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CALCAREOUS NANNOFOSSIL EVENTS IN THE LOWER-MIDDLE PLEISTOCENE TRANSITION AT THE MONTALBANO JONICO SECTION AND ODP SITE 964: CALIBRATION WITH ISOTOPE AND SAPROPEL STRATIGRAPHY

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Abstract. We present quantitative data on calcareous nannofossil biostratigraphy in the section of Montalbano Jonico (Southern Italy). This is one of the candidate Global Statotype Section and Point (GSSP) of the Middle Pleistocene. The first common occurrence (FCO) and last common occurrence (LCO) of *Reticulofenestra asanoi* are well detectable in the section and are here proposed as additional events for improving biostratigraphic resolution in the interval corresponding to the transition between the small *Gephyrocapsa* Zone and *Pseudoemiliania lacunosa* Zone. The potential value of the bioevents is tested in a Mediterranean deep-sea core of ODP Site 964, located in the Ionian Sea. At Site 964 the FCO of *R. asanoi* occurs in the marine oxygen isotope stage (MIS) 30, and the LCO of the species correlates with MIS 23. The ages of the FCO and LCO of *R. asanoi* have been estimated at 1.06 Ma and 0.93 Ma respectively. The first occurrence (FO) of *Gephyrocapsa* sp. 3 has been correlated to MIS 25, both at Site 964 and at the Montalbano Jonico section. The age of the FO of *Gephyrocapsa* sp. 3 is estimated at 0.95 Ma, based on the astronomical datings of sapropels occurring at the Montalbano Jonico section. In addition, an interval of temporary disappearance of *Gephyrocapsa* sp. 3 has been identified within the *P. lacunosa* Zone. The beginning of this interval is correlated with MIS 20/19 and can be considered a reliable event in the Mediterranean area, occurring close to the Brunhes/Matuyama magnetic boundary. The recognized events provide a basis for interpreting the Montalbano Jonico section within a standard chronostratigraphic framework.

Riassunto. In questo lavoro vengono presentati nuovi dati biostratigrafici ottenuti dallo studio quantitativo delle associazioni a nannofossili calcarei della sezione di Montalbano Jonico (Italia meridionale), che rappresenta una potenziale sezione stratotipica per la definizione del limite Pleistocene inferiore-medio. La "first common occurrence" (FCO) e la "last common occurrence" (LCO) di *Reticulofenestra asanoi* sono eventi biostratigrafici ben riconoscibili nella sezione, che incrementano la risoluzione biostratigrafica alla transizione tra la Zona a *Gephyrocapsa* e la Zona a *Pseudoemiliania lacunosa*. Lo studio biostratigrafico del pozzo ODP 964, ubicato nel Mar Ionio, ha consentito di verificare l'utilità biostratigrafica degli eventi riconosciuti e di correlarli con i dati di stratigrafia isotopica disponibili. La FCO di *R. asanoi*, correlata allo stadio isotopico 30, risulta avere un'età di 1.06 Ma, mentre la LCO di *R. asanoi* si correla con lo stadio isotopico 23, con un'età di 0.93 Ma. Nelle sezioni studiate la "first occurrence" (FO) di *Gephyrocapsa* sp. 3 è correlata allo stadio isotopico 25. Sulla base della cronologia astronomica dei sapropel individuati nella sezione di Montalbano Jonico l'età ottenuta per la FO di *Gephyrocapsa* sp. 3 è di 0.95 Ma. Inoltre, viene segnalata la presenza di un intervallo di temporanea assenza di *Gephyrocapsa* sp. 3 nella Zona a *Pseudoemiliania lacunosa*; l'inizio di questo intervallo è correlato agli stadi isotopici 20/19 e può essere considerato un evento biostratigrafico significativo nel Mediterraneo, in prossimità del limite magnetico Matuyama/Brunhes. I dati biostratigrafici ottenuti forniscono un valido contributo per collocare la sezione di Montalbano Jonico in un chiaro quadro cronostratigrafico.

Introduction

Although, at present, marine Pleistocene stratigraphy is well constrained by means of calcareous nannofossils, sapropels and oxygen isotopes (Fig. 1), a Global Stratotype Section and Point (GSSP) for the Middle Pleistocene has not been yet accomplished. The selection of a Middle Pleistocene GSSP is among the objectives of the Subcommission of Quaternary Stratigraphy (Abbate et al. 2002). The Mediterranean region and particularly Southern Italy, has always been considered the type-area for the marine Quaternary. The Montalbano Jonico section, located in the Bradano trough of the Southern Apennines (Fig. 2), was proposed as a potential section suitable for the selection of the GSSP of the Middle Pleistocene (Ciaranfi et al. 1997, 2001). The boundary could be traced close to the small *Gephyrocapsa*/*P. lacunosa* zonal boundary, near the last warm isotope stage before the beginning of the glacial Pleistocene (Cita & Castradori 1994). However, greater consensus exists for

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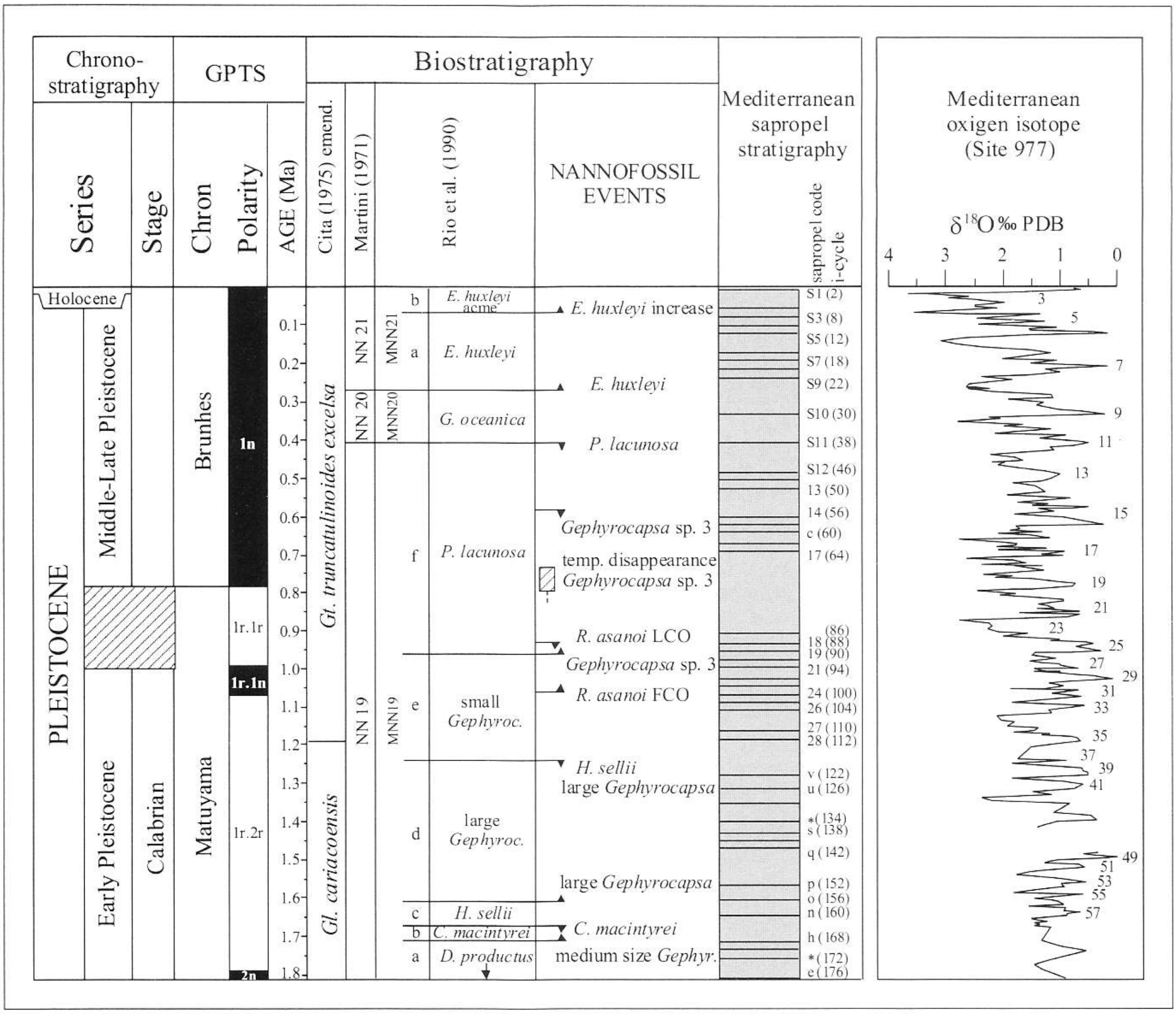

Fig. 1 - The Pleistocene stratigraphic framework for the Mediterranean (modified from Ciaranfi et al. 2001). The Calabrian stage is according to Cita & Castradori (1994). The geomagnetic polarity time scale is after Lourens et al. (1996) and the sapropel stratigraphy is according to Lourens et al. (1996), Kroon et al. (1998), Pierre et al. (1999). The oxygen isotope stratigraphy comes from von Grafenstein et al. (1999). Early Pleistocene calcareous nannofossil biochronology follows Lourens et al. (1996), the middle-late Pleistocene biochronology follows de Kaenel et al. (1999), and the last occurrence of *Gephyrocapsa* sp. 3 is from Sprovieri et al. (1998). The foraminiferal biochronology is from Lourens et al. (1996) and Sprovieri (1993). The temporary disappearance of *Gephyrocapsa* sp. 3, and the first common occurrence (FCO) and the last common occurrence (LCO) of *R. asanoi* are from this study.

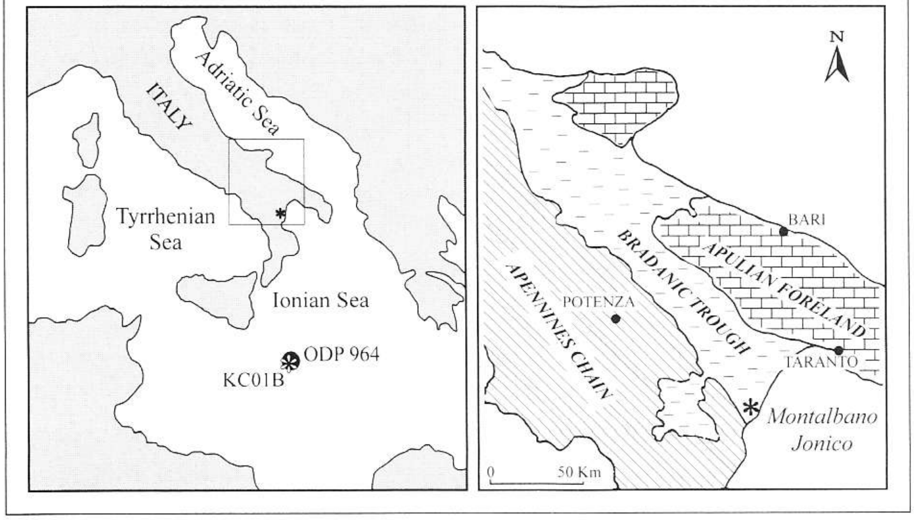

Fig. 2 - The location of the Montalbano Jonico section and ODP Site 964 (36°15.62'N; 17°45'E). Location of Core KC01B (36°15.25'N, 17°44.34'E), which was used as reference, is also shown.

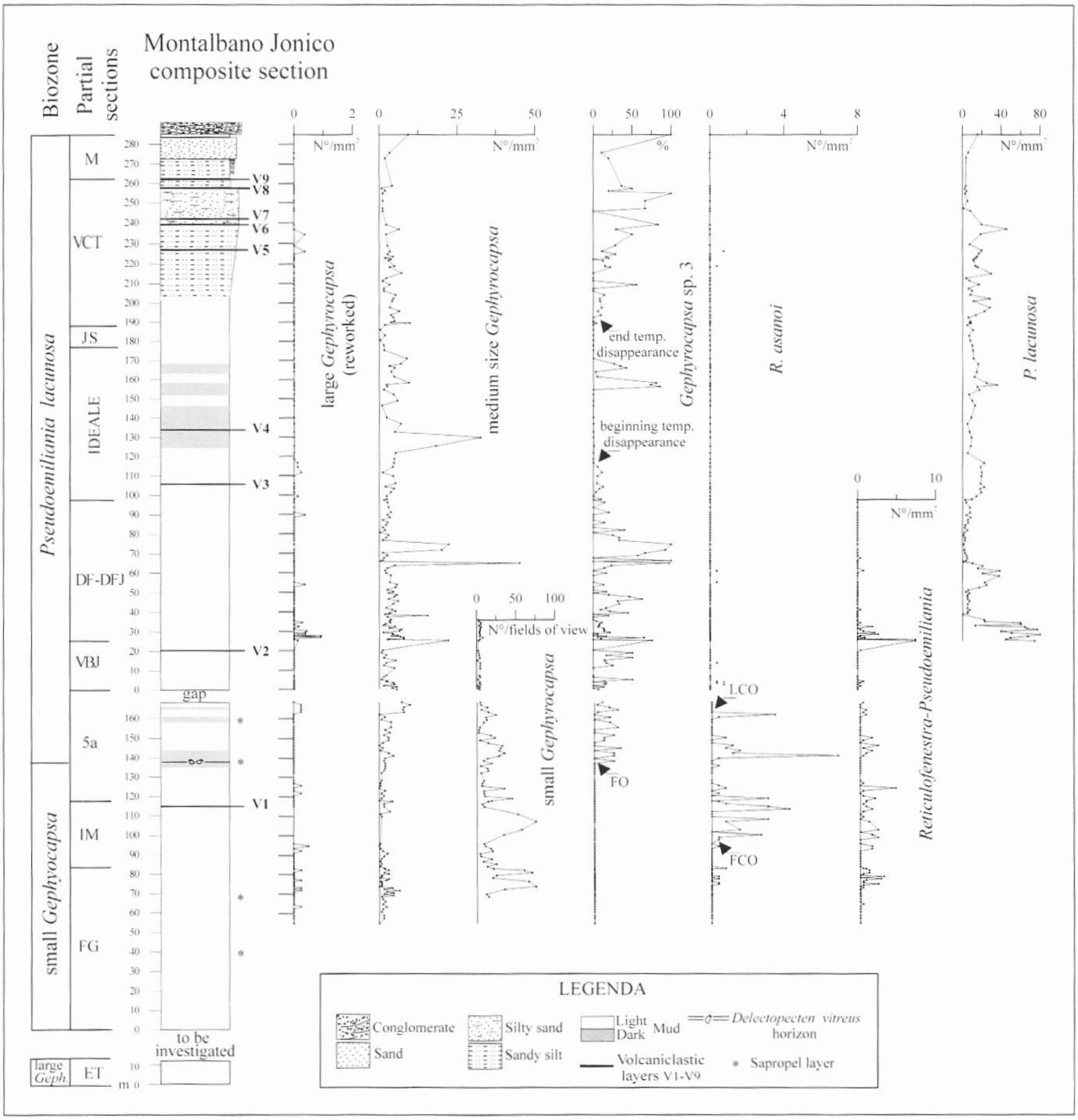

Fig. 3 - The patterns of abundance of selected calcareous nannofossils at the Montalbano Jonico section. The sapropel layers are according to Stefanelli (2000) and D'Alessandro et al. (2003). The partial sections are according to Ciaranfi et al. (2001).

the placement of the Lower/Middle Pleistocene boundary near the Brunhes/Matuyama boundary (Richmond 1996). Until an official decision is made by ICS/IUGS, both proposals may be discussed and defended. This paper considers the interval that straddles both the suggested locations for the Lower/Middle Pleistocene boundary.

Previous calcareous nannofossil studies have been performed in the Montalbano Jonico section (Marino 1996) and ODP Site 964 located in the Ionian Sea (Sprovieri et al. 1998). We provide additional quantitative biostratigraphic data of calcareous nannofossils at the Lower-Middle Pleistocene transition in both the sections, primarily focusing on the distribution of *Reticulofenestra asanoi* and *Gephyrocapsa* sp. 3. Several studies in Pleistocene deep sea successions (Takayama & Sato 1987; Matsuoka & Okada 1989; Sato et al. 1991; Sato & Takayama 1992; Wei 1993; de Kaenel et al. 1999; Flores et al. 2000; Raffi 2002) have shown that the stratigraphic range of *R. asanoi* improves the biostratigraphic resolution of this interval, despite the fact that the taxonomy of the species is ambiguous, different stratigraphic distributions are reported in the literature,

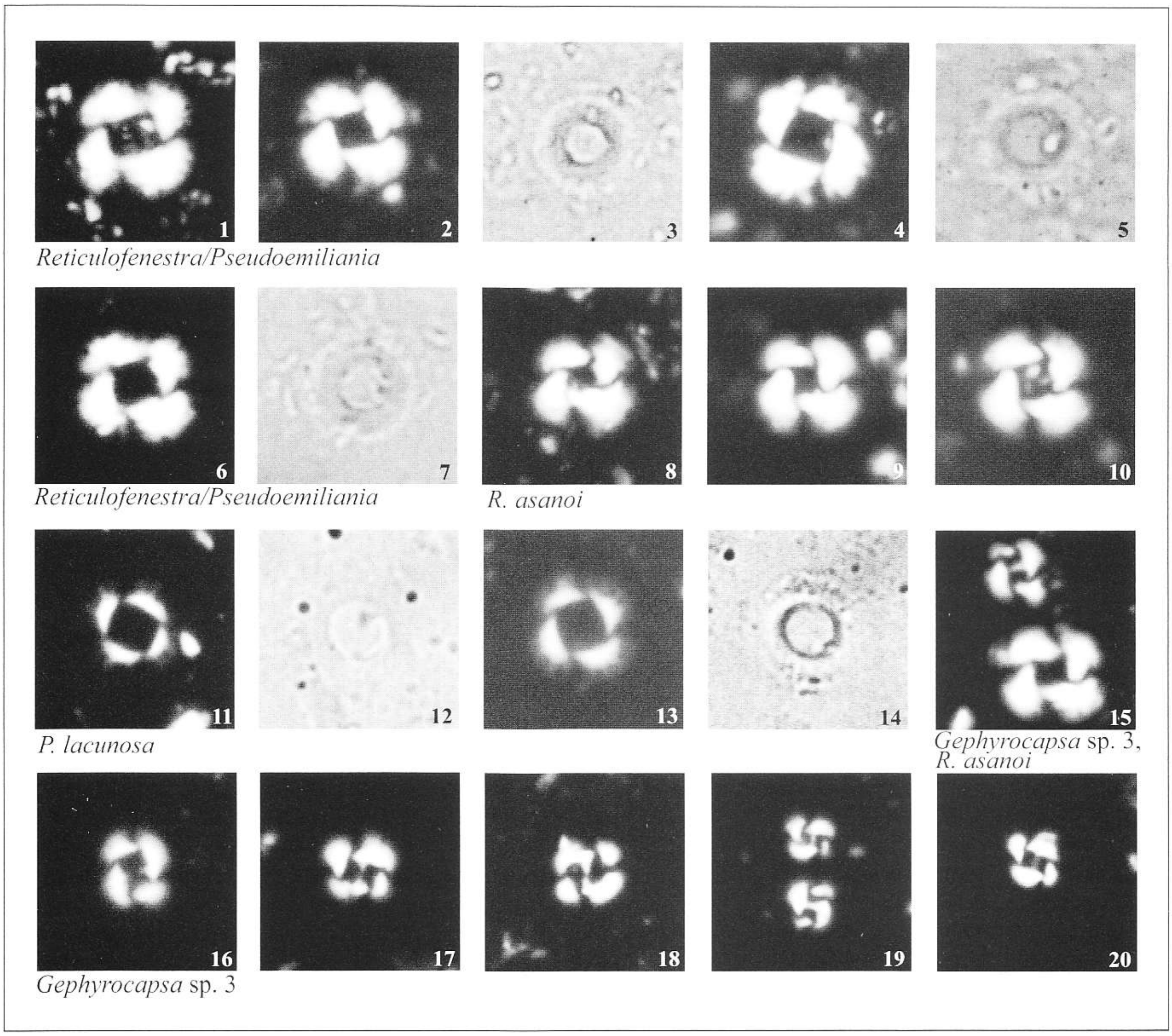

PLATE 1

XP = crossed polarized light, PL = parallel light.
Magnification: 2000X.

1-7 - *Reticulofenestra-Pseudoemiliania*. 1: XP, ODP Hole 964D, 32.44 mcd; 2-3: 2 XP, 3 PL, ODP Hole 964D, 33.34 mcd; 4-5: 4 XP, 5 PL, ODP Hole 964D, 34.36 mcd; 6-7: 6 XP, 7 PL, ODP Hole 964D, 33.14 mcd.

8-10 - *Reticulofenestra asanoi* Sato & Takayama. 8: XP, Montalbano Jonico section ("5a" partial section), 141.4 m; 9: XP, ODP Hole 964D, 35.44 mcd; 10: XP, ODP Hole 964D, 35.04 mcd.

11-14 - *Pseudoemiliania lacunosa* (Kamptner) Gartner. 11: XP, 12: PL, Montalbano Jonico section, ("JS" partial section), 177.9 m; 13: XP, 14: PL, Montalbano Jonico section, ("M" partial section), 285 m.

15 - *Gephyrocapsa* sp. 3 sensu Rio (1982) and *Reticulofenestra asanoi* Sato & Takayama. XP, ODP Hole 964D, 32.44 mcd.

16-20 - *Gephyrocapsa* sp. 3 sensu Rio (1982). XP, Montalbano Jonico section. 16-18: "M" partial section, 285 m; 19-20: "DF-DFJ" partial section, 25.35 m.

and only little quantitative data are available.

The available oxygen isotope curves in the studied sections (Brilli et al. 2000; Brilli unpublished data; Howell et al. 1998; Sprovieri et al. 1998), as well as the occurrence of some sapropel layers in the Montalbano Jonico section, provide additional stratigraphic controls at the Lower/Middle Pleistocene transition and biochronologic data for some of the recognized bioevents.

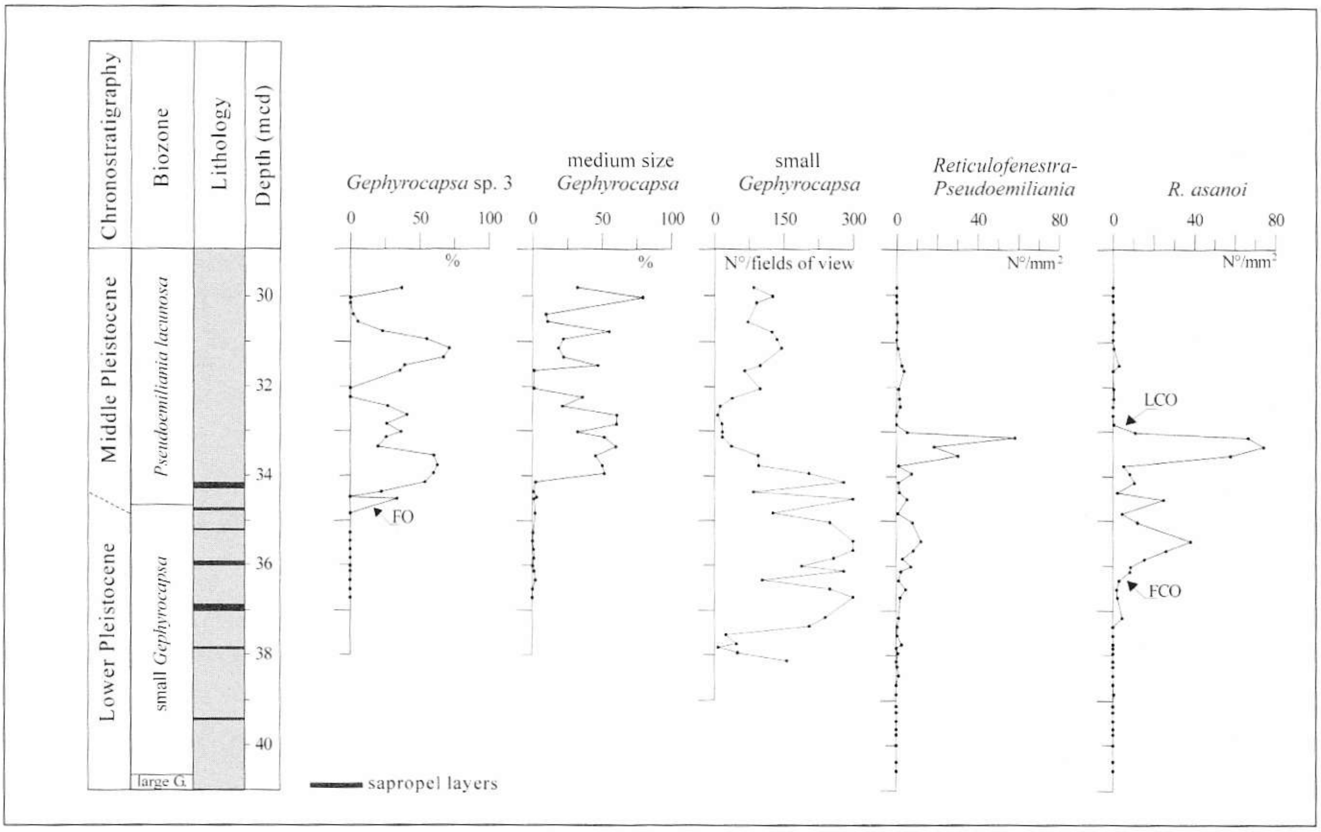

Fig. 4 - The abundance patterns of selected calcareous nannofossils at ODP Site 964. The distributions of *Gephyrocapsa* sp. 3 and of medium sized *Gephyrocapsa* are from Sprovieri et al. (1998). The sapropel layers are in accordance with the Shipboard Scientific Party (1996) and Sakamoto et al. (1998); mcd = meter composite depth.

Materials and Methods

The composite Montalbano Jonico section consists primarily of hemipelagic silts and silty clays (Fig. 3). Its stratigraphic and paleoecological framework is well-constrained by calcareous nannofossil, benthic macrofauna and microfauna assemblage data (Ciaranfi et al. 1996, 1997; 2001; Marino 1996; Girone 2000; Stefanelli 2000; Soldani 2000; D'Alessandro et al. 2003). Macrofauna assemblages, as well as benthic and planktonic foraminifera, have also been used to identify sapropel layers (Stefanelli 2000; Ciaranfi et al. 2001; D'Alessandro et al. 2003).

Sample resolution for calcareous nannofossil analyses is about 1 sample every 1- 2 metres, which, given the mean sedimentation rate of about 1 meter/ky, permits a high-resolution biostratigraphy.

The lithologic sequence at Site 964 consists primarily of nannofossil ooze with several sapropel layers (Shipboard Scientific Party 1996; Sakamoto et al. 1998). Sampling resolution in the Site 964 succession was about 1 sample every 20 cm, which corresponds to about 1 sample per 8000 years.

Smear slides were prepared according to standard methodologies, which have been widely used so far in order to recognized all major abundance patterns of taxa (Backman & Shackleton 1983; Rio et al. 1990; Baumann et al. 1998). Smear slides were analysed under a polarized light microscope at 1000x magnification.

Quantitative data were obtained by counting selected index species in about 150 fields of view (containing about 10.000 coccoliths on average), both in the Montalbano Jonico and Site 964 sections. Specimens of small *Gephyrocapsa* occurring in the first five fields of view have been counted and their patterns of abundance are presented as the mean number of specimens per field of view. Quantitative abundances of *Gephyrocapsa* sp. 3 are shown as a percentage of the total number of medium sized *Gephyrocapsa*. For Site 964, the abundance patterns of *Gephyrocapsa* sp. 3 and medium sized *Gephyrocapsa* are taken from Sprovieri et al. (1998).

Taxonomic notes

The morphological criteria for the gephyrocapsids follow Gartner (1977), Rio (1982) and Raffi et al. (1993). Taxonomically problematic taxa are briefly discussed below.

Genus *Reticulofenestra* Hay, Molher & Wade, 1966

Reticulofenestra asanoi Sato & Takayama, 1992

Pl. 1, figs 8-10, 15

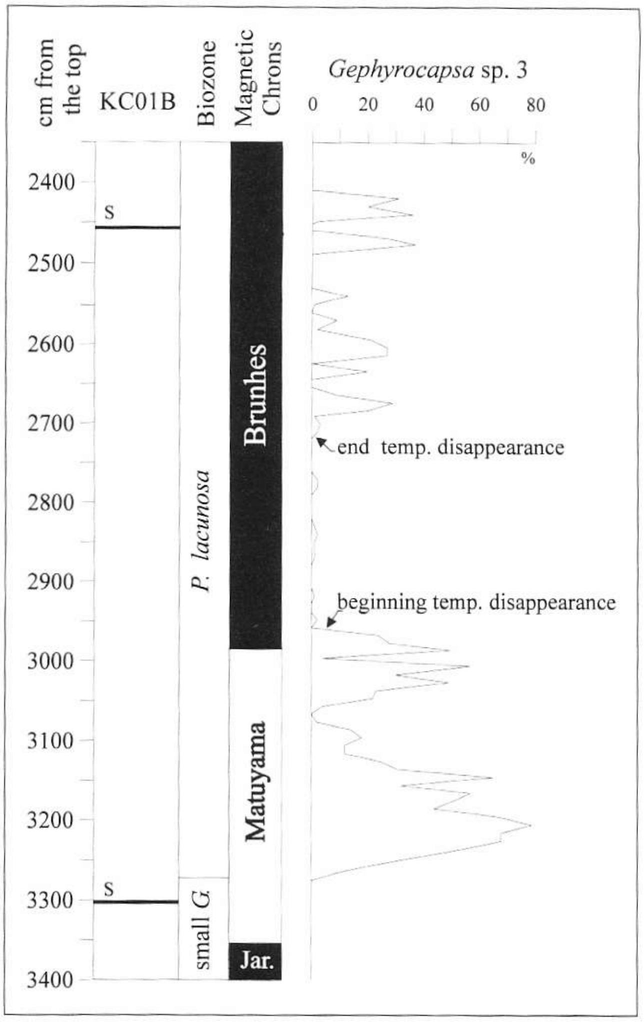

Fig. 5 - Correlation of abundance pattern of *Gehyrocapsa* sp. 3 with magnetic chrons at the Mediterranean core KC01B. Analytical data of *Gephyrocapsa* sp. 3, location of sapropel layers (S) and of magnetic boundary are from Castradori (1992; 1993).

Reticulofenestrids that are larger than 6 μm, and have a circular to sub-circular outline and a wide collar, are here assigned to *R. asanoi*. Adopting this formal description, diagnostic and unambiguous taxonomy is provided for this species.

Different Pleistocene ranges are given in the literature for *R. asanoi,* probably because both elliptical specimens and/or only those specimens larger than 6.5 μm in size have been included in this species (Matsuoka & Okada 1989; Sato et al. 1991; Wei 1993; Erba 1995; de Kaenel et al. 1999; Fornaciari 2000).

Intermediate morphotypes between *Reticulofenestra-Pseudoemiliania*
Pl. 1, figs 1-7

These morphotypes exhibit a subcircular outline and are generally larger than 5 microns; the collar is prominent and wider than in *Pseudoemiliania*; the central opening has intermediate size between that of the genera *Reticulofenestra* and *Pseudoemiliania* and represents about 30% of the total length of the coccoliths. The distal shield shows fewer slits than in *P. lacunosa*, but this feature is not always clearly detectable in poorly preserved material at the polarized light microscope. These intermediate morphotypes are distinguished from *R. asanoi* by their slits in the distal shield, their wider central opening, and the less prominent collar. They can be similar to *Pseudoemiliania pacifica* (Nishida) that shows less than twelve slits in the distal shield. We consider the number of slits an ambiguous taxonomic criterion, especially in poorly preserved material.

Pleistocene reticulofenetrids that exhibit intermediate characteristics between *Reticulofenestra* and *Pseudoemiliania* have been documented as "*P. lacunosa* variety A" by Matsuoka & Okada (1989), as "*Reticulofenestra/Pseudoemiliania* sp." by Castradori (1992), and as "intermediate morphotypes between *Reticulofenestra* and *Pseudoemiliania*" by Marino (1996). In the studied sections these intermediate morphotypes occur within the small *Gephyrocapsa* and *P. lacunosa* biozonal interval, in agreement with their distribution observed in the previous studies.

Biostratigraphic results

The Montalbano Jonico section ranges from the large *Gephyrocapsa* to the *Pseudoemiliania lacunosa* Zones (MNN19d to MNN19f) (Marino 1996) according to the biozonal scheme of Rio et al. (1990). The investigated interval at Site 964 corresponds to the small *Gephyrocapsa* and *P. lacunosa* zones (Sprovieri et al. 1998). The obtained biostratigraphic data and the most remarkable bioevents are discussed below.

FCO and LCO of *Reticulofenestra asanoi*

At the Montalbano Jonico section *R. asanoi* is rare and scattered in the lower part of its distribution range (Fig. 3); during most of the range relatively high abundance values are followed by intervals in which the species is absent or rare. In the uppermost part of its range the rarity of the species prevents to discriminate between reworking or normal rare occurrences. The mode of occurrence and extinction of *R. asanoi* suggests that the FCO and LCO are more reliable events than the absolute FO and LO of the species.

The distribution of *R. asanoi* at Site 964 (Fig. 4) is consistent with that observed within the Montalbano Jonico section, with distinct fluctuations in abundance. As in the Montalbano Jonico section, the FCO and LCO of the species occur below and above the FO of *Gephyrocapsa* sp. 3, respectively. The range of the intermediate morphotypes between *Reticulofenestra* and *Pseudoemil-*

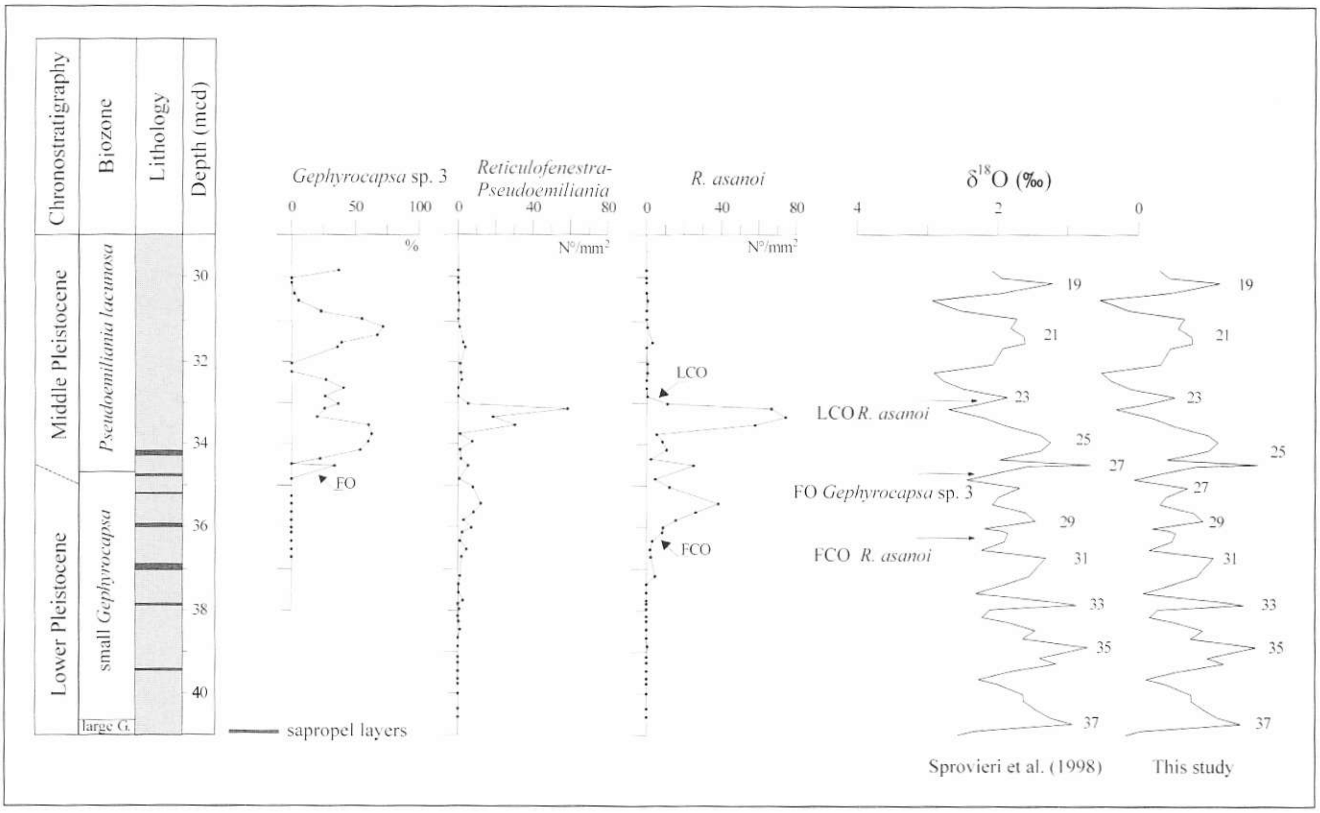

Fig. 6 - Correlation between the calcareous nannofossil events and the oxygen isotope stages at ODP Site 964. Farthest to the right in the diagram is our proposed new interpretation of the oxygen isotope stratigraphy at the Lower-Middle Pleistocene transition.

iania apparently follows the abundance patterns of *R. asanoi* both at the Montalbano Jonico section and at Site 964 (Figs. 3-4).

First Occurrence of *Gephyrocapsa* sp. 3

The FO of *Gephyrocapsa* sp. 3 marks the base of the *P. lacunosa* Zone (Fig. 1). Although the species is rare and scattered in the lower part of its distribution range in the Montalbano Jonico section, its FO is a distinct event in the "5 Agosto" partial section (5a) and occurs within a thick sapropel layer (Fig. 3). The re-entry of the medium-sized *Gephyrocapsa*, which occurs simultaneously with the FO of *Gephyrocapsa* sp. 3 (Rio et al. 1990; Castradori 1993; Raffi et al. 1993), is not identified in the Montalbano Jonico section. Actually, rare specimens of medium-sized *Gephyrocapsa* occur continuously within the small *Gephyrocapsa* Zone. These presences are due to reworking, also evidenced by scattered occurrences of specimens of large *Gephyrocapsa* (Fig. 3).

Temporary disappearance of *Gephyrocapsa* sp. 3

As already shown in Marino (1996), in the upper part

Biovent	MIS	Site/Core	Location, latitude	Reference
FO *R. asanoi*	29-30	Site 677	Eastern Pacific, 1° N	Wei (1993)
	30	Site 502	Western Atlantic, 11° N	
	31	Site 593	Western Pacific, 41° S	
	35	Site 607	Eastern Atlantic, 41° N	
	33/34	Site 977	Western Mediterranean, 36° N	de Kaenel et al. (1999)
	35	Core PS2709-1	Southern Ocean, 57° S	Flores et al. (2000)
	35	Site 1063	Western Atlantic, 33° N	Raffi (2002)
	35/34	Site 926	Western Atlantic, 33° N	
		Site 1014	Eastern Pacific, 32° N	
FCO *R. asanoi*	30	Site 964	Eastern Mediterranean, 36° N	this study
LCO *R. asanoi*	23	Site 964	Eastern Mediterranean, 36° N	this study
LO *R. asanoi*	22	Site 647	Western Atlantic, 53° N	Wei (1993)
	22	Site 607	Eastern Atlantic, 41° N	
	22	Site 677	Eastern Pacific, 1° N	
	22	Site 593	Western Pacific, 41° S	
	22/23	Site 502	Western Atlantic, 11° N	
	19	Site 975	Western Mediterranean, 38° N	de Kaenel et al. (1999)
	22	Core PS2709-1	Southern Ocean, 57° S	Flores et al. (2000)
	22/23	Site 967	Eastern Mediterranean, 34° N	Raffi (2002)
	23	Site 1014	Eastern Pacific, 32° N	

Tab. 1 - Summary of correlation of *R. asanoi* datums with oxygen isotope stages.

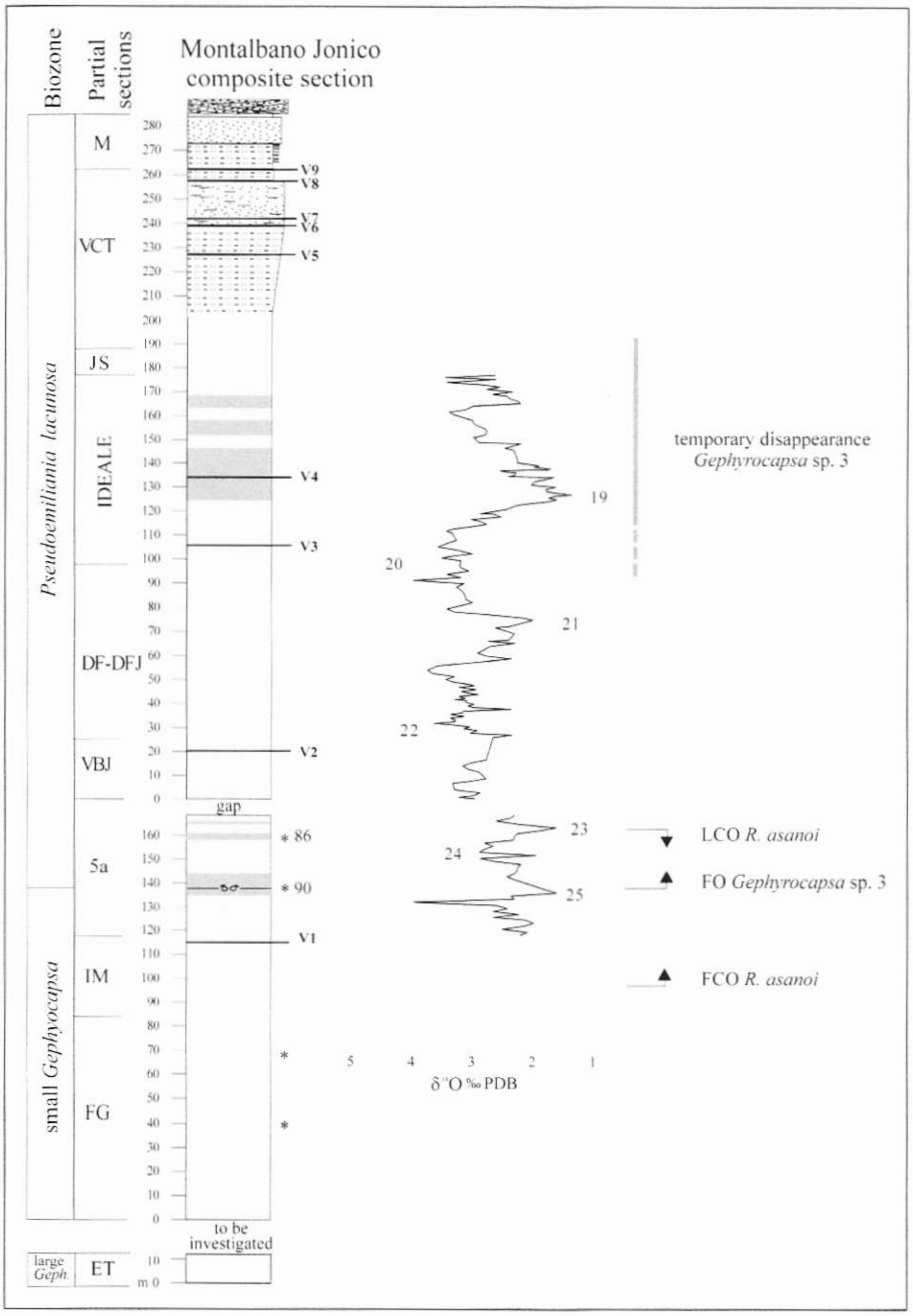

Fig. 7 - Interpretation of the oxygen isotope stratigraphy at the Montalbano Jonico section based on nannofossil events discussed in the text. Sapropels in the "5a" section are labelled as the corresponding insolation cycles. The oxygen isotope data are from Brilli et al. (2000) and Brilli (unpublished data). For symbols see legend in Fig. 3.

of Montalbano Jonico section, a distinct temporary disappearance of *Gephyrocapsa* sp. 3 with few abundance peaks is recorded within the *P. lacunosa* Zone (Fig. 3). The quantitative distribution of *Gephyrocapsa* sp. 3 in some Mediterranean sections (Rio et al. 1990; Sprovieri et al. 1998) did not show any significant paracme interval. It can however be clearly inferred from the distribution pattern of *Gephyrocapsa* sp. 3 within the *P. lacunosa* Zone, available in the Mediterranean core KC01B (Fig. 5) (Castradori 1992), and suggests its potential utility as additional biostratigraphic event. The recognition of the paracme interval could be prevented by low sampling resolution and/or low sedimentation rates.

Calibration of bioevents with the oxygen isotope stratigraphy

The oxygen isotope data available at Site 964 (Sprovieri et al. 1998) are used to correlate the FCO and the LCO of *R. asanoi* to the marine oxygen isotope stages (MIS). The FCO of the species falls in MIS 30 (Fig. 6), even though rare occurrences of the species are recorded from MIS 31/32; scattered and very rare occurrences (1 specimens in the total scanned area of slide) are present from MIS 34/35. The LCO of *R. asanoi* is recorded in MIS 23 but very rare specimens occur up to MIS 20 (Fig. 6). A disagreement exists with the previous correlations of FO and LO of *R. asanoi* to oxygen isotope data (Tab. 1). These discrepancies can be due to the previously mentioned taxonomic ambiguities, to possible environmental factors and/or perhaps to the rare and scattered occurrences of the species in the lowermost and uppermost part of its range, which make its FO and LO difficult to be detected for accurate biostratigraphic correlation. Following the nannofossil biochronology available at Site 964 (Sprovieri et al. 1998) in the Lower/Middle Pleistocene transition interval, the estimated ages of the FCO and the LCO of *R. asanoi* resulted 1.06 and 0.93 Ma, respectively.

The FO of *Gephyrocapsa* sp. 3 at Site 964 has been correlated to MIS 27 (Sprovieri et al. 1998) (Fig. 6). This event in the Mediterranean deep-sea cores has been correlated to MIS 25 (Castradori 1993), MIS 26 (de Kaenel et al. 1999), MIS 25/26 transition (Raffi 2002), and MIS 27 (Sprovieri 1993; Sprovieri et al. 1998) and is considered as diachronous between low and mid-high latititudes (Wei 1993; Raffi et al. 1993; Raffi 2002). Discrepancies within the Mediterranean area might be due to different method of analyses and sampling resolution, rarity of *Gephyrocapsa* sp. 3 in the lowermost part of its range, as well as to different interpretations of the oxygen isotope data and identification of isotope stages. In fact at Site 964, the correlation of the FO of *Gephyrocapsa* sp. 3 to the isotope stages should be slightly revised. According to the standard oxygen isotope curve of Shackleton et al. (1990) as well as the more recent oxygen isotope data from the Mediterranean Sea (Kroon et al. 1998; von Grafenstein et al. 1999; Doose et al. 1999), the warmer MIS 25 has lighter $\delta^{18}O$ values if compared to the warm MIS 27 (Fig. 1) and represents the last warm isotope stage before the beginning of the glacial Pleistocene; a significant cooling occurs above MIS 25 towards MIS 22 and very heavy values of $\delta^{18}O$ are recorded in MIS 22. This is also apparent in the oxygen isotope curve at Site 964, thus suggesting the reinterpretation of MIS 27 (Sprovieri et al. 1998) as MIS 25 (Fig. 6).

The revised interpretation of oxygen isotope stratigraphy at Site 964 supports the correlation of the FO of *Gephyrocapsa* sp. 3 to MIS 25 or to MIS25/26 transition in the Mediterranean area as documented from most of the above mentioned literature.

Chronostratigraphic constraints at the Montalbano Jonico section

The lower part of the oxygen isotope curve in the Montalbano Jonico section does not directly correlate to the standard oxygen isotope stages (Fig. 7). However, the above mentioned correlation of the FO of *Gephyrocapsa* sp. 3 to oxygen isotope stratigraphy and of the LCO of *R. asanoi* to MIS 23 recorded at Site 964, are powerful stratigraphic constraints for the interpretation of oxygen isotope data at Montalbano Jonico section (Fig. 7). On the basis of the interpretation proposed herein from the 22/23 transition upwards, the $\delta^{18}O$ signal generally shifts to the heavier values of the glacial stages and shows the wider amplitude fluctuations of the glacial/interglacial cycles (Fig. 7). This signal could be related to the global paleoclimatic event of intensified Northern Hemisphere glaciation at about 900 k.y. which produced the change in the $\delta^{18}O$ signal from a dominant periodicity of 100 k.y. to 40 k.y. (Shackleton & Opdyke, 1973; Ruddiman et al. 1986).

Following the present interpretation of the oxygen isotope curve at the Montalbano Jonico section, the beginning of the temporary disappearance of *Gephyrocapsa* sp. 3 correlates to the MIS 20/19 transition (Fig. 7), although a decrease in its abundance (Fig. 3) is apparent even slightly below, at the MIS 21/20 transition. Correlation of the quantitative distribution of *Gephyrocapsa* sp. 3 in core KC01B (Fig. 5) indicates that the beginning of temporary disappearance of the species occurs close to the Brunhes/Matuyama boundary which well correlates to MIS 20/19 transition (Shackleton et al. 1990), thus supporting the present interpretation of the oxygen isotope curve at Montalbano Jonico section. The LO of *Gephyrocapsa* sp. 3 has been correlated to MIS 15 in the Mediterranean Sea (Sprovieri et al. 1998). Since *Gephyrocapsa* sp. 3 is still present at the top of the Montalbano Jonico section, the top of the section lies below MIS 15.

Based on the published correlations among oxygen isotope stages, sapropel stratigraphy, calcareous nannofossil events and insolation cycles (Fig. 1) (Lourens et al. 1996; Kroon et al. 1998; de Kaenel et al. 1999; Pierre et al. 1999), the two sapropel layers in the partial section "5a" might be assigned to i-cycle 90 and i-cycle 86 (Fig. 7). It is noteworthy that the sapropel correlated to i-cycle 90 (sapropel 19) corresponds to a high amplitude insolation maximum, according to the astronomical correlation of Lourens et al. (1996), and this can explain its distinctiveness in the Montalbano Jonico section. The age estimate for the FO of *Gephyrocapsa* sp. 3 at the Montalbano Jonico section is 0.95 Ma, based on the sapropel chronology by Kroon et al. (1998) and Pierre et al. (1999).

Conclusions

The calcareous nannofossils in the Lower/Middle Pleistocene transition have been investigated in detail at the Montalbano Jonico section and at Site 964. This transitional interval seems to be well constrained by the biostratigraphic data: the FCO and LCO of *R. asanoi* improve the biostratigraphic resolution in the interval of the small *Gephyrocapsa*/*Pseudoemiliania lacunosa* zone transition, close to the FO of *Gephyrocapsa* sp. 3.

The FCO and LCO of *R. asanoi*, and the FO of *Gephyrocapsa* sp. 3 have been correlated to the oxygen isotope curve both at Site 964 and Montalbano Jonico section as well as to the sapropel stratigraphy identified at Montalbano Jonico. The FCO of *R. asanoi* correlates with MIS 30 at Site 964, while its LCO correlates with MIS 23. The FO of *Gephyrocapsa* sp. 3 has been correlated to MIS 25 in the section of Montalbano Jonico and at Site 964, where a reinterpretation of the oxygen isotope stages has been proposed. In the Montalbano Jonico section, the FO of *Gephyrocapsa* sp. 3 falls within a thick sapropel that may be referred to sapropel 19 according to the available correlations of calcareous nannofossil, sapropel and oxygen isotope stratigraphy (Lourens et al. 1996; Kroon et al. 1998; de Kaenel et al. 1999).

A distinct temporary disappearance of *Gephyrocapsa* sp. 3 is recorded in the Montalbano Jonico section within the *P. lacunosa* Zone. The beginning of the temporary disappearance correlates with MIS 20/19 and may be an additional event within this biozone. This is in agreement with data from Core KC01B, where the event is also documented as close to the Brunhes/Matuyama magnetic boundary. Additional data are however required in order to verify the spatial and temporal occurrence of the event for improving the biostratigraphic resolution within the *P. lacunosa* Zone.

The Montalbano Jonico section appears a possible reference section for the selection of the Lower/Middle Pleistocene GSSP. It includes the boundary between the small *Gephyrocapsa* Zone and *P. lacunosa* Zone, which is chronologically constrained by MIS 25 and sapropel 19. According to our interpretation of the oxygen isotope curve, the Montalbano Jonico section includes MIS 19, which corresponds to the Brunhes/Matuyama chron boundary (Shackleton et al. 1990), and would provide an alternative placement for the Lower/Middle Pleistocene boundary stratotype, according to Richmond (1996).

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