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Proposal for the Global Stratotype Section and Point (GSSP) for the Calabrian Stage basal boundary (Quaternary System/Period, Pleistocene Series/Epoch)

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Foreword

The Calabrian Stage of Gignoux (1910) has been generally applied in the past as a division of the Pleistocene, but not in the recent decades, as a consequence of a number of misinterpretations and contrasting interpretations of the data collected by dozens of scientists, belonging to different schools.

A fully documented redefinition of the Calabrian Stage was recently published by Cita et al. (2008, appendix 2) in which the history of the stage definition, and a wealth of co-ordinated data including the lithostratigraphy, biostratigraphy (planktonic foraminifers, benthic foraminifers, calcareous nannoplankton), magnetostratigraphy, isotopic stratigraphy, astrostratigraphy, palynostratigraphy and tephrochronology were presented. The type section for the definition of the stage was that at Vrica in Calabria, southern Italy (lat 39°02'18.61"N, long 17°08'05.79" E). Auxiliary sections on land at Singa and Capo Rossello for the lower part; and Montalbano Jonico for the upper part, were also indicated. To avoid duplication, reference is made to pages 410-418 of Cita et al. (2008) and references therein. Figures 1 to 5 and the following definition are here reproduced for clarity and consistency.

Figs 1-5

The proposed GSSP for the base of the Calabrian Stage

The silty claystones exposed in the Vrica section (Fig. 3) have been intensively investigated in the last twenty years. The numerous studies reflect the progress in the integrated Neogene stratigraphy (cf. Selli et al. 1977, Colalongo et al. 1980, Pasini & Colalongo 1982, Tauxe et al. 1983, Backman et al. 1983, Aguirre & Pasini 1985, Bassett 1985, Howell et al. 1990, Azzaroli et al. 1996, Rio et al. 1996a, and Lourens et al. 1996a, 1996b):

Name of boundary*:** Base of Calabrian. ***Rank of boundary*:** Stage/Age. ***Position of the unit*:** Stage of the Pleistocene Series, immediately overerlying the Gelasian Stage and underlying the potential 'Ionian' stage. ***Type locality of the Global Stratotype Section and Point: Vrica, Crotone, Calabria, Italy. The Vrica section is located 4 km south of the town of Crotone, close to Capo Colonne, in the Marchesato Peninsula, Calabria, Italy (Figs. 2a = 2 here, 2b = 3 here).

***Latitude*:** 39°02'18.61" north; Longitude: 17°08'05.79" east. ***Accessibility*:** The section is freely and easily accessible. ***Conservation*:** The extensive badlands represent an excellent exposure, distant from human activities.It will therefore remain well-exposed in the near future. ***The section*:** The section consists of open marine deposits of an outcropping portion of a Late Cenozoic sedimentary basin. It is composed of three easily correlated segments: A, B (where the boundary stratotype was fixed), and C. They cover a thickness of about 300 m and comprise epibathyal, fossiliferous, silty marl claystone (dark grey or blue-grey in colour) with interbedded repeated grey-pink sapropelic layers. Rare sandy strata and three volcanic ash layers (i.e. tephra, including level '*m*') also occur within the section (Aguirre & Pasini, 1985; Pasini & Colalongo, 1994).
Sediment accumulation rates are high. In the interval encompassing the GSSP (*Discoaster brouweri* LA [last appearance]–*Gephyrocapsa oceanica* s.l. FA [first appearance]), using the nannofossil biochronology and the magnetostratigraphical data of Tauxe et al. (1983), sediment accumulation ranges between a minimum rate of 25 cm/ka and a maximum rate of 34 cm/ka (Rio et al., 1996).

Calabrian Stage GSSP definition. The base of the marine claystone that conformably overlies the sapropelic bed '*e*', within Segment B in the Vrica section, is proposed here as the GSSP for the base of the Calabrian Stage (Fig. 3). This level coincides with the GSSP of the Pleistocene Series ratified by IUGS in 1984 (Aguirre & Pasini, 1985; Bassett, 1985), but rejected as base of the Quaternary by INQUA in 1995. Full details of the reassignment of the base Pleistocene and the definition of the Quaternary Period are given in Gibbard & Head (2009a, b, 2010) and Gibbard et al. (2010). This lithological level represents the primary marker for the recognition of the boundary and it has been assigned an astronomical age of 1.806 Ma on the basis of sapropel calibration (Lourens et al., 2004). It coincides with the transition from Marine Isotope Stages (MIS) 65–64 and with the Mediterranean Precession Related Sapropel (MPRS) layer 176 (Lourens et al., 1996a; Lourens et al., 1998) (Fig. 4).
Secondary markers are represented by distinctive calcareous plankton biological events of widely distributed taxa. The boundary falls between the LA of *Discoaster brouweri* (below) and the LO of *Globigerinoides obliquus extremus* (above) and below the FAs of medium-sized *Gephyrocapsa* (incl. *G. oceanica*) and *Globigerinoides tenellus*. It virtually coincides with the first increase in abundance of *Neogloboquadrina pachyderma* sx. (Fig. 5)
From a palaeomagnetic point of view, the boundary falls about 10 m below the top of the Olduvai normal polarity Subchron (Zijderveld et al., 1991) (Fig. 4).

The Cita *et al.* (2008) paper, noted above, was pre-dated by two additional articles (Cita et al., 2006; Cita, 2008, appendices 3, 1), which presented the results of investigations of the deep-marine sections exposed in Sicily and southern Italy. Although these sequences include all the attributes suitable for their definition as a global standard, and in spite of the fact that the term Calabrian has been used for over a century as a quasi-formal time division within the Italian late Cenozoic sequence, no previous submission was made to the ICS by the Quaternary Subcommission for the formal ratification of the Calabrian Stage basal boundary (cf. Afterword, below)

It should be emphasised here that: 1) the concept of 'northern guests' (i.e. fossil taxa of northern affinities, interpreted as reflecting temperature decline in the region) entering the Mediterranean is now abandoned, and carries no weight in determining the stage basal boundary in any of the numerous papers published in the last two decades or so.

2) the precise position of the GSSP has never been questioned or modified. What has been changed is the significance of the boundary stratotype as the Neogene/Quaternary for Selli et al. (1977); the Pliocene/Pleistocene for Aguirre & Pasini, (1985) and the base of the Calabrian Stage for Cita et al. (2008).

3) the identification of the sapropelic layer 'e', which is the primary marker is not easily identified and therefore immediate found in the field. The colour change from the dominant lithology (dark grey to dark blue grey silty marls) to the minor lithology (laminated grey-pink sapropelic layers) is better distinguished in humid condition, early in the morning or near sunset. Figure 7 shows a close-up of an exposure of the Vrica section (segment a of Figure 2) where weathering and creeping is widespread. For this reason,when sampling it is important that the *in situ*, unweathered sediment must be exposed.

Figs 6 and 7

New Evidence

This was the state-of-the art at the time of the 33rd International Geological Congress (IGC) in Oslo, where a debate on the basal boundary and definition of the Quaternary took place under the auspices of the International Commission on Stratigraphy and by the Quaternary Subcommission. A symposium entitled 'Plio-Pleistocene correlation and global change' was organised by M. B. Cita, in her capacity of chair of the International Subcommission on Stratigraphic Classification (ISSC) of the International Union of Geological Sciences (IUGS), and by B.Pillans, in his capacity of chair of the INQUA Stratigraphy and Chronology Commission. The symposium was informative and well attended, with all the protagonists of the debate presenting their points of view (cf. Editorial, *Quaternary International*, 219, 1-5, 2010). The symposium was followed by an open discussion convened by S.Finney (chair of the ICS) and by J.Clague (past-President of INQUA). The subject of the open meeting, held on 8 August, 2008, was 'Redefinition of the Quaternary and Pleistocene'.

The special issue of *Quaternary International*, published in June, 2010 (vol. 219), with the same title as the Oslo Symposium, includes a number of papers presented at the 33rd IGC, together with a provocative paper entitled "Global stages, regional stages or no stages for the Plio-Quaternary?" where the authors strongly support the application of the internationally accepted rules of classical, formal stratigraphy, where the stage is the basic chronostratigraphical unit, defined on the basis of the typological criteria (Cita & Pillans, 2010). Two papers from the special issue (Suc et al., 2010 and Ciaranfi et al., 2010) presented new data which are pertinent to the re-definition of the Calabrian Stage, and are summarised and discussed below.

Suc et al. (2010) presented a synthesis and new evidence on the Pleistocene succession exposed in the badlands south of Crotone, which is considered the best-studied early Pleistocene succession in the world. The three sections investigated, i.e. Santa Lucia, Vrica and Semaforo, extend much lower in space and time than the succession described by Selli et al. (1977) containing the Neogene/Quaternary boundary (Figs. 8 and 9). In terms of time, the exposures extend from 2.47 to 1.21 Ma, and include 30 complete glacial-interglacial climatic cycles, corresponding to Marine Isotope Stages (MIS) 97 to 37.

The investigations were begun over twenty years ago, with the dissertation of Combourieu-Nebout (1987) who studied the palynological record. The proximity of the Crotone area to the summit of the Sila granitic massif (*ca*. 30 km) and the strong vertical relief (over 1300 m) offer an unique possibility for comparison of the succession of palaeontological events recorded by the evolution of the deep-sea micro-and nannofossils and the climatically controlled response of the vegetation to changes in temperature and aridity. The study by Suc et al. (2010) includes all the most advanced aspects of integrated multidisciplinary stratigraphy (biochronology, magnetostratigraphy, astrostratigraphy and tephrostratigraphy). From a geological standpoint, the highest part of the Vrica section is truncated by a marine erosional terrace of mid-Pleistocene age, which is clearly seen in maps (Figs.1, 2 and 8), such that only the basal part of the Calabrian is represented at this locality, very close to the Apennine Mountains' deformation front. In contrast, the greatest part of the composite section is included in the immediately pre-Calabrian Gelasian Stage of Rio et al. (1998), a unit that was not defined at the time of the first palynological investigations.

Figs. 7 and 8

Most recently, Ciaranfi et al. (2010) have presented new isotopic and geochemical data from the Montalbano Jonico section, that has been investigated in great detail by a large group of scientists. Located some 170 km north of the Crotone area, in the core of the Apennine foredeep, it offers the best possible marine continuity from the Early to the Middle Pleistocene, extending in age from 1.24 to 0.64 Ma (Figs. 10-11). Here the lower segment (Interval a) begins at the level of MIS 36 and extends to MIS 23, on the basis of correlation with the isotopic record of planktonic and benthic foraminifers. Interval b represents a higher sedimentation rate, and may be correlated with MIS 22 through to 16 (Fig. 11). This is supported by the sapropel stratigraphy and tuning with the extra-terrestrial signal determined for the central and eastern Mediterranean (ODP Sites 964 and 967). Ciaranfi et al. (2010) pointed out that two biostratigraphical markers are not considered by other authors (cf. Cita et al., 2008): *Reticulofenestra asanoi* is a nannofossil of intra-oceanic distribution, that has a characteristic stratigraphic range, limited to the latest part of the Calabrian. In addition *Gephyrocapsa omega* corresponds to *Gephyrocapsa* sp.3 of Rio et al. (1990). Several tephra strata have been identified and investigated geochemically from within this sequence. One of them (V2 of Ciaranfi et al., 2010) has been Ar/Ar dated to 719.5 $\pm$12.6 ka, supporting the assumption that the Brunhes/Matuyama magnetic reversal should be recorded in the Montalbano Jonico section. However, following several unsuccessful attempts, Sagnotti et al. (2009) discovered that the Montalbano sequence has undergone remagnetisation during the Brunhes Chron, as indicated by the occurrence of greigite in the sediments. The Montalbano Jonico section is one of three potential stratotype localities for the Early-Middle Pleistocene boundary, the others being the the Valli di Manche section, also in southern Italy, and the Chiba section in Japan (Head et al., 2008).

Figs. 10 and 11
Afterword

In the letter dated 1 September 2008, addressed to S. Finney (Chair, International Commission on Stratigraphy), formally requesting that the base of the Quaternary System/Period be lowered to the Gelasian Stage GSSP (at 2.588 Ma) and that the base of the Pleistocene Series/Epoch be lowered to the same

position, point 4 of the specific details of the request was that (cf. Gibbard & Head, 2009a, p. 127):

"The Vrica GSSP (the present Quaternary and Pleistocene basal boundary) be retained as the base of the Calabrian Stage, the second stage of the revised Pleistocene Series".

This, together with the vote for the base Quaternary and Pleistocene was accepted by a majority of the voting members of the Subcommission of Quaternary Stratigraphy on 'Yes' 17, 'No' 1, no reply '2', i.e the majority in favour 85%.

However, the ICS proposal to the IUGS omitted this request, due to an oversight, and the IUGS ratification made no mention of the Calabrian Stage. This stage, while meeting all necessary requirements (as noted above) and having been accepted by the ICS Subcommission on Quaternary Stratigraphy, therefore awaits future confirmation and ratification by the ICS and IUGS. It is this that is now proposed.

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FIGURE CAPTIONS

Figure 1 Location map of prominent land sections and ODP sites cited in the text.

Figure 2. Location of the Vrica boundary stratotype section. A, B, and C are the component segments of the section. The dot on segment B represents the position of the Calabrian GSSP (modified from the ICS website www.stratigraphy.org).

Figure 3. Lithological sequence of B segment of Vrica stratotype section showing the prominent sapropel layers: b, c, d, e, f, g, and h. The GSSP of the Calabrian Stage is fixed (dashed line) at the top of level 'e' (modified from the ICS website: www.stratigraphy.org).

Figure 4. Comparative and correlative stratigraphic framework of lithology, biostratigraphy, magnetostratigraphy of the Vrica boundary stratotype section and of other Mediterranean land sections and ODP sites in which the Calabrian Stage is well represented. Based upon: Vrica-Crotone, Singa, Lourens et al. (1996a); Capo Rossello, Di Stefano et al. (1993); Ficarazzi, Di Stefano & Rio (1981), Sprovieri (1993); Valle di Manche, Massari et al. (2002); Capraro et al. (2005); Montalbano Jonico, Ciaranfi et al. (2001); Monte San Nicola, Channell et al. (1992), Sprovieri (1993); ODP Site 975, Murat (1999); ODP Site 964, Emeis et al. (2000); ODP Site 967, Kroon et al. (1998) (after Fig. 3 of Cita et al., 2008).

Figure 5. Lithological log and distribution of the significant microfossil taxa and magnetostrigraphy of the Vrica section (300 m thick), extending from the Gelasian to the Calabrian stages (modified from Pasini & Colalongo, 1997)..

Figure 6. Integrated stratigraphical framework for four selected land sections (Italy) which represent all the oxygen-isotope records for the Calabrian Stage compared with standard Atlantic and Pacific benthic foraminiferal d18O stacks (after Fig. 6 of Cita et al., 2008).

Figure 7. Creeping is a common feature in the bad-lands of the Vrica section, as shown by this close-up photograph. For further details see text.

Figure 8. Simplified geological sketch of the late Pliocene – early Pleistocene successions southwards from Crotone, showing the surface trace of the ash layers (according to Selli et al., 1977); the successive holes performed at the base of the Vrica section (hand-drilled holes h1 and h2, Hilgen, 1990; cored hole h3, Suc et al., 2010); the trace of the cross-section shown in Figure 8. (1) Milazzian terrace; (2) Cross-section; (3) Ash layer; (4) Studied section; (5) Borehole. S, Semaforo section; VA , Vrica A section; VB , Vrica B section; VC , Vrica C section; and SL, Santa Lucia section (after Suc et al., 2010, Fig. 1).

Figure 9. Stratigraphy of the Semaforo to Vrica areas. (A) Cross-section from the lower part of the Semaforo section to the top of the succession in the area of the Vrica: A section, showing the intermediate sections (Donato, Watertank) by Hilgen (1990). Thickness and dip are exaggerated. (1) Clays; (2) Ash; (3) Sapropel; (4) Milazzian calcarenite. Sapropels are numbered from 1 to 10 (Semaforo area) and from a to o (Vrica area), main ashes from a1 to a4 (= m: Pasini & Colalongo, 1994). (B) Some cores with respective depth of hole h3 with location of ash a2 and sapropels 7 and 8 (after Suc et al., 2010, Fig. 2).

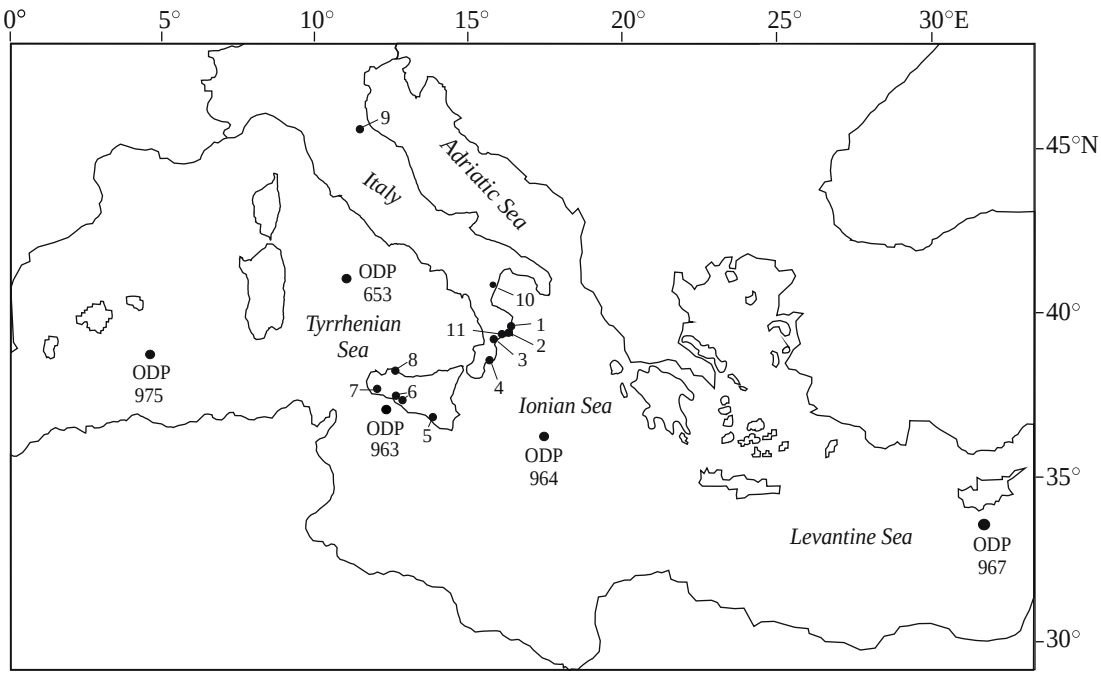
Figure 10. Biostratigraphic correlation between Montalbano Jonico composite section and ODP Sites 964 and 967. Calcareous nannofossil events are from Maiorano et al. (2004) and this study at

Montalbano Jonico section, and from Maiorano & Marino (2004) at Sites 964 and 967. *Globorotalia crassaformis* influx at Montalbano Jonico section is from Joannin (2007). Sapropel stratigraphy is according to Emeis et al. (2000) at Site 964, and to Kroon et al. (1998) at Site 967. Corrected composite depth (ccd) at Site 964 is from Lourens (2004) (after Ciaranfi et al., 2010, Fig. 4).

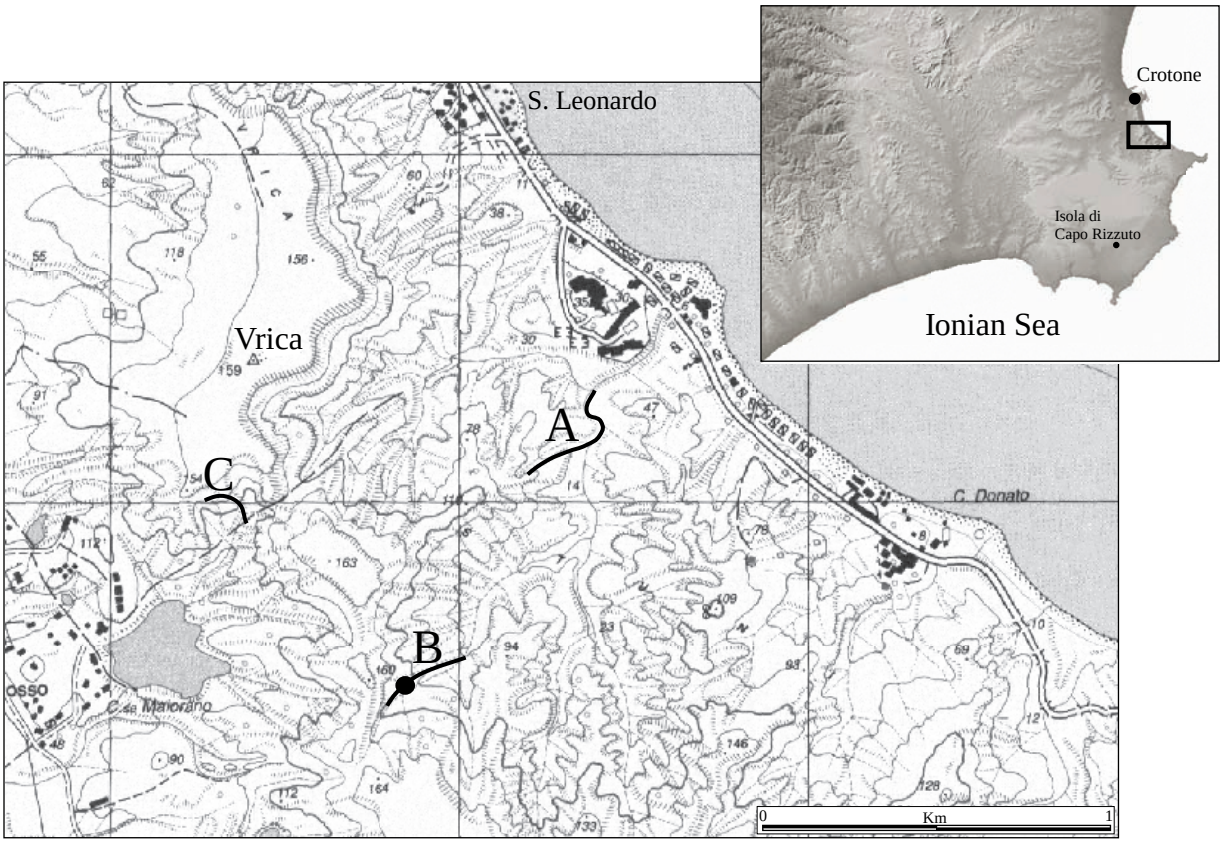
Figure 11. Stratigraphic correlation of Montalbano Jonico composite section (benthic and planktonic oxygen stable isotope stratigraphy) with Atlantic (Bickert et al., 1997) and Pacific $d^{18}O$ benthic records (Shackleton et al., 1995; Mix et al., 1995a, b) and Mediterranean $d^{18}O$ planktonic foraminifer *Globigerinoides ruber* (core KC01B) and *Globigerina bulloides* (ODP Site 975) stacked records (Lourens, 2004). Astronomical ages of Ocean calcareous nannofossil events are from Lourens et al. (2004), Raffi et al. (2006), and Ciaranfi et al. (2010). Mediterranean calcareous nannofossil events at ODP Sites 964 and 967 are from Maiorano & Marino (2004), recalibrated in Ciaranfi et al. (2010, Table 3), and Lourens et al. (1998), Lourens (2004) and Raffi et al. (2006). Summer insolation 65°N (La041:1) is from Laskar et al. (2004). Sapropel stratigraphy from Lourens et al. (2004) and Lourens (2004). V1-V9: tephra layers in Montalbano Jonico section. Ages of polarity boundaries are from Lourens (2004). Thick grey dotted line is the position of tephra V5 plotted versus Ar/Ar age (after Ciaranfi et al., 2010, Fig. 9).

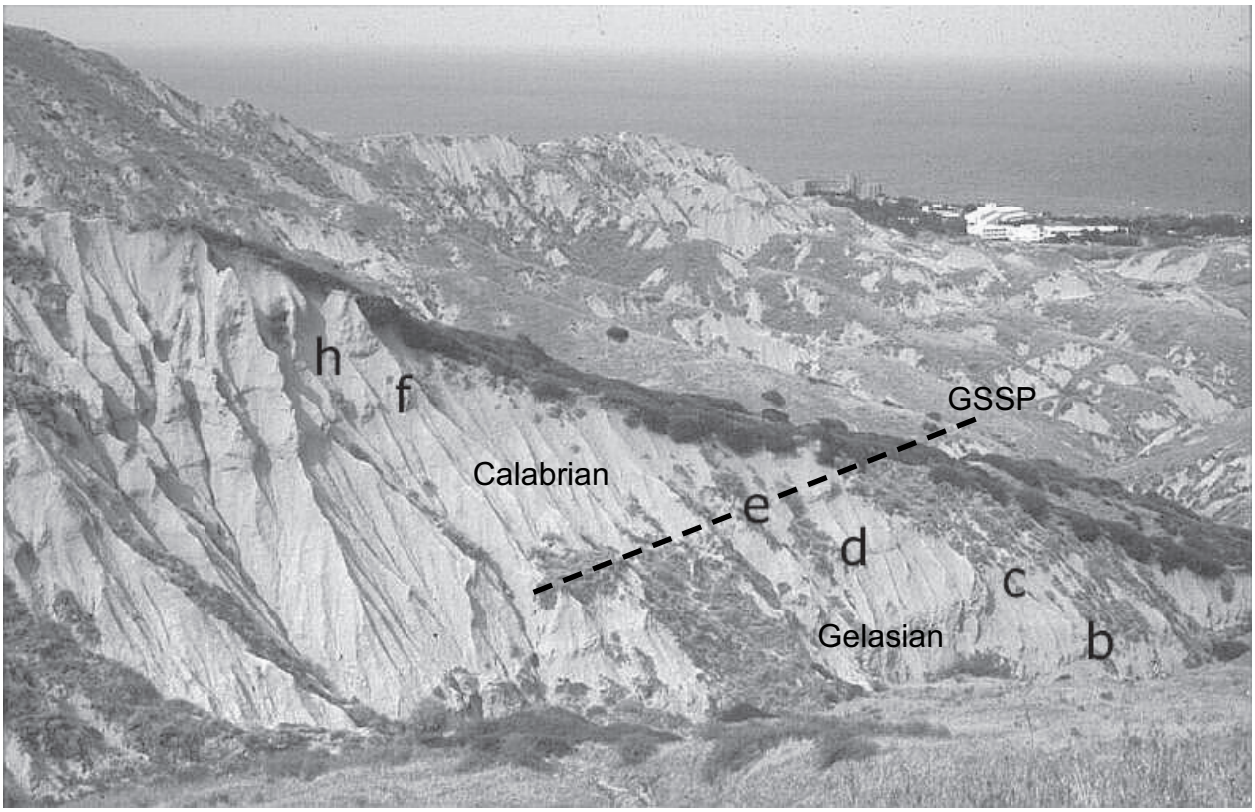
Appendices

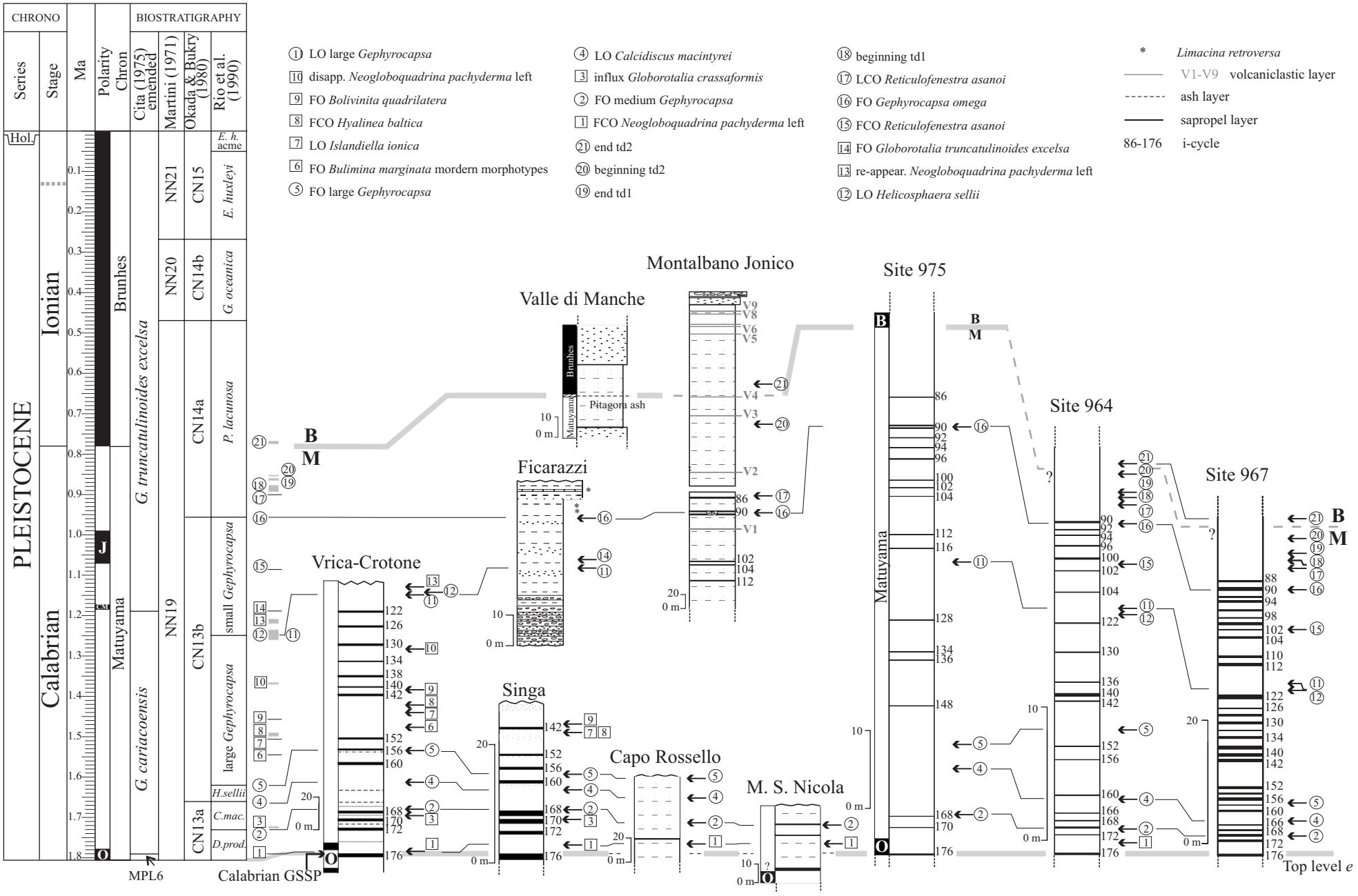
1. Cita, M.B., 2008. Summary of Italian Marine Stages. Episodes, v. 31/2, p. 251-254.
2. Cita, M. B., Capraro, L., Ciaranfi, N., Di Stefano, E., Lirer F., Maiorano P., Marino, M., Raffi I., Rio, D., Sprovieri, R., Stefanelli S., and Vai, G. B., 2008. The Calabrian Stage redefined. Episodes, v. 31/4, p. 408-419.
3. Cita, M. B., Capraro, L., Ciaranfi, N., Di Stefano, E., Marino, M., Rio, D., Sprovieri, R., and Vai, G. B., 2006. Calabrian and Ionian: A proposal for the definition of Mediterranean stages for the Lower and Middle Pleistocene. Episodes, v. 29/2, p. 107-114.

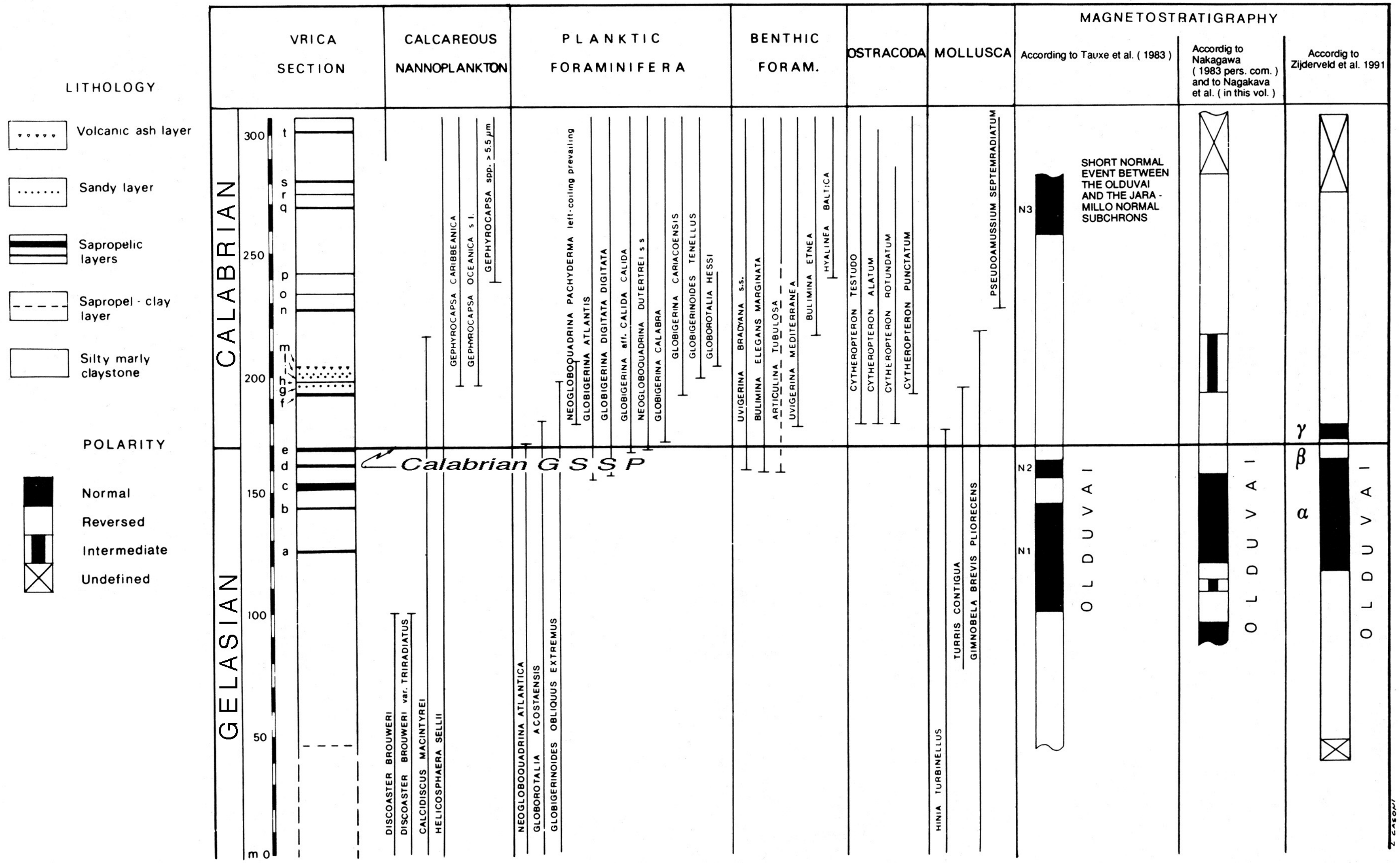


1 Vrica
2 Le Castella
3 Santa Maria di Catanzaro
4 Singa
5 Monte San Nicola
6 Capo Rossello and Rossello Composite
7 Valle del Belice-Selinunte
8 Ficarazzi-Palermo
9 Valle del Santerno
10 Montalbano Jonico-Santa Maria d'Anglona
11 Valle di Manche


S. Leonardo
Vrica
A
B
C
C. Donato
C. da Maiorano
OSSO
0
Km
1
Crotone
Isola di
Capo Rizzuto
Ionian Sea


h
f
GSSP
Calabrian
e
d
c
Gelasian
b


CHRONO
Series
Stage
Ma
Polarity Chron
BIOSTRATIGRAPHY
Cita (1975) emended
Martini (1971)
Okada & Bukry (1980)
Rio et al. (1990)
PLEISTOCENE
Hol.
Calabrian
Ionian
Brunhes
Matuyama
J
O
MPL6
Calabrian GSSP
G. cariacoensis
G. truncatulinoides excelsa
NN19
NN21
NN20
CN15
CN14b
CN14a
CN13b
CN13a
E. h. acme
E. huxleyi
G. oceanica
P. lacunosa
small Gephyrocapsa
large Gephyrocapsa
H.sellii
C.mac.
D.prod.
① LO large Gephyrocapsa
⑩ disapp. Neogloboquadrina pachyderma left
⑨ FO Bolivinita quadrilatera
⑧ FCO Hyalinea baltica
⑦ LO Islandiella ionica
⑥ FO Bulimina marginata mordern morphotypes
⑤ FO large Gephyrocapsa
④ LO Calcidiscus macintyrei
③ influx Globorotalia crassaformis
② FO medium Gephyrocapsa
① FCO Neogloboquadrina pachyderma left
㉑ end td2
⑳ beginning td2
⑲ end td1
⑱ beginning td1
⑰ LCO Reticulofenestra asanoi
⑯ FO Gephyrocapsa omega
⑮ FCO Reticulofenestra asanoi
⑭ FO Globorotalia truncatulinoides excelsa
⑬ re-appear. Neogloboquadrina pachyderma left
⑫ LO Helicosphaera sellii
* Limacina retroversa
V1-V9 volcaniclastic layer
ash layer
sapropel layer
86-176 i-cycle
Montalbano Jonico
Valle di Manche
Brunhes
Matuyama
Pitagora ash
Ficarazzi
Vrica-Crotone
Singa
Capo Rossello
M. S. Nicola
Site 975
Site 964
Site 967
B
M
Top level e


LITHOLOGY
Volcanic ash layer
Sandy layer
Sapropelic layers
Sapropel - clay layer
Silty marly claystone
POLARITY
Normal
Reversed
Intermediate
Undefined
VRICA SECTION
CALCAREOUS NANNOPLANKTON
PLANKTIC FORAMINIFERA
BENTHIC FORAM.
OSTRACODA
MOLLUSCA
MAGNETOSTRATIGRAPHY
According to Tauxe et al. (1983)
Accordig to Nakagawa (1983 pers. com.) and to Nagakava et al. (in this vol.)
Accordig to Zijderveld et al. 1991
CALABRIAN
GELASIAN
Calabrian GSSP
SHORT NORMAL EVENT BETWEEN THE OLDUVAI AND THE JARA-MILLO NORMAL SUBCHRONS
OLDUVAI
N1
N2
N3
α
β
γ
DISCOASTER BROUWERI
DISCOASTER BROUWERI var. TRIRADIATUS
CALCIDISCUS MACINTYREI
HELICOSPHAERA SELLII
GEPHYROCAPSA CARIBBEANICA
GEPHYROCAPSA OCEANICA s.l.
GEPHYROCAPSA spp. > 5.5 μm
NEOGLOBOQUADRINA ATLANTICA
GLOBOROTALIA ACOSTAENSIS
GLOBIGERINOIDES OBLIQUUS EXTREMUS
NEOGLOBOQUADRINA PACHYDERMA left-coiling prevailing
GLOBIGERINA ATLANTIS
GLOBIGERINA DIGITATA DIGITATA
GLOBIGERINA aff. CALIDA CALIDA
NEOGLOBOQUADRINA DUTERTREI s.s.
GLOBIGERINA CALABRA
GLOBIGERINA CARIACOENSIS
GLOBIGERINOIDES TENELLUS
GLOBOROTALIA HESSI
UVIGERINA BRADYANA s.s.
BULIMINA ELEGANS MARGINATA
ARTICULINA TUBULOSA
UVIGERINA MEDITERRANEA
BULIMINA ETNEA
HYALINEA BALTICA
CYTHEROPTERON TESTUDO
CYTHEROPTERON ALATUM
CYTHEROPTERON ROTUNDATUM
CYTHEROPTERON PUNCTATUM
HINIA TURBINELLUS
TURRIS CONTIGUA
GIMNOBELA BREVIS PLIORECENS
PSEUDOAMUSSIUM SEPTEMRADIATUM

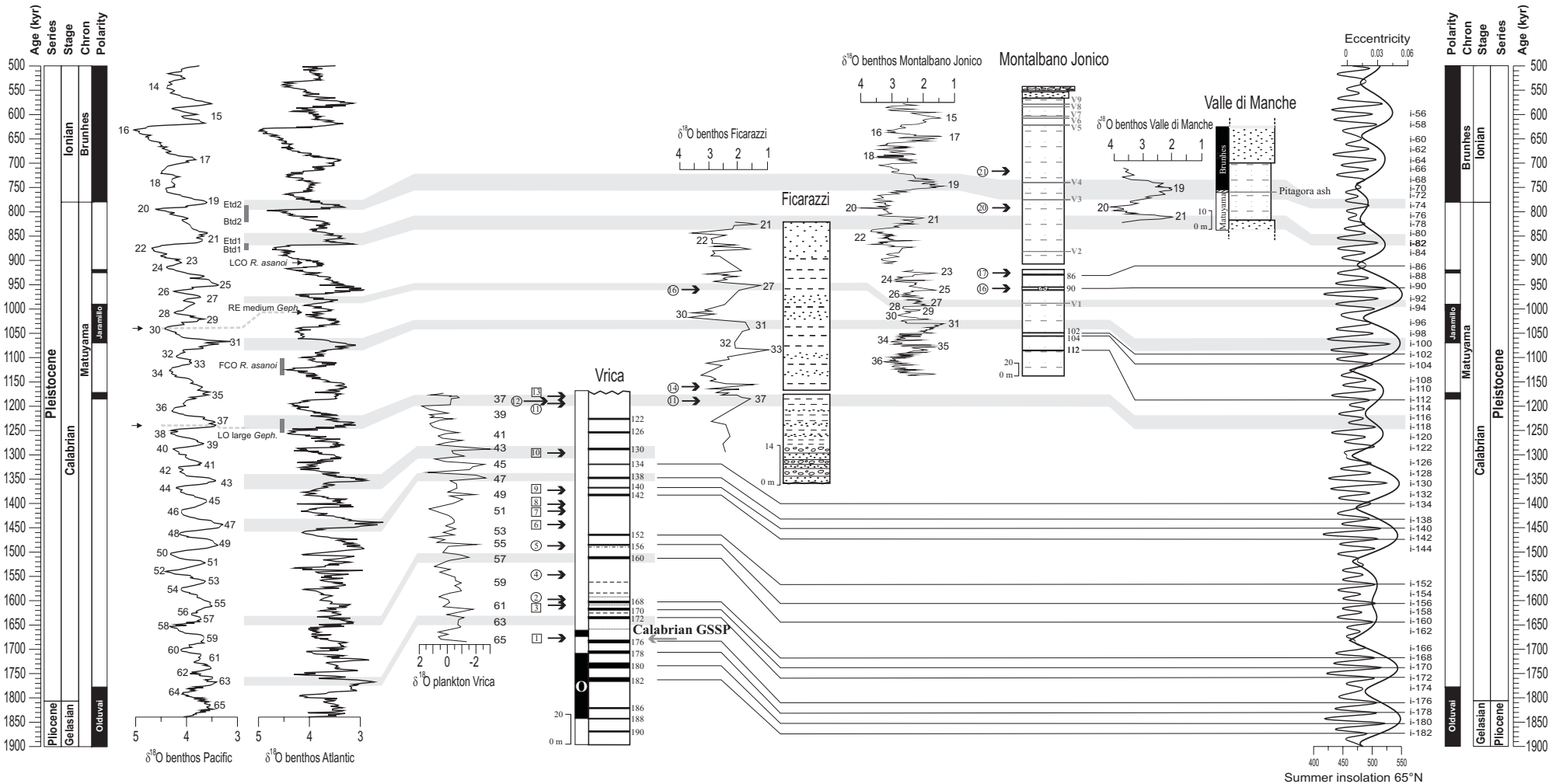
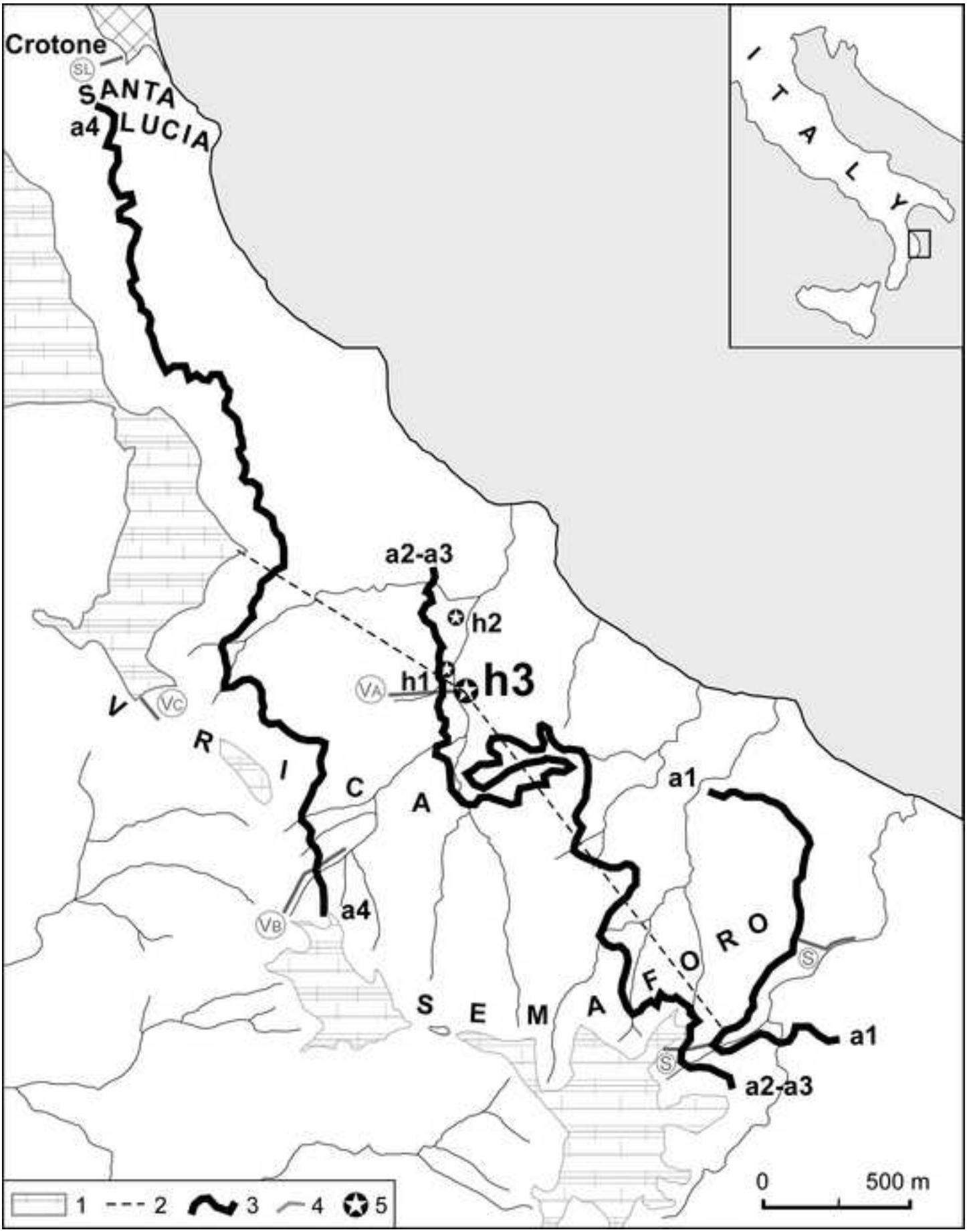
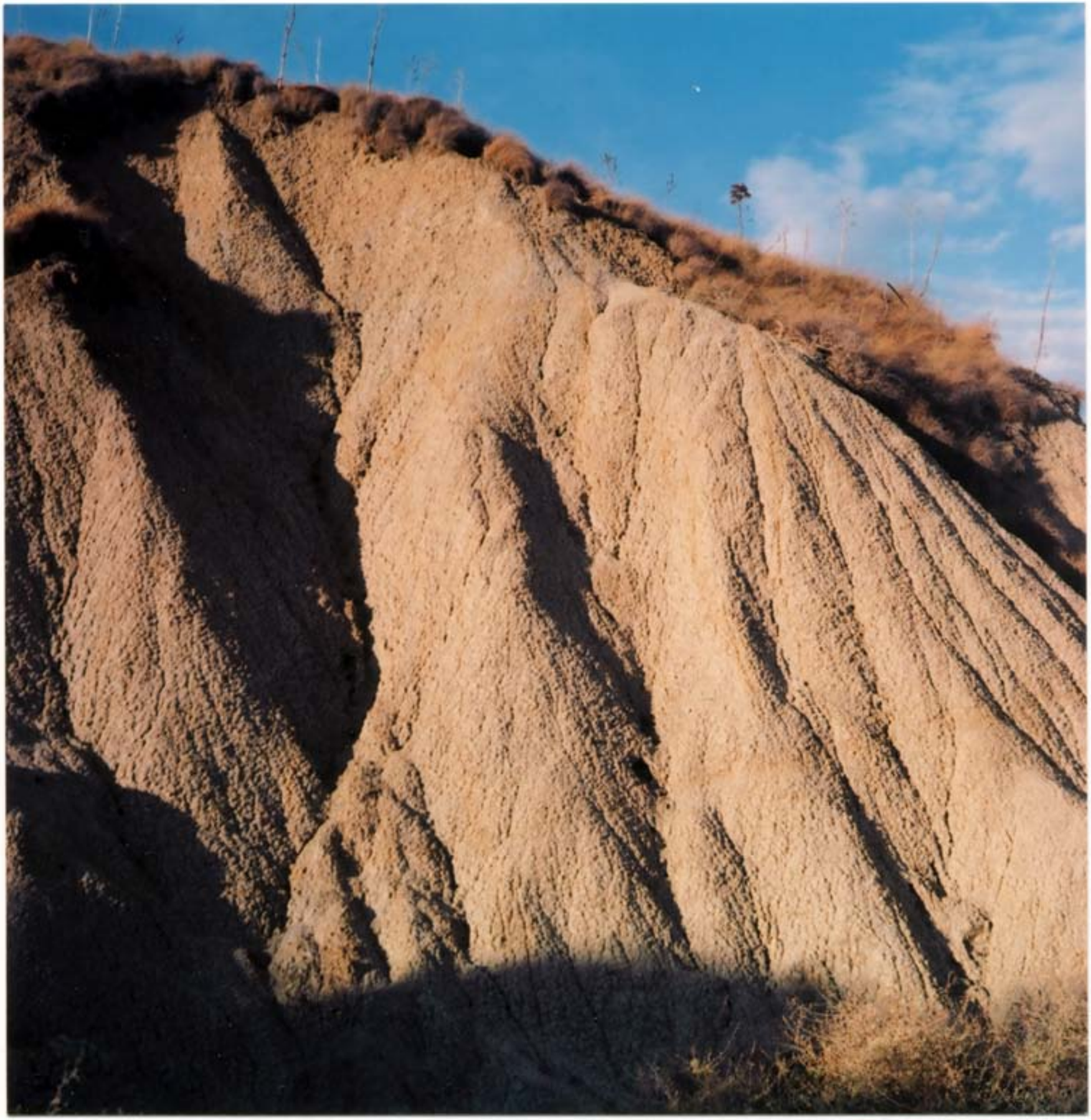

Age (kyr)
Series
Stage
Chron
Polarity
Pleistocene
Pliocene
Gelasian
Calabrian
Ionian
Brunhes
Matuyama
Jaramillo
Olduvai
Etd2
Btd2
Etd1
Btd1
LCO R. asanoi
RE medium Geph.
FCO R. asanoi
LO large Geph.
δ18O benthos Pacific
δ18O benthos Atlantic
δ18O plankton Vrica
Vrica
Calabrian GSSP
δ18O benthos Ficarazzi
Ficarazzi
δ18O benthos Montalbano Jonico
Montalbano Jonico
δ18O benthos Valle di Manche
Valle di Manche
Pitagora ash
Eccentricity
Summer insolation 65°N

Figure
Click here to download high resolution image





Figure

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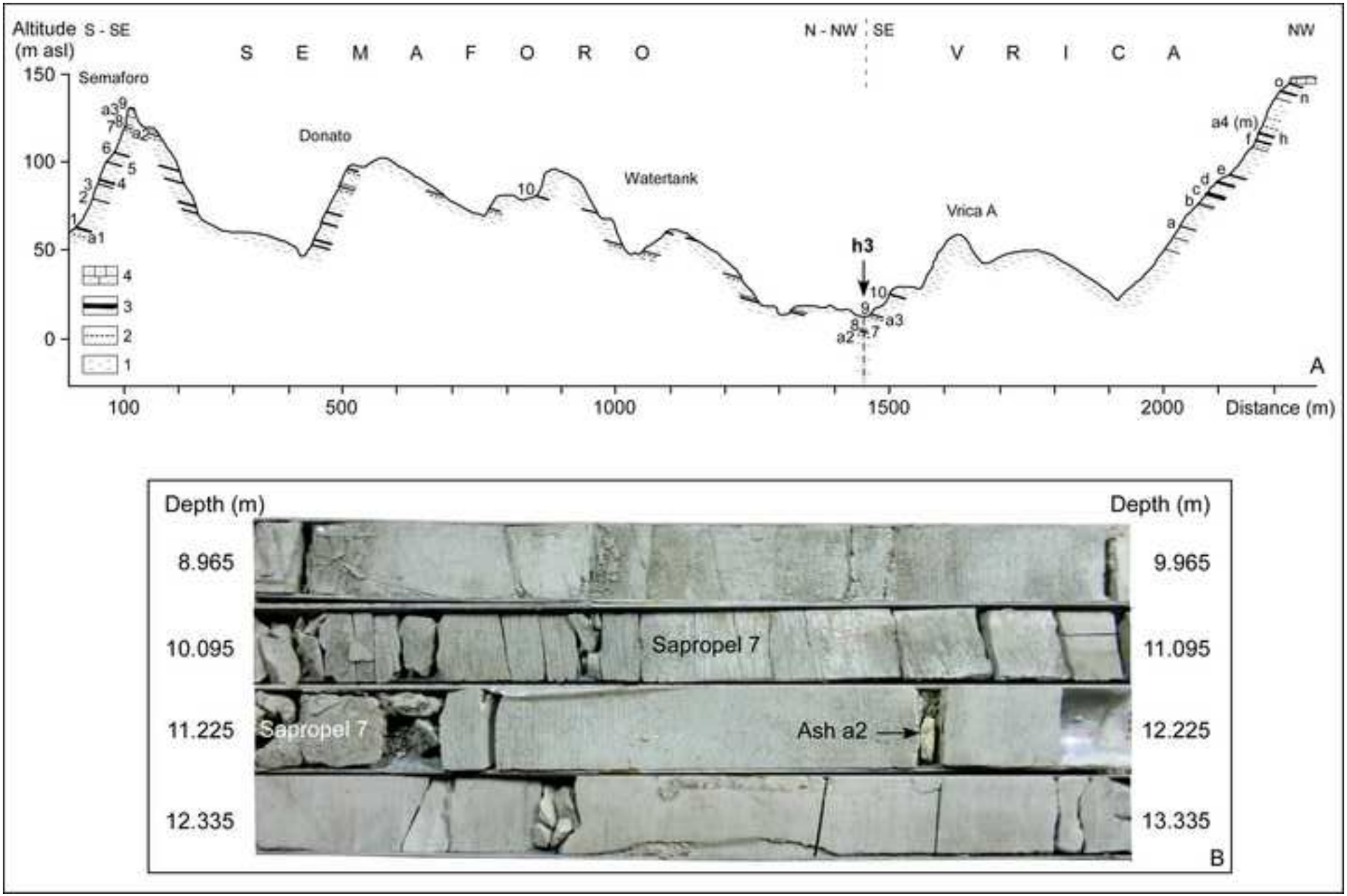
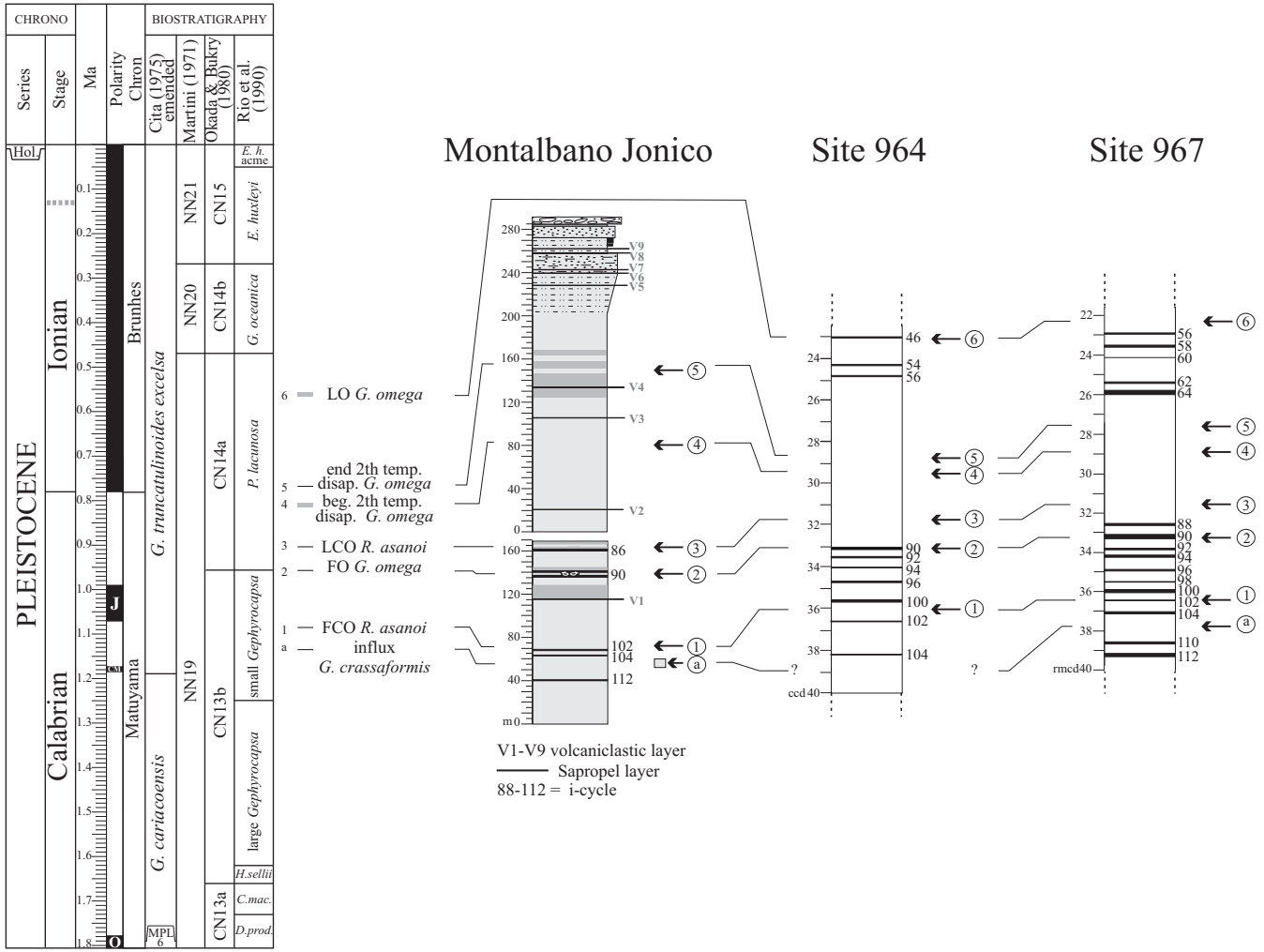
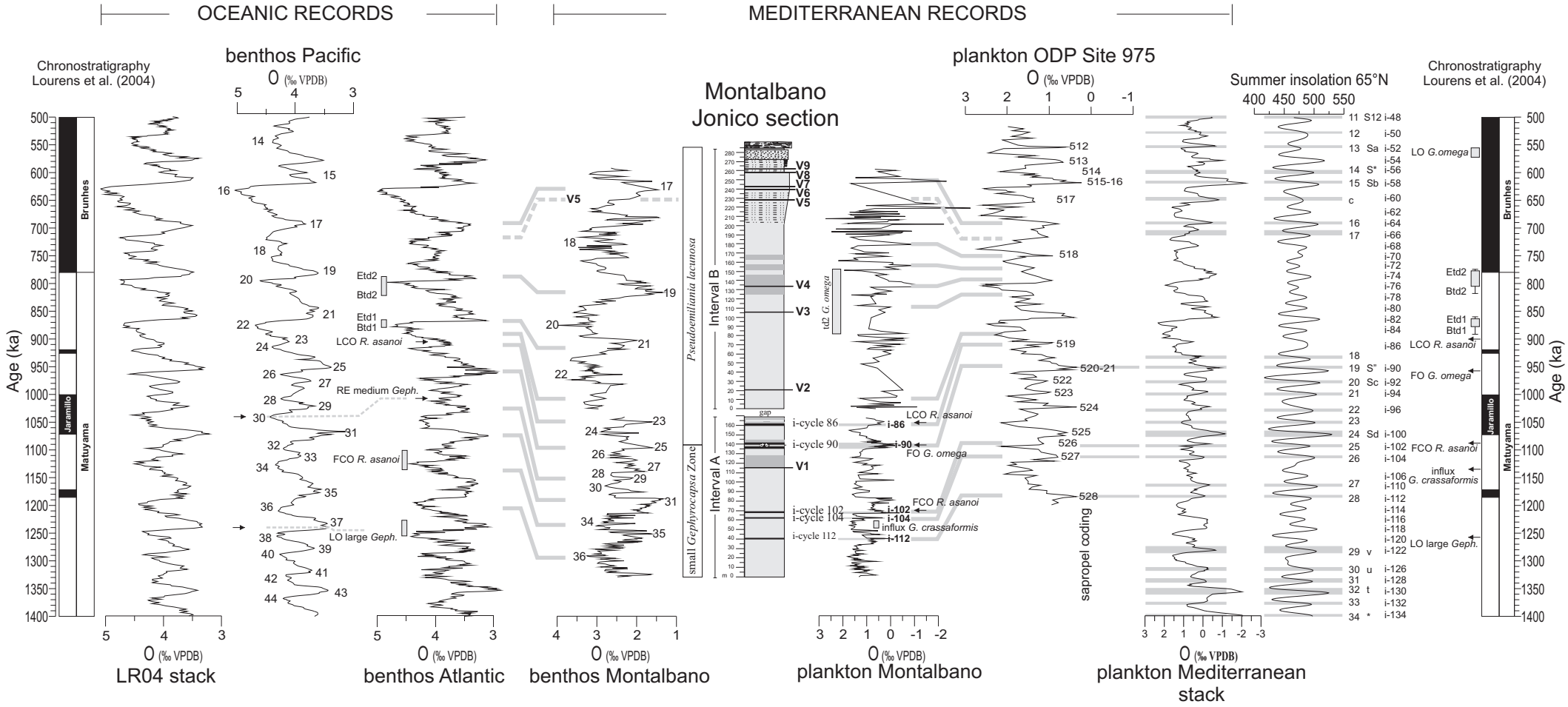



CHRONO
Series
Stage
Ma
Polarity Chron
BIOSTRATIGRAPHY
Cita (1975) emended
Martini (1971)
Okada & Bukry (1980)
Rio et al. (1990)
PLEISTOCENE
Calabrian
Ionian
Hol
Brunhes
Matuyama
J
O
MPL 6
G. cariacoensis
G. truncatulinoides excelsa
NN19
NN20
NN21
CN13a
CN13b
CN14a
CN14b
CN15
small Gephyrocapsa
large Gephyrocapsa
H.sellii
C.mac.
D.prod.
P. lacunosa
G. oceanica
E. huxleyi
E. h. acme
6 LO G. omega
5 end 2th temp. disap. G. omega
4 beg. 2th temp. disap. G. omega
3 LCO R. asanoi
2 FO G. omega
1 FCO R. asanoi
a influx G. crassaformis
Montalbano Jonico
Site 964
Site 967
V1-V9 volcaniclastic layer
Sapropel layer
88-112 = i-cycle


OCEANIC RECORDS
MEDITERRANEAN RECORDS
Chronostratigraphy
Lourens et al. (2004)
Age (ka)
Brunhes
Jaramillo
Matuyama
LR04 stack
benthos Pacific
benthos Atlantic
benthos Montalbano
Montalbano
Jonico section
Pseudoemiliania lacunosa
small Gephyrocapsa Zone
Interval B
Interval A
gap
V9
V8
V7
V6
V5
V4
V3
V2
V1
td2 G. omega
i-cycle 86
i-cycle 90
i-cycle 102
i-cycle 104
i-cycle 112
LCO R. asanoi
FO G. omega
FCO R. asanoi
influx G. crassaformis
plankton Montalbano
plankton ODP Site 975
sapropel coding
plankton Mediterranean
stack
Summer insolation 65°N
LO G.omega
Etd2
Btd2
Etd1
Btd1
RE medium Geph.
LO large Geph.
‰ VPDB