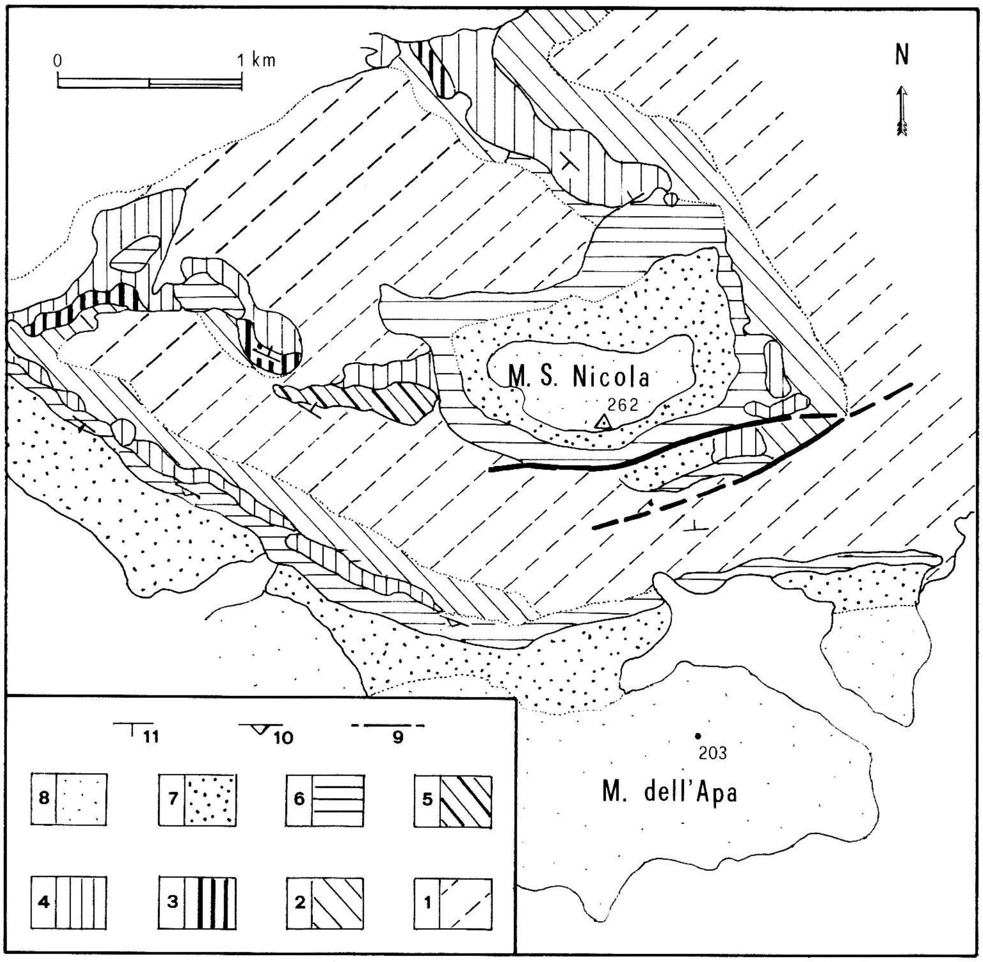


Fig. 6 - Geologic map of the area of the Monte San Nicola section. 1) Marls and Clay (Oligocene - Miocene); 2) Marls and Clays (Upper Miocene); 3) "Tripoli" (Messinian); 4) Basal Limestones (Messinian); 5) Gypsum (Messinian); 6) "Trubi" (Lower-Middle Pliocene); 7) Marls and Clays (Middle-Upper Pliocene); 8) Marls and Sands (Lower Pleistocene). 9) Faults; 10-11) Strike and dip. Modified from Carta Geologica d'Italia, Foglio 272, Ed. 1955.

and occurs in an interval of about 8 m. The Monte Narbone Formation shows a coarsening up trend and becomes siltier in the upper part. At the top of the section a 8 m thick sandy layer is present (not reported in the columnar log of Fig. 7). Noteworthy is the presence in the Monte Narbone Formation of brownish manganesiferous, not laminated levels and of brownish-red laminated levels, all of which are reported in Fig. 7. The laminated levels have been referred to in the most recent Mediterranean literature as "sapropels" (Lourens et al., 1992). Both manganesiferous levels and "sapropels" are of topmost stratigraphic importance for regional correlations. The

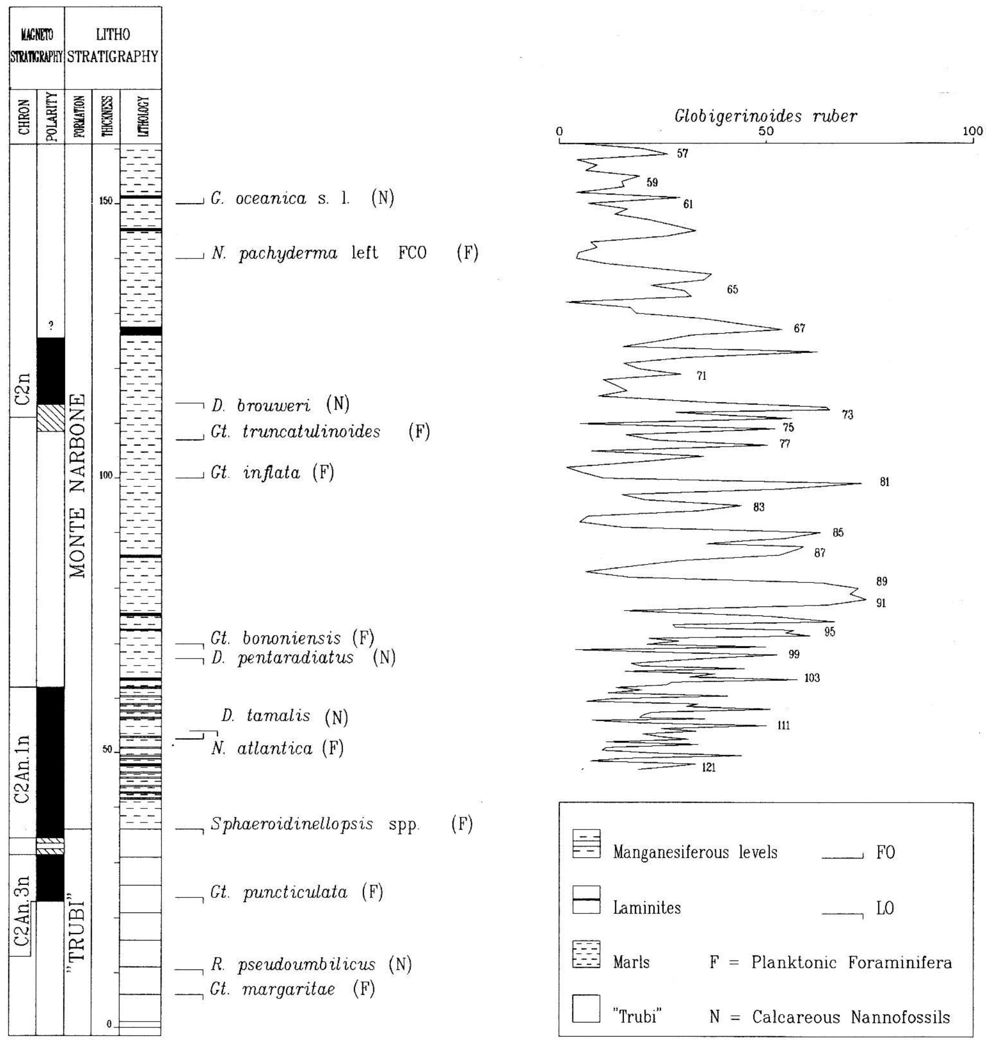


Fig. 7 - Monte San Nicola section: lithology, biomagnetostratigraphy and abundance fluctuations of the warm water indicator *Globigerinoides ruber* (after Channell et al., 1992 and Sprovieri, 1992).

"sapropels" have been demonstrated by Hilgen (1991) to be an important tool for calibrating astronomically the Mediterranean marine sedimentary record.

Chronology of the Monte San Nicola section.

In the last years it has been shown that in the Mediterranean marine Pliocene record the chronological resolution (of the order of a few hundred Kyr), which can be obtained by integrating calcareous plankton biostratigraphy and magnetostratigraphy (Rio et al., 1990b) can be further enhanced to a few Kyr by using paleontological, lithological and geochemical proxy indicators of the Earth climatic system. Specifically, fluctuations in abundance of planktonic foraminifera (Sprovieri, 1992, 1993), oxygen and carbon stable isotopes variations (Lourens et al., 1992), rythmic colour variations in the lithology (Hilgen, 1991) and the distribution of "sapropels" show cyclicity related to the quasi-periodic oscillations of the Earth's orbital parameters. The cyclostratigraphy developed in the Mediterranean on the base of the previous proxies has been calibrated to the astronomical cycles allowing the construction of an astronomically calibrated time-framework for the entire Pliocene (Hilgen, 1991). In Fig. 8 we report the elements of this framework for the interval of interest in the present paper.

As reported in Fig. 7, in Monte San Nicola section magnetostratigraphy, calcareous plankton biostratigraphy and fluctuations in abundance of planktonic foraminifera are available from the study of Channell et al. (1992) and Sprovieri (1992, 1993). These data, together with the "sapropels" stratigraphy, allow to insert the section in the time framework of Fig. 8, and, hence, to evaluate its completeness and its correlatability with other Mediterranean sections and on global scale.

Calcareous plankton biostratigraphy.

Calcareous nannofossils and planktonic foraminifera are abundant and well preserved. All the biohorizons normally utilized in the Mediterranean (Fig. 8) are present in the section maintaining their known relative position (ranking) and showing the same position with respect to magnetostratigraphy and cyclostratigraphy established in other Mediterranean sections (Fig. 7). In terms of the standard calcareous nannofossil zonations of Martini (1971) and Okada & Bukry (1980), the entire section is extended from Zone NN 15-CN 11b to Zone NN 19-CN 13a. In terms of the Mediterranean zonation of Rio et al. (1990a) it is extended from Zone MNN 14-15 to above the top of Zone MNN 9b. With reference to the planktonic foraminifera zonation of Blow (1969) the entire section is extended from Zone 19 to Zone 21. With reference to the Mediterranean zonations of Cita (1973, 1975b), as emended by Sprovieri (1992), it is extended from Zone MPL 3 to the *Globigerina cariacoensis* Zone.

Magnetostratigraphy.

The sediments of the Monte San Nicola section have been shown to be amenable to a magnetostratigraphic analysis by Channell et al. (1992). The base of the section can be correlated to the upper part of the Gilbert Chron (2Ar in the nomenclature of Cande & Kent, 1992) and the top to the base of the portion of the Matuyama Chron above the Olduvai Subchron (Subchron C1r in the nomenclature of Cande & Kent, 1992). The Kaena subchron has not been detected (Fig. 7), probably because

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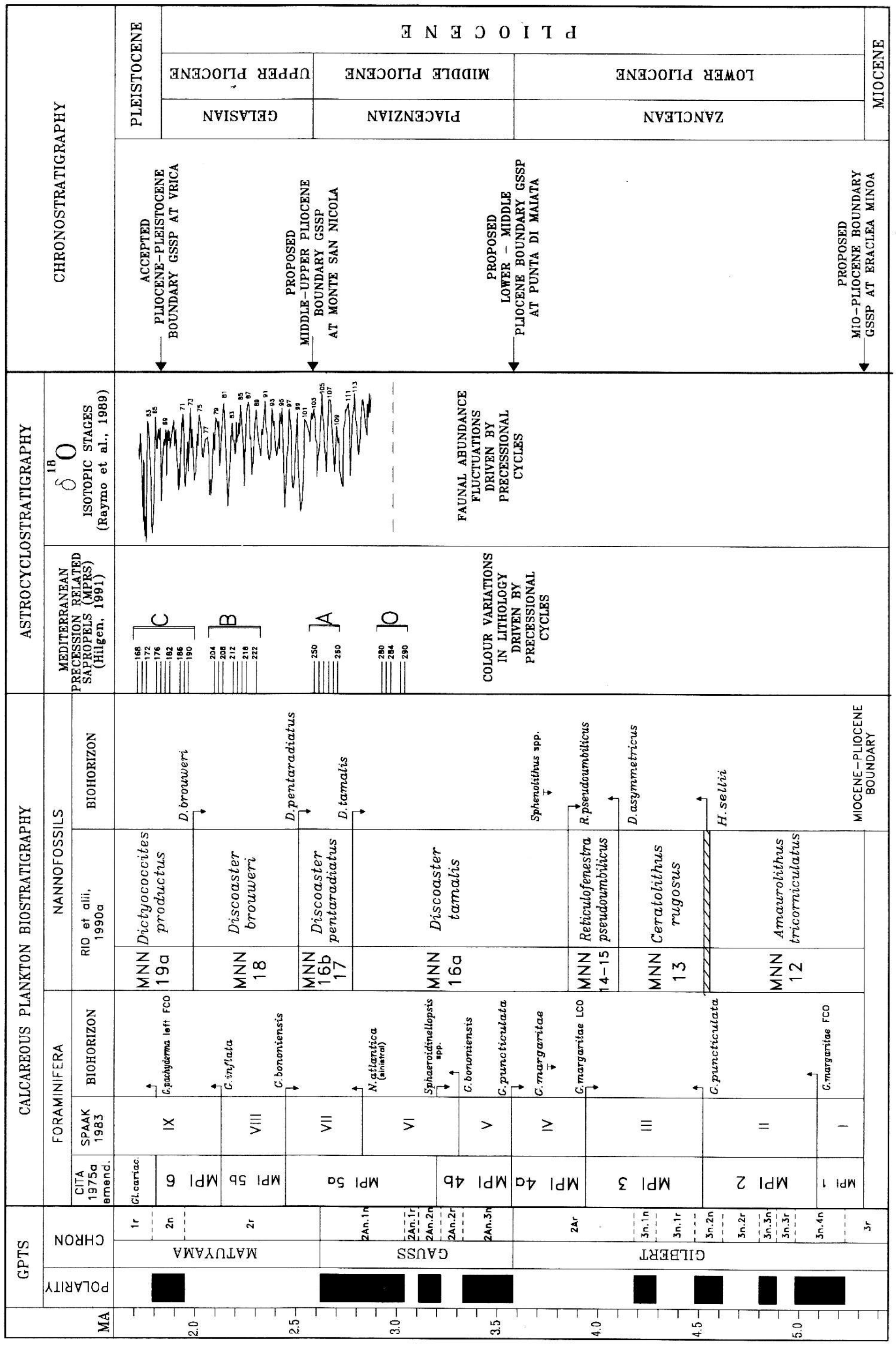
Fig. 8 - Mediterranean Pliocene time framework. The adopted chronology for the Geomagnetic Reversal Time Scale is after Hilgen (1991).


CHRONOSTRATIGRAPHY
ASTROCYCLOSTRATIGRAPHY
CALCAREOUS PLANKTON BIOSTRATIGRAPHY
GPTS
PLEISTOCENE
PLIOCENE
MIOCENE
UPPER PLIOCENE
MIDDLE PLIOCENE
LOWER PLIOCENE
GELASIAN
PIACENZIAN
ZANCLEAN
ACCEPTED PLIOCENE-PLEISTOCENE BOUNDARY GSSP AT VRICA
PROPOSED MIDDLE-UPPER PLIOCENE BOUNDARY GSSP AT MONTE SAN NICOLA
PROPOSED LOWER - MIDDLE PLIOCENE BOUNDARY GSSP AT PUNTA DI MAIATA
PROPOSED MIO-PLIOCENE BOUNDARY GSSP AT ERACLEA MINOA
ISOTOPIC STAGES (Raymo et al., 1989)
FAUNAL ABUNDANCE FLUCTUATIONS DRIVEN BY PRECESSIONAL CYCLES
MEDITERRANEAN PRECESSION RELATED SAPROPELS (MPRS) (Hilgen, 1991)
COLOUR VARIATIONS IN LITHOLOGY DRIVEN BY PRECESSIONAL CYCLES
NANNOFOSSILS
RIO et alii, 1990a
BIOHORIZON
FORAMINIFERA
SPAAK 1983
CITA 1975a emend.
MIOCENE-PLIOCENE BOUNDARY
POLARITY
CHRON
MATUYAMA
GAUSS
GILBERT
MA

of the wide sampling interval and/or small faults present in the lower part of the section. The Gauss-Matuyama boundary is clearly detectable and has been tightly located (Fig. 7).

The faunistic curve.

It has been shown by Ruddiman et al. (1989) and by Lourens et al. (1992) that in the Early Pleistocene oceanic and Late Pliocene Mediterranean marine sediments abundance fluctuations of selected planktonic foraminifera are in phase with the variations of the oxygen stable isotope $\delta^{18}O$. Therefore the easily determined abundance fluctuations in planktonic foraminifera can provide a surrogate for recognizing oxygen isotope Stages (Sprovieri, 1993). Specifically, in the Monte San Nicola section the fluctuations in abundance of *Globigerinoides ruber* can be correlated consistently to the standard oxygen isotope Stages of Raymo et al. (1989) as demonstrated by cross-check with magnetostratigraphy, biostratigraphy and sapropel stratigraphy (Fig. 7 and 8). In particular, all the abundance fluctuations correlatable to the oxygen isotope Stages from 116 to 56 have been recognized (Fig. 7).

Sapropel stratigraphy.

In the interval critical for defining the GSSP of the Gelasian, around the Gauss - Matuyama boundary in Monte San Nicola section a cluster of 6 laminated or manganesiferous levels occur. In the same stratigraphic position a similar cluster is present in Singa, Punta Piccola and Val Marecchia sections (Fig. 9 and references in the Figure caption), which was labelled as "cluster A" by Verhallen (1987). The single "sapropels" of cluster A were coded by Hilgen (1991) as MPRS (Mediterranean Precessional Related Sapropels) and numbered on the base of the corresponding precessional cycle. In particular, the prominent, about 20 cm thick, reddish and laminated bed at 62 meter level in the columnar log at the top of this cluster A (Fig. 7) can be correlated to precessional cycle 250 (MPRS 250). The bed is located in the lowermost Matuyama, below the *D. pentaradiatus* LO (Last occurrence) (Fig. 7). It is present in all the coeval considered sections (Fig. 9) and in the Singa section it is coincident with oxigen isotope Stage 103 (Lourens et al., 1992). This bed in the Monte San Nicola section is in correspondance with an abundance peak of *G. ruber* which is correlatable to oxygen isotope Stage 103.

Chronostratigraphy.

From a chronostratigraphic point of view the Monte San Nicola section is extended from the upper part of the Zanclean to the Lower Pleistocene, as demonstrated by its correlation (Fig. 9) with the Piacenzian stratotype section at Castell'Arquato (Northern Italy) and with the GSSP of the Pliocene-Pleistocene boundary in Vrica section. Specifically, the top of the Piacenzian as stratotypified at Castell'Arquato (Barbieri, 1967) falls in the interval between the last occurrences of *Discoaster tamalis* and

Discoaster pentaradiatus, i.e. close to the Gauss-Matuyama boundary (Fig. 9) (Rio et al., 1988).

Completeness of the section.

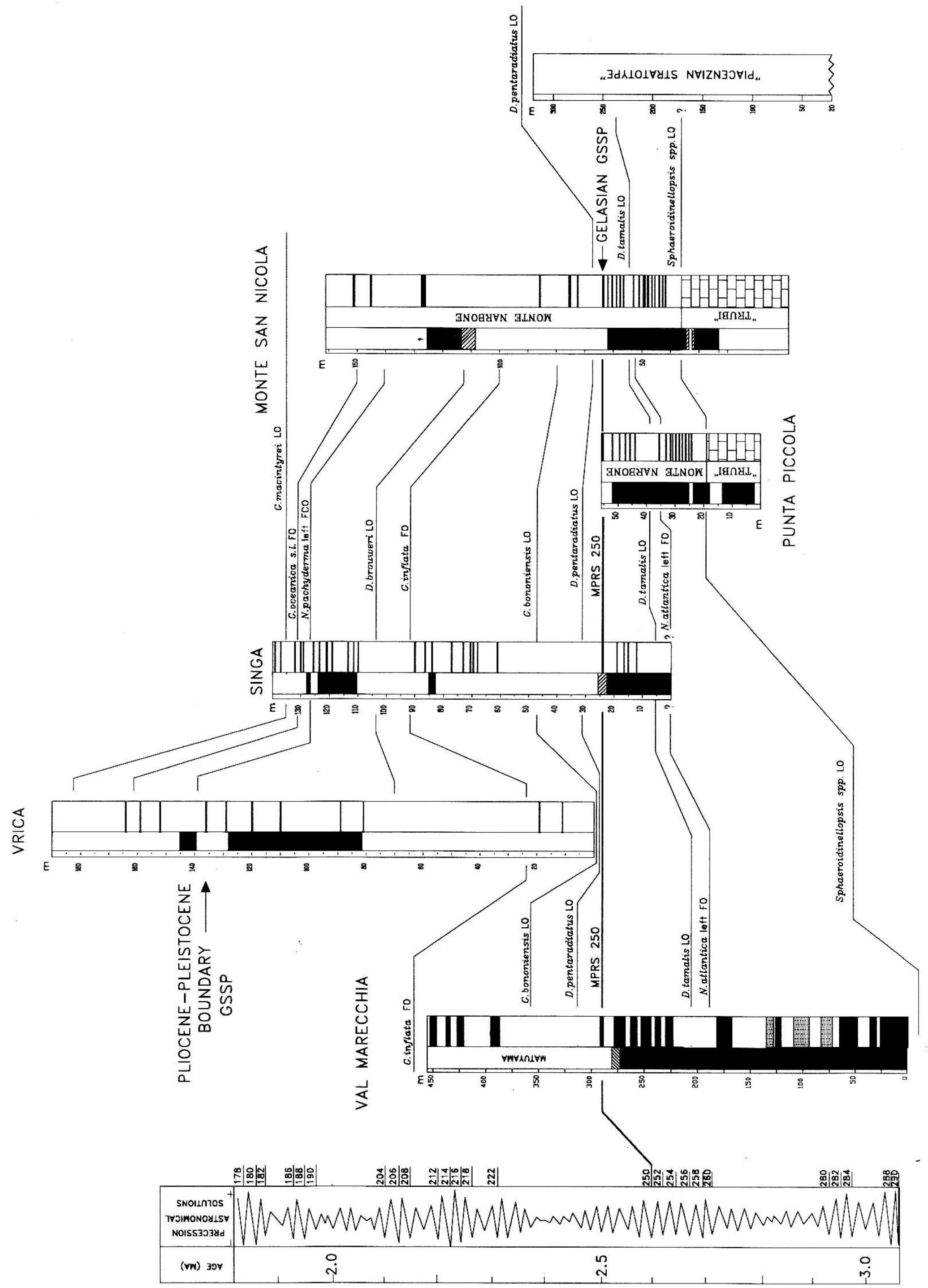
Previous discussion and correlations shown in Fig. 9 indicate that in the interval critical for defining the GSSP of the base of the Gelasian, around the Gauss-Matuyama boundary, the Monte San Nicola section is remarkably complete. In fact, all the known biostratigraphic events, precessional "sapropel" cycles, obliquity forced faunistic cycles are present. If hiatuses occur, their duration is below the resolution provided by astrocyclostratigraphy (of the order of a few kyr).

Reason for selection of the boundary level.

It is normally recommend that the GSSP be located in a facies favourable for development of widespread, reliable and time significant horizons. Indeed, long distance and different facies (continental and marine) correlations are essentially geochronological in nature (Van Couvering & Berggren, 1977). It is to say, time and not a particular stratigraphic feature is used. Therefore, it is important that the GSSP section be characterized by facies favourable to the establishment of a finely resolved chronology and that the GSSP be related to a point (but a short interval is sufficient for most practical needs) around which many long distance, different facies (marine to continental) correlation tools are available, which allow potentially global correlations. To this purposes, magnetostratigraphy and climatostratigraphy, both of which are correlation and not definition tools, are of great moment for correlating continental and marine stratigraphic records. Ideally, in the Late Neogene and Pleistocene the GSSP should be located close to clearly identifiable geomagnetic field reversals and around major tresholds of the Earth climatic system. For these reasons we will propose as GSSP a level easily recognizable in the field, which can be accurately constrained in time by astronomical calibration, close to the Gauss-Matuyama boundary and close to a major climatic event of the entire Neogene history, i.e. close to what has been referred to as the final build-up of the Northern Hemisphere glaciation.

Definition of the GSSP of the base of the Gelasian (Middle Pliocene-Late Pliocene boundary): a proposal.

We formally propose the top of "sapropel" MPRS 250, located in the Monte San Nicola section at 62 meter level (Fig. 5B and 7), as the GSSP of the base of the Gelasian Stage and of the Middle Pliocene-Upper Pliocene Boundary. The astrochronological age of the GSSP is 2.589 Ma, the age attributed to MPRS 250. It corresponds to the oxygen isotopic Stage 103 of Raymo et al. (1989) and precedes of some 60 kyr the base of oxygen isotope Stage 100, which represents the beginning of a prominent glacial interval, often referred to as the final build-up of the Northern Hemisphere glaciation.


VAL MARECCHIA
PLIOCENE-PLEISTOCENE BOUNDARY GSSP
VRICA
SINGA
MONTE SAN NICOLA
PUNTA PICCOLA
"PIACENZIAN STRATOTYPE"
GELASIAN GSSP
MONTE NARBONE
"TRUBI"
MATUYAMA
MPRS 250
G.inflata FO
G.bononiensis LO
D.pentaradiatus LO
D.tamalis LO
N.atlantica left FO
Sphaeroidinellopsis spp. LO
G.macintyrei LO
C.oceanica s.l. FO
N.pachyderma left FCO
D.brouweri LO
AGE (MA)
PRECESSION ASTRONOMICAL SOLUTIONS
2.0
2.5
3.0

Identification in the field of the GSSP.

Sapropel MPRS 250 can be easily identified in the field some 100 meters below the top of the marls outcropping in the slope along which the Monte San Nicola section was sampled (Fig. 3, 4 and 5).

Correlations.

The GSSP is "the only place where we actually know (by definition) that time and rock coincide within our classification" (Holland, 1984). Elsewhere from the type section a chronostratigraphic boundary can only be approximated by using and cross-checking the different available correlation tools. In the following we present some of these correlatability potentials, in order of decreasing precision and accuracy.

Astrochronology.

Since the Gelasian base is correlated to precessional cycle 250 from the present and to correlative obliquity forced oxygen isotope Stage 103, the most precise tool for its recognition is represented by astrocyclostratigraphy. Since the above mentioned cycles are close to the Gauss/Matuyama boundary their recognition is made easier.

Magnetostratigraphy.

The Gauss-Matuyama boundary, located some 20 kyr below oxygen isotope Stage 103 (Raymo et al., 1989) serves as a good approximation of the base of the Gelasian.

Marine biostratigraphy.

It is beyond our scope to review all the marine fossil groups which may provide tools for recognizing the base of the Gelasian. Considering the most widely used microfossils for long distance correlations the following events do represent good approximations.

1) The LOs of *D. pentaradiatus* and *Discoaster surculus* occur in most low- and mid-latitude areas close to the oxygen isotope Stage 99, i.e. some 80 kyr above the base of the Gelasian.

2) In the Mediterranean and North Atlantic areas the LO of *Gt. bononiensis* (or *Gt. puncticulata* of some Authors) is recorded at oxygen isotope Stage 96, i.e. some 140 kyr above the base of Gelasian.

Fig. 9 - Biostratigraphic correlations among the sections discussed in the paper. Magnetostratigraphies are after Channell et al. (in preparation) for Val Marecchia section, after Zjiderveld et al. (1991) for Vrica and Singa sections and after Langereis et al. (1991) for Punta Piccola section. The correlation of the "Nicola bed", corresponding to "sapropel" MPRS 250 in the terminology of Hilgen (1991), is evidenced by the heavy line. Precession astronomical cycles and related position of the Mediterranean Precessional Related Sapropels (MPRS) are reported on the left (after Hilgen, 1991).

3) The LO of *Stichocorys peregrina* (Radiolaria), coincident with the base of the *Pterocanium prismaticum* Zone, approximates the Gauss-Matuyama boundary (Sanfilippo et al., 1985).

4) The FO of *Nitzschia joussaea* (diatoms) in low latitudes and the LO of *Denticulopsis kamtschatica* in the North Pacific mid- to high-latitude approximate the Gauss-Matuyama boundary (Barron, 1985).

Climatostratigraphy.

As stated above, the base of the Gelasian is positioned some 60 kyr below the onset of a prominent cold climatic phase (corresponding to the three oxygen isotope Stages 100, 98, and 96 of Raymo et al., 1989) which apparently prompted wide environmental changes detectable in the stratigraphic record, both marine and continental, as : 1) increase in ice rafted detritus in northern latitude oceanic sediments (Raymo et al., 1989); 2) change in the vegetation distribution patterns (i.e.,Tiglian-Pretiglian boundary of Zagwijn, 1974; Arquatian phase of Lona, 1962); 3) beginning of loess sedimentation in China (Kukla & An, 1989); 4) migratory events in the continental vertebrate fauna (i.e., the elephant-*Equus* event in the Eurasian region; Lindsay et al., 1980; see Azzaroli et al., 1988 and references herein).

Conclusions.

We have proposed to introduce in the Standard Chronostratigraphic Scale a new Stage, named Gelasian, for indicating the third uppermost part of the Pliocene Series. The reason for introducing this Chronostratigrahic Unit is that it appears as being an interval of geologic time recognizable virtually on global scale, with reasonable approximation, in both marine and continental records. We have designated a prominent laminated level ("sapropel") in the Monte San Nicola section, near the town of Gela, in southern Sicily, as the GSSP of the base of the Gelasian. The top of the Gelasian, in accordance with the indications of the ICS, is defined by the GSSP of the Pliocene-Pleistocene boundary in the Vrica section in Calabria, southern Italy. The introduction of the Gelasian will enhance the chronostratigraphic resolution of the Pliocene Series.

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