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43. PLIOCENE-EARLY PLEISTOCENE CHRONOSTRATIGRAPHY AND THE TYRRHENIAN DEEP-SEA RECORD FROM SITE 653[1]

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ABSTRACT

A new integrated calcareous plankton biostratigraphy for the Mediterranean has been developed in the last few years which allows the continuous Plio-Pleistocene sedimentary sequence recovered at Site 653 to be rather precisely correlated to other Leg 107 Sites and to sedimentary sequences on land. Although no magnetostratigraphy is available from Site 653, the biostratigraphic correlations to magnetostratigraphically controlled Mediterranean sections allow the sequence at Site 653 to be indirectly correlated to the geomagnetic reversal timescale. The correlation of the chronostratigraphy at Site 653 to the Plio-Pleistocene proposed stratotype sections indicates several anomalies in the time coverage of the stratotype sections. Hiatuses are present at the top of the Zanclean stratotype section at Capo Rossello and at the base of the Piacenzian stratotype section (in the Arda valley). In addition the Piacenzian stratotype section does not reach the Plio-Pleistocene boundary. There is therefore a gap of about 0.85 m.y. which is not covered by a stratotype section. As the top of the Piacenzian stratotype corresponds to a rather important climatic event (the onset of Northern Hemisphere Glaciation and the "Glacial Pliocene"), we advocate maintaining the Piacenzian as a chronostratigraphic unit and propose a threefold subdivision of the Pliocene. For the early Pleistocene, the previously proposed stratotype sections also do not adequately cover the time interval. For example, the Calabrian and Sicilian stratotype sections largely overlap. It has been suggested that the Calabrian stage be abandoned and that the Santernian, Emilian, and Sicilian be combined into a single stage, referred to as the Selinuntian.

INTRODUCTION

A dramatic improvement in the last 20–30 yr in plankton biostratigraphy of deep-sea sediments, and the advent of magnetostratigraphy and chemostratigraphy, has led to the development of time-frames which provide tighter relative and absolute age control than the traditional Geologic Time Scale (GTS). Nevertheless, the GTS is the generally accepted relative timescale, and is firmly entrenched in the Earth Sciences. One of the basic fundamentals of the GTS is the stratotype concept, which implies that the best method for defining a point and/or interval of geologic time is by reference to a particular stratigraphic section exposed on land (Hedberg, 1976, 1978). Unfortunately, most stratotype sections were proposed in the last century in shallow to marginal marine sections, and were chosen on the basis of major changes in facies and or macrofossil assemblages. The unfavorable characteristics of stratotype sections have complicated the assignment of absolute ages to individual stages in the GTS and hampered their correlation outside the type region. This has led to conflicting use of some stage names, to the development of local chronostratigraphic scales, and the temptation to abandon entirely the traditional stage subdivision of the GTS in favor of a scale based directly on plankton biochronology. The Plio-Pleistocene provides a good example of this dilemma. The generally accepted stage stratotypes for this interval are all located in Italy, where these stages were first introduced. Not only has the marginal facies characteristics of most of the stratotype sections hampered local stratigraphic correlation, but also the provinciality of the Mediterranean fauna and flora, and the lack of good magnetostratigraphic records have hindered correlation with the open ocean.

One of the objectives of ODP Leg 107 in the Tyrrhenian Sea was to recover a continuous stratigraphic sequence for use as a Mediterranean deep-sea reference section to facilitate correlation of the Italian Plio-Pleistocene marine record to the open ocean. Specifically, Site 653 (Fig. 1) in the Cornaglia basin was cored using the double APC technique, and was the one site dedicated to this stratigraphic purpose. The aim of this paper is to correlate the essentially continuous deep-sea sequence at Site 653, which is rich in planktonic microfossils, to the stratotype sections of the Pliocene and early Pleistocene. In the light of this correlation, an updated Mediterranean plankton biochronology, and the status of Pliocene and early Pleistocene chronostratigraphy are discussed.

PLIO-PLEISTOCENE CHRONOSTRATIGRAPHY

It is beyond the scope of the present paper to review the history of development of Plio-Pleistocene chronostratigraphy, and two excellent reviews of this topic are available in the literature (Berggren, 1971; Berggren and Van Couvering, 1974). In addition, the stratigraphies of the relevant stratotype sections are reviewed in the Proceedings of the CRMNS Congresses of Bologna (Carloni et al., 1971) and Bratislava (1975). In this paper we are only concerned with those stages which are currently used in the literature (Tables 1 and 2). It should be noted that Pliocene chronostratigraphy and, to an even more greater extent, Pleistocene chronostratigraphy, is in a state of flux due to conflicting philosophical approaches to stratigraphy. With the exception of the Pliocene/Pleistocene boundary itself, the Plio-Pleistocene stages and their boundaries have not been formally defined by the International Commission on Stratigraphy. This paper, by members of the IUGS Subcommission on Neogene Stratigraphy, is intended to promote and facilitate a much needed formal revision of the chronostratigraphic scheme.

Prior to a discussion of the correlation of ODP Site 653 to the stratotype sections, it is necessary to briefly discuss the integrated calcareous plankton biostratigraphic scheme which we adopt (Fig. 2). We use the planktonic foraminiferal zonation proposed by Cita (1973, 1975) emended (especially for the late Pliocene and Pleistocene) by Rio et al. (1984). A subsequent revision involves the base of the *Globigerina cariacoensis* zone which we now recognize by the first common occurrence (FCO)

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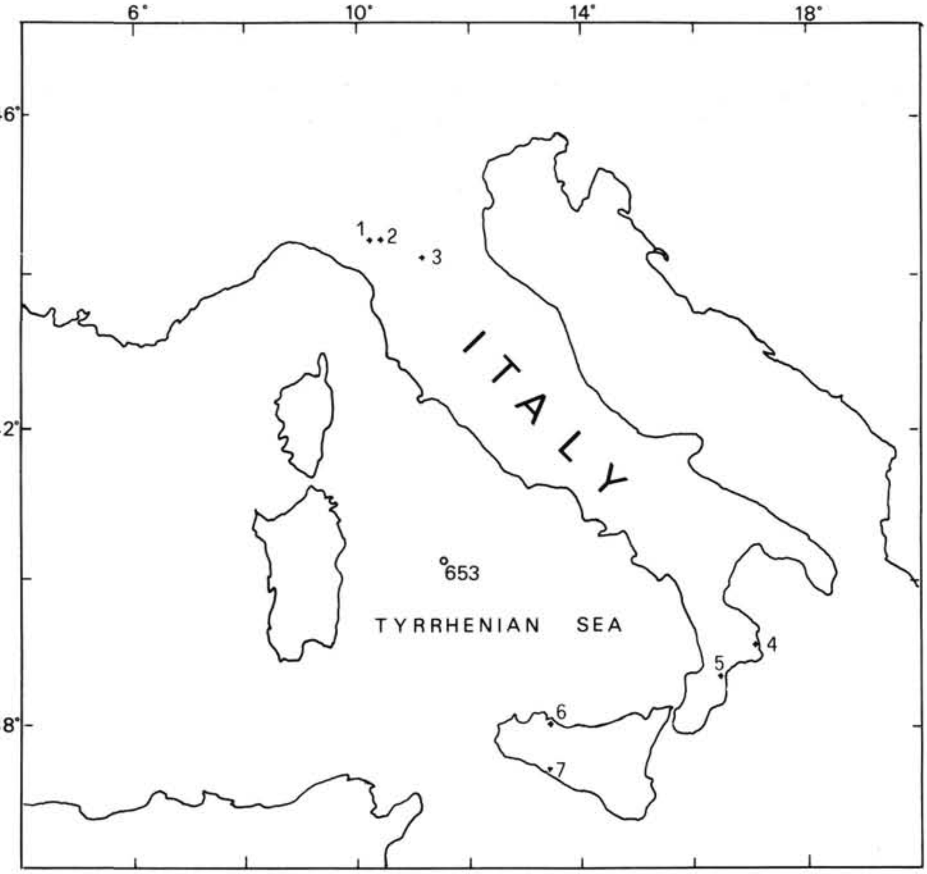

Figure 1. Location map of Site 653 and the relevant land sections: 1, Castell-Arquato; 2, Tabiano; 3, Santerno; 4, Vrica; 5, S. Maria di Catanzaro; 6, Ficaiazzi; 7, Capo Rossello.

of *Neogloboquadrina pachyderma* (left coiling). For calcareous nannofossils, we adopt the zonation proposed by Raffi and Rio (1979) as emended by Rio et al. (this volume). The correlations between the two schemes is based on the work of Rio et al. (1984) and on the results obtained from ODP Leg 107 material (Glaçon et al., this volume). A critical point of this scheme (Fig. 2) is the calibration of the biostratigraphic events and zonal boundaries to the Geomagnetic Reversal Time Scale (GRTS). Until recently, very few direct calibrations of Mediterranean biostratigraphic events to the GRTS were considered reliable, and the proposed calcareous plankton biochronology of Rio et al. (1984) was mainly based on indirect methods of scaling biostratigraphic events (i.e., Shaw diagram techniques). Recently, some successful magnetostratigraphic studies in Italian land sections (Tauxe et al., 1983; Zijderveld et al., 1985; Channell et al., in press) and at Sites 652 and 654 of Leg 107 (Channell et al., this volume) have allowed a direct correlation to the GRTS of most of the Pliocene biostratigraphic events utilized in Figure 2. For the Pleistocene, the age calibration of the events has been achieved by direct correlation at Site 653, with the well established oxygen isotope stages (Rio, Raffi, and Villa, this volume; Vergnaud-Grazzini et al., this volume). Although refinements of the Mediterranean calcareous plankton biochronology will occur as the number of sections with good biostratigraphic and magnetostratigraphic control is increased, the scheme presented here has sufficient resolution, and provides an accurate and practical Plio-Pleistocene time-frame.

ODP SITE 653

For Site 653, a synthesis of the calcareous plankton biostratigraphy (Rio, Raffi, and Villa, this volume; Glaçon et al., this volume) and chronostratigraphy is given in Figure 3. The sequence is remarkably continuous with a minor hiatus in the *Discoaster brouweri* zone, close to the Pliocene/Pleistocene boundary.

Unfortunately the magnetic properties of the sediments retrieved at Site 653 were such that a magnetic stratigraphy could not be resolved (Channell et al., this volume), and therefore no direct correlation of biostratigraphic events to the GRTS was possible. However, biostratigraphic correlation to Sites 652 and 654, where magnetostratigraphy is available, allows the sequence at Site 653 to be indirectly correlated to the GRTS. In Figure 3 we have correlated the Pliocene and early Pleistocene chronostratigraphic stages listed in Tables 1 and 2 to the sequence at Site 653. All the stratotype sections can be biostratigraphically correlated to this deep-sea sequence and therefore to the GRTS. This allows us to appreciate the coverage in geologic time of the stratotype sections, their mutual relationships, and the continuity of deposition (Fig. 4). Below, we discuss each chronostratigraphic stage in the light of the results presented in Figures 3 and 4, and in view of the guidelines of the International Stratigraphic Commission (Hedberg, 1976).

MIOCENE/PLIOCENE BOUNDARY

The Miocene/Pliocene boundary has traditionally been considered be coincident with the re-establishment of open marine conditions in the Mediterranean following the Messinian salinity crisis. Accordingly, Cita (1975) proposed that the boundary stratotype section be established at Capo Rossello (Sicily). Correlations of this boundary to the open oceans, and to the absolute time scale has been particularly difficult because of the lack of reliable magnetostratigraphy across the boundary in the Medi-

Table 1. Pliocene chronostratigraphic units.

Unit	Type localities	Stratotype or Neostratotype	Source of calcareous plankton biostratigraphic data
TABIANIAN Mayer, 1867	Tabiano Bagni (Parma)	Chiesa Nuova section Tabiano Bagni (Northern Apenninens, Parma Prov.) (Iaccarino, 1967)	Iaccarino, 1967 Sprovieri, unpubl. Raffi & Rio, 1980
ZANCLEAN Seguenza, 1868	Gravitelli (Messina, Sicily)	Capo Rossello (Agrigento Prov. Southern Sicily) (Cita & Gartner, 1973	Cita & Gartner, 1973 Rio et al., 1984
PIACENZIAN Mayer, 1858	Val d'Arda (Piacenza Prov.)	Vernasca Castell'Arquato section (N. Apennines Piacenza Prov. (Barbieri, 1967)	Colalongo et al., 1974 Rio et al., in press
ASTIAN De Rouville, 1853	Valle Andona Tertiary Piedmont Basin (Asti Province)	Valle Andona section Sampo' et al., 1967	Colalongo et al., 1974 Rio, unpubl.

terranean sections. In addition, biochronology is difficult across a boundary characterized on one side by an absence of marine fauna, and on the other side by a peculiar biogeographic setting, where many calcareous plankton markers are missing or possibly diachronous (Rio et al., 1984).

The popular recent time scale of Berggren et al. (1985) places the Miocene/Pliocene boundary at the top of Chron 5 (Chron 3A of Cox, 1982), at about 5.35 Ma. New magnetostratigraphic data from Italian (Calabria) land sections (Zijderveld et al., 1986; Channell et al., in press) and from ODP Leg 107 (Channell et al., this volume) are in conflict with this correlation. Although no reliable magnetic stratigraphy has been forthcoming from the proposed stratotype section at Capo Rossello, magnetostratigraphies from the Calabria region are from sections which are time-equivalent. According to these data, the re-establishment of open marine conditions in the Mediterranean occurred slightly below the Thvera subchron, at the top of the lowest reversed interval of the Gilbert (Chron 3r of Cox, 1982). Zijderveld et al. (1986) gave an age of 4.83 Ma for this event by extrapolation between paleomagnetically dated tie-points in the Singa section (Calabria). Using a magnetostratigraphic time-frame in the Capo Spartivento section in Calabria, Channell et al. (in press) showed that limestone-marl couplets, which characterize the lithology, have a duration close to 19 k.y. By counting the number of couplets between the base of the Thvera subchron and the Miocene-Pliocene boundary, these authors obtained an age of 4.93 Ma for the boundary. The section at Capo Spartivento can be correlated biostratigraphically to the stratotype section at Capo Rossello. The MPl1 biozone is about 30% thicker at Capo Spartivento, suggesting that the lowermost Pliocene is at least as complete as that at Capo Rossello. Now that the age of the Miocene-Pliocene boundary in the Mediterranean is on a firmer footing there are numerous biostratigraphic events in the open ocean which provide an improved approximation to this boundary (see for instance, Berggren et al., 1985). From a stratigraphic point of view, the boundary definition at Capo Rossello remains unsatisfactory because it is not recorded in a continuous marine section, the boundary coinciding with a sharp lithologic break between marine and nonmarine sediments. We propose that the definition of the M/P boundary be taken out of the Mediterranean.

PLIOCENE CHRONOSTRATIGRAPHY

Of the plethora of chronostratigraphic stages proposed for the Pliocene, only the Tabianian and Zanclean for the lower Pliocene and the Piacenzian for the upper Pliocene are currently utilized. These stages have been recently defined or redefined in stratotype sections (Table 1). The correlations of these stratotype sections to the GRTS, and to ODP Site 653, are shown in Figures 3 and 4. Due to the fact that the basal Pliocene is missing in the Tabianian stratotype section (Fig. 3), it was recommended at the 25th Geological Congress (Sidney, 1976) that the Zanclean stage be adopted (see Geological News Letter, 1976, p. 322). The Zanclean stratotype section at Capo Rossello (Cita and Gartner, 1973) has been recently studied by Rio et al. (1984) who recognized a hiatus at the top of the section (probably a local slump scar) which covers an interval of 0.3–0.4 m.y. (Fig. 3). This hiatus seems to be a very localized event. The Piacenzian

Table 2. Early-middle Pleistocene chronostratigraphic units.

UNIT	Type Locality	Stratotype	Source of calcareous plankton biostratigraphic data
TYRRHENIAN Issel, 1914	not considered		
MILAZZIAN Deperet, 1918	not considered		
CALABRIAN Gignoux, 1913	S. Maria di Catanzaro	S. Maria di Catanzaro	Bayliss, 1969 Sprovieri et al., 1973 Rio, 1974 Ruggieri et al., 1984
SICILIAN Doderlein, 1872	Ficarazzi (Palermo, Sicily)	Cava Puleo (Ficarazzi, Palermo)	Rugg. & Sprov., 1977 Di Stefano & Rio, 1981 Ruggieri et al., 1984
EMILIAN Rugg. & Selli, 1950 emended Rugg. et al., 1975	Santerno river (Bologna)	Santerno river (Bologna)	Ruggieri et al., 1975 Colalongo, 1968 Ruggieri et al., 1984
SANTERNIAN Rugg. & Sprov., 1977	Santerno river (Bologna)	Santerno river (Bologna)	Rugg. & Sprov., 1977 Colalongo, 1968 Raffi & Rio, 1980 Ruggieri et al., 1984
SELINUNTIAN Rugg. & Sprov., 1969	Selinunte (South Sicily)		Rugg. & Sprov., 1979 Ruggieri et al., 1984

has its stratotype (Barbieri, 1967) in the Arda valley, which is the classic area for the Pliocene series (Brocchi, 1814; Lyell, 1833). The sequence in the Arda valley was considered until recently to be continuous in the Pliocene-early Pleistocene interval. The sequence is represented by epibathyal marly clays in the lower part ("Tabianian" of the authors) and by circalittoral and littoral silty clays and sands in its middle and upper part (successively "Piacenzian," "Astian," and "Calabrian" of the authors). We have recently re-examined the part of the sequence which represents the Piacenzian as defined by Barbieri (Rio et al., in press; Raffi et al., in press). Some of the unexpected results can be summarized as follows:

1. A hiatus is present at the base of the Piacenzian stratotype section. MPl3 and the correlative calcareous nannofossil zones *C. rugosus* and *R. pseudoumbilica* are totally missing. Also, the hiatus is marked by an indurated bored sandy glauconitic horizon which, as indicated by the benthic foraminifers and the mollusks, represents a sharp environmental change from epibathyal to circalittoral conditions (Rio et al., in press). The age of this level, and therefore the base of the Piacenzian, does not correspond to the exit of *G. margaritae* in the Mediterranean, as has been widely thought (Cita, 1973; Berggren and Van Couvering, 1974; Rio et al., 1984). The calcareous plankton biochronology (Figs. 3 and 4) indicates that the basal Piacenzian is approximately between 3.5 and 3.3 Ma (the age of the *G. margaritae* LAD and *G. puncticulata* LAD, respectively).

2. The top of the Piacenzian stratotype section is placed within the short *D. pentaradiatus* nannofossil zone, and therefore has an age between 2.6 and 2.4 Ma. This age estimate is in agreement with planktonic and benthic foraminiferal evidence. *G. bononiensis* and *G. crassaformis* are still present and *G. inflata,* contrary to what is generally reported in the literature, is missing. This suggests that the top of the Piacenzian stratotype section is close to the onset of Northern Hemisphere Glaciation (Shackleton et al., 1984). This is nicely confirmed by pollen analysis carried out in the early sixties by Lona (1962) who found right at the top of the Piacenzian stratotype section a pollen assemblage which was interpreted as "glacial" ("Arquatian" phase). In the same interval a major extinction event in molluscan fauna with tropical affinity has been recorded (Raffi et al., in press).

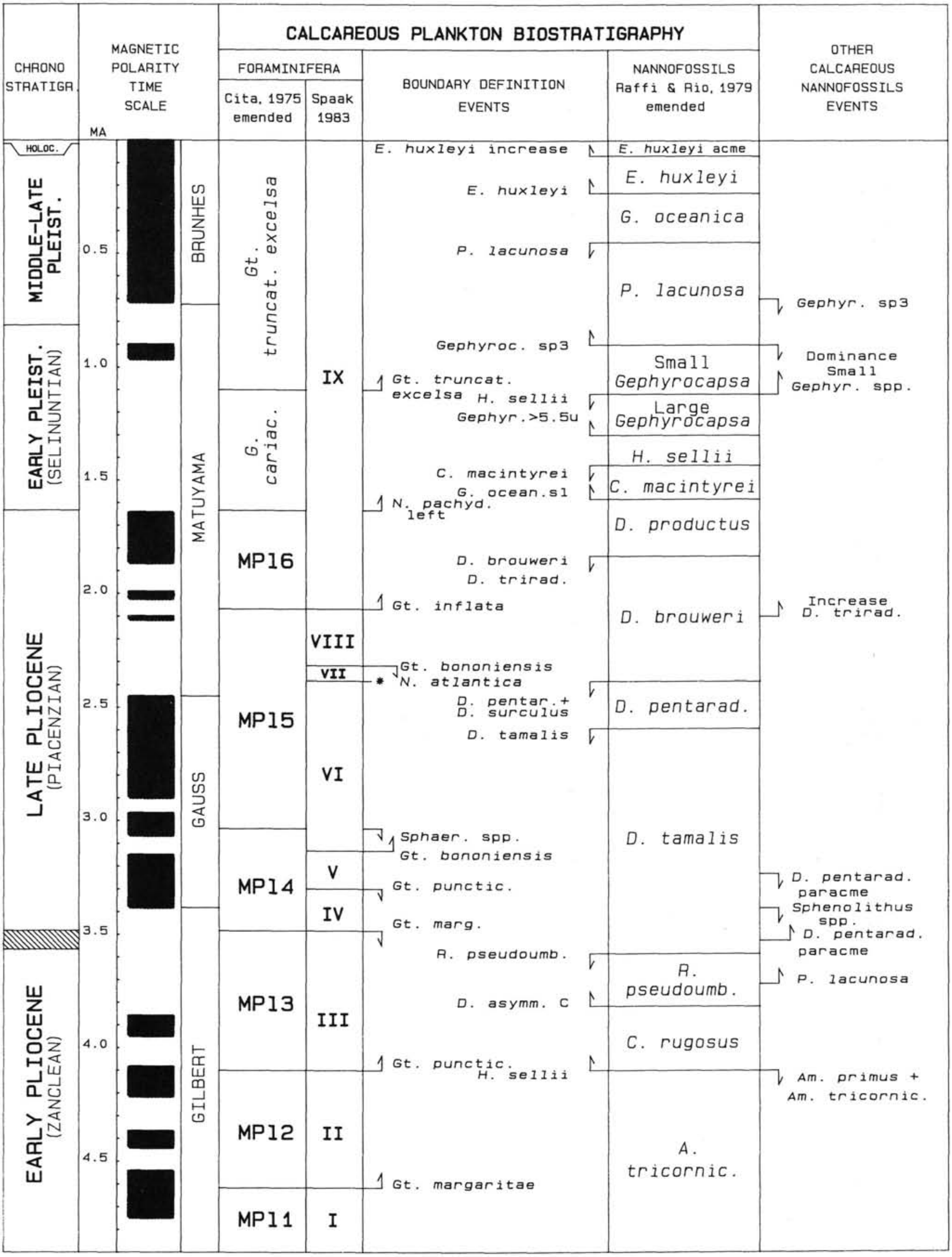

Figure 2. Biostratigraphic and biochronologic schemes adopted in this paper.

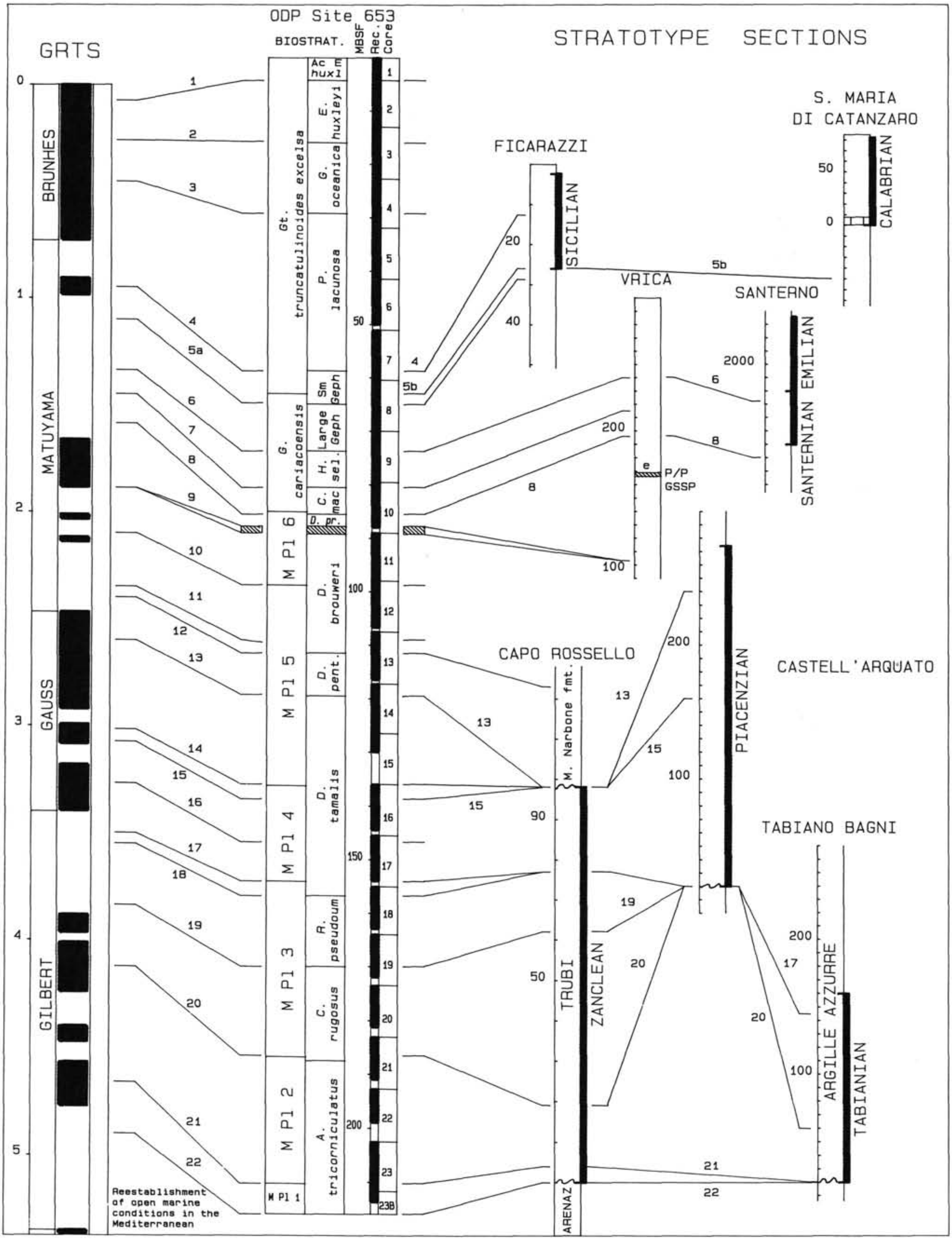

Figure 3. Calcareous plankton biostratigraphy and chronostratigraphy of Hole 653A and their correlation with the stratotype sections. Numbered tie line refers to biostratigraphic events listed in Table 4.

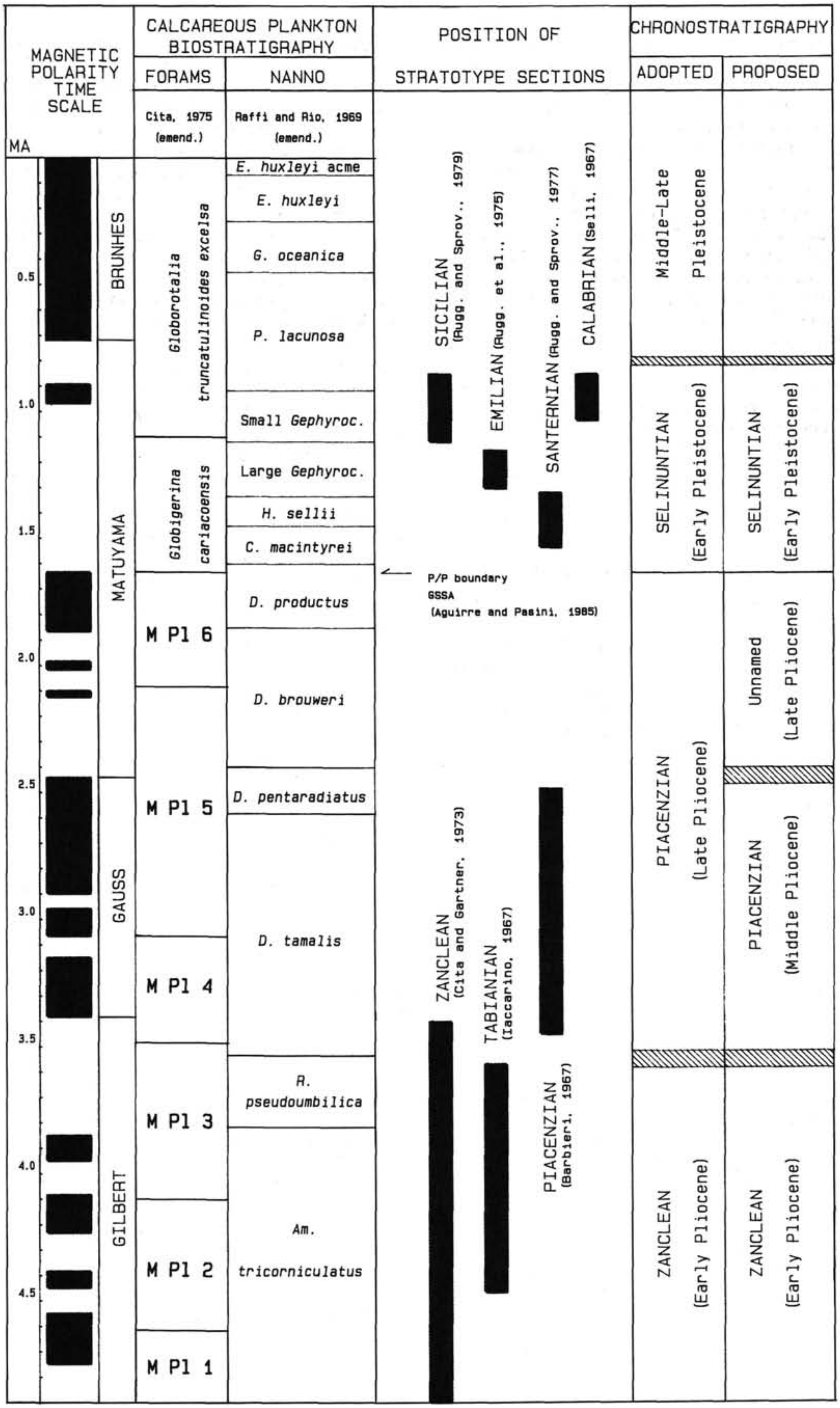

Figure 4. Stratigraphic position, mutual relationship, and temporal framing of the stratotype sections.

As a consequence of these results it is clear that the Zanclean/Piacenzian boundary must be redefined in a continuous marine section. Considering the timing of the basal Piacenzian, it seems advisable to place the "golden spike" for the Z/P boundary so that it is close to the Gilbert/Gauss boundary. This would facilitate worldwide correlations.

Since the top of the Piacenzian stratotype is significantly older (by about 0.8–0.9 m.y.) than the recently defined Pliocene/Pleistocene boundary (Aguirre and Pasini, 1985) and is close to a major threshold of the Neogene climate, the practice of extending the Piacenzian to the Pliocene/Pleistocene boundary can be argued. On the contrary, we suggest that the top of the Piacenzian, originally defined such that it corresponds to the beginning of the "Glacial Pliocene" should be incorporated in the GTS by introducing a new stage between the top of the Piacenzian and the Pliocene/Pleistocene boundary. We therefore propose a threefold subdivision of the Pliocene (Fig. 4) which will be easily recognized and correlated using magnetostratigraphy, biostratigraphy, and climatostratigraphy, and will give enhanced chronostratigraphic resolution in a time interval characterized by important environmental events. This proposal is not as radical as it might appear, as most biostratigraphers already informally use a subdivision of the Piacenzian into a lower "preglacial Pliocene and an upper "glacial Pliocene" (Rio and Sprovieri, 1986).

PLIOCENE/PLEISTOCENE BOUNDARY

The Plio-Pleistocene boundary has been and still is one of the most controversial stratigraphic horizon, largely due to different philosophical approaches to stratigraphy (Berggren and van Couvering, 1974; Pelosio et al., 1980). However, an international agreement has recently been achieved (Aguirre and Pasini, 1985) and the boundary has been formally defined in Vrica section (Calabria, southern Italy). The boundary corresponds to the top of the laminated level "e" in this section, which is regarded as the GSSP for this boundary. Magnetostratigraphy and calcareous plankton biostratigraphy in the Vrica section indicate that the boundary is close to the top of the Olduvai subchron (Pasini et al., in press), and various events can be used to correlate this boundary outside the stratotype area. At Site 653, a short hiatus is present close to the Plio-Pleistocene boundary. Nevertheless this sequence has been very useful in contributing to our understanding of the climatic significance of the Pliocene/Pleistocene boundary. As reported by Rio, Sprovieri, et al. (this volume), this boundary is marked in the Mediterranean by significant, albeit local and somewhat unclear, changes in the climatic system.

PLEISTOCENE

Although the detailed chronologic subdivision of the Pleistocene has high potential resolution (Berggren et al., 1980), the chronostratigraphic scheme is in a such confusion that many authors have proposed abandoning it (Kukla, 1975; Cooke, 1973), favoring a climatostratigraphic approach. However, the ISC has stressed the traditional approach of defining chronostratigraphic units in the lithologic record. The Pleistocene marine stages (Table 3), which are defined in Italy, are beset by so many difficulties in definition and correlation that they have been used only in the Mediterranean region. Of the chronostratigraphic units of the Pleistocene, only those of the early Pleistocene have been defined in type sections and can be correlated with traditional biostratigraphy.

Most of the recent timescales (Van Eysinga, 1975; Haq and Van Eysinga, 1987; Berggren et al., 1985; Ruggieri et al, 1984) utilize the following units in subdividing the early-middle Pleistocene: Calabrian, Emilian, Santernian, Selinuntian, and Sicilian (Table 3). All these units have been proposed with reference to Italian stratotype sections (Table 2). Recent studies of calcareous plankton biostratigraphy of the stratotypes sections allow us to correlate them with Site 653 (Fig. 3 and Table 4). The most striking result is that the Calabrian stratotype section at Santa Maria di Catanzaro (Calabria) is time equivalent or younger than the Sicilian as defined at Ficarazzi (Palermo). This is consistent with the conclusion of Ruggieri and Sprovieri (1977) who suggested over 10 yr ago that the two stages were synonymous. Therefore, the Calabrian stage should be abandoned in spite of its popularity in stratigraphic literature, unless a profound revision of its definition is made (Rio and Sprovieri, 1986). Since there is a time-gap between the Pliocene/Pleistocene boundary (about 1.65 Ma) and the base of the Emilian (1.3 Ma) (see Figs. 3 and 4), Ruggieri and Sprovieri (1977) proposed a new stage, the Santernian, to cover this early Pleistocene interval. The same authors (Ruggieri and Sprovieri, 1979) also introduced a new chronostratigraphic unit, the Selinuntian, intended as a superstage to include all the early Pleistocene (Santernian, Emilian, and Sicilian). Rio (1982) correlated the chronostratigraphic units of Ruggieri and Sprovieri (1979) to the calcareous nannofossil biochronology, questioned the usefulness of maintaining such short stages and proposed to erect a single stage for the early Pleistocene, as is often used informally in the literature (see Bowen, 1978). Following this proposal, Ruggieri et al. (1984) suggested that the Selinuntian be considered as a stage representing the early Pleistocene, with Santernian, Emilian, and Sicilian being regarded as substages or chronozones.

The base of the Selinuntian is defined by the Pliocene/Pleistocene boundary at Vrica, while its top, as proposed by Ruggieri and Sprovieri (1979), is coincident with the top of the Sicilian. The biocalcarenite bed with *Arctica islandica* outcropping in Cava Puleo (Ficarazzi, Palermo), the type locality of the Sicilian (Doederlein, 1872; Gignoux, 1913), is the proposed definition of the top of the Sicilian (Ruggieri et al., 1984). The same authors considered the top of the Selinuntian (and of the Sicilian) as correlative to the beginning of the Glacial Pleistocene (Oxygen isotopic Stage 22 of Shackleton and Opdyke, 1973). Ongoing work on oxygen isotope stratigraphy by Vergnaud-Grazzini and co-workers on the Sicilian stratotype section and comparison with Site 653, indicate that the top of the Sicilian probably predates oxygen isotopic Stage 22 and is best correlated with the cold oxygen isotopic Stage 24 in the terminology of Williams et al. (1988).

All units of the early Pleistocene defined in Italy are easily recognized in the deep-sea sequence of Site 653 (Figs. 3 and 4) mainly by using calcareous nannofossils, which provide an high degree of stratigraphic resolution in this interval.

CONCLUSIONS

All stratotype sections of the Pliocene/early Pleistocene chronostratigraphic units can be correlated with the continuous deep-sea record at ODP Site 653 by means of calcareous plankton biostratigraphy. The calcareous plankton biochronology and magnetostratigraphy, developed in the last few years in the Mediterranean marine record, allows the Mediterranean chronostratigraphic stages to be correlated to an absolute time-frame, which is a pre-requisite for their long-distance correlation.

The high resolution provided by the new integrated calcareous plankton biostratigraphy indicates several problems in the stratotype sections. Specifically, sedimentary hiatuses are present at the top of the Zanclean stratotype section and at the base of the Piacenzian stratotype section. The latter section serves as the definition of the Zanclean/Piacenzian boundary (McQueen and Oriel, 1977), but the situation demands that the Z/P boundary be redefined in a continuous marine section. Reappraisal of the biochronology close to the base of the Piacenzian indicate that the presently used criteria for recognizing this boundary

Table 3. Contrasting usage of chronostratigraphic units in the early-middle Pleistocene.

AGE	Berggren et al., 1985	Haq et al., 1986	Van Eisinga, 1975	Ruggieri et al., 1979	Ruggieri et al., 1984	Haq & Van Eisinga, 1986
0.5, 1.0, 1.5	Calabrian	Milazzian; Sicilian; Emilian; Calabrian	Tyrrhenian; Milazzian; Sicilian; Emilian; Calabrian	Selinuntian (Superstage): Sicilian; Emilian; Santernian	Selinuntian: Sicilian; Emilian; Santernian	Tyrrhenian; Sicilian; Calabrian / Milazzian; Emilian

Table 4. Biostratigraphic markers used for correlations in Figure 3.

1 Base acme *Emiliania huxleyi*	11 *Globorotalia bononiensis* LO
2 *Emiliania huxleyi* FAD	12 *Discoaster pentaradiatus* LAD
3 *Pseudoemiliania lacunosa* LAD	13 *Discoaster tamalis* LAD
4 End dominance small *Gephyrocapsa*	14 *Spaerodinellopsis* spp. LAD
5a Base dominance small *Gephyrocapsa*	15 *Globorotalia bononiensis* FO
5b *Globorotalia truncatulinoids excelsa* FO	16 *Globorotalia puncticulata* LO
6 *Halicosphaera sellii* LAD	17 *Globorotalia margaritae* LAD
7 *Cyclococcolithus macintyrei* LAD	18 *Reticulofenestra pseudoumbilica* LAD
8 *Gephyrocapsa oceanice* s.l. FAD	19 *Discoaster asymmetricus* FAD
9 *Discoaster brouweri* LAD	20 *Globorotalia puncticulata* FO
10 *Globorotalia inflata* FO	21 *Globorotalia margaritae* FO

(*G. margaritae* LAD, Gilbert/Gauss boundary, *R. pseudoumbilica* LAD) may be practical criteria even if they do not coincide with the base of the stratotype section. The top of the Piacenzian stratotype section is close to a major climatic change (onset of the North Hemisphere Glaciation) and is recognizable worldwide in both the continental and marine record. A long interval of time is present between the top of the Piacenzian stratotype (at 2.5 Ma) and the Plio-Pleistocene boundary (at about 1.67 Ma). The question arises as to whether to include this time interval in the Piacenzian as is the common practice. Since the base of the interval corresponds to a major threshold in Cenozoic climate, and the top to the Pliocene/Pleistocene boundary, both are easily recognized worldwide. It is suggested that this time interval be incorporated in the GTS by introducing a new stage, thus creating a threefold subdivision of the Pliocene.

The early Pleistocene is best represented by a single stage (Selinuntian). The top of this stage is coincident with the top of the Sicilian, which has an ages close to the Jaramillo event and to the beginning of the "Glacial Pleistocene."

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