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Lower–Middle Pleistocene ostracod assemblages from the Montalbano Jonico section (Basilicata, Southern Italy)



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ARTICLE INFO

Article history:

Available online 27 December 2014

Keywords:

Ostracoda
 Montalbano Jonico section
 Lower–Middle Pleistocene
 MIS 21–18
 Paleobathymetry
 Paleo-oxygen levels

ABSTRACT

The Montalbano Jonico section is a Pleistocene sequence, about 450 m thick, comprising silty clays and silty sands deposited during the upper part of the Calabrian Stage and lower part of the “Ionian” Stage. It is a candidate global boundary stratotype section and point for the Middle Pleistocene Subseries. Ostracod assemblage analyses were carried out on 40 samples from the uppermost levels of the Lower Pleistocene and the lowermost part of the Middle Pleistocene, with the aim of reconstructing the paleoenvironmental evolution around the Matuyama–Brunhes boundary. Taxonomic investigations, quantitative distribution data and statistical analysis (Q-mode cluster analysis) define four intervals, correlated with sea-level changes linked to Marine Isotope Stages (MIS) 21–18. The lower part of the section, ranging from 864.00 to 820.00 ka, was deposited in an outer shelf paleoenvironment during a period of high sea level associated with MIS 21. The transition to the second interval (815.42–785.62 ka) is marked by a shallowing trend, reflecting the MIS 20 decrease in sea level. The overlying part of the section (783.54–749.91 ka) yielded assemblages indicating a return to deeper-water conditions corresponding to the warm phase MIS 19. The uppermost interval was deposited during 746.60–740.54 ka, when cooling in MIS 18 produced a sea level drop. Here, some levels (164.20 m, 745.51 ka; 170.10 m, 743.05 ka; 176.10 m, 740.54 ka) show the presence of both “deep” and “shallow” autochthonous taxa, suggesting the occurrence of upwelling episodes during this cold phase. In some layers, deposited during warm stages, the ostracod assemblages indicate the presence of kenoxic bottom waters. The lowest paleo-oxygen levels are correlated with Marine Isotope Substages 21.3 and 19.1.

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1. Introduction

Investigations into the taxonomy and distribution of Southern Italy's Plio–Pleistocene ostracods have provided, since the 19th Century (e.g. Costa, 1853; Seguenza, 1880), a level of data suitable for reliable paleoecological and stratigraphic reconstructions. The most relevant studies concerning Quaternary assemblages of the Ionian side of Southern Italy are the contributions by Ruggieri (1953), Colalongo (1966), Ciampo (1972), Greco et al. (1974) and Colalongo and Pasini (1980). The last of these papers analyses the ostracods of the well-known Vrica section, of great significance for

the chronostratigraphy of the Pleistocene. The Pliocene–Pleistocene boundary was ratified by the International Union of Geological Sciences in 1984 at the top of sapropel “e” in the Vrica section (Aguirre and Pasini, 1985). Presently the section is recognized as Gelasian–Calabrian in age (brief review and extensive references in Maiorano et al., 2010), and now serves as the global boundary stratotype section and point (GSSP) of the Calabrian Stage, with an astronomical age of 1.80 Ma (Cita et al., 2012). The ostracod assemblages of the Monte San Nicola section, which contains the GSSP of the Gelasian Stage (Gibbard and Head, 2010; Gibbard et al., 2010), have been studied in detail by Abate et al. (1993, 1994), Aiello et al. (1993, 1996a, 1996b, 1996c, 2000), Barra et al. (1996) and Bonaduce et al. (1999, 2000), providing the basis, together with the aforementioned contributions, for Pleistocene ostracod systematics and paleoenvironmental interpretations. The only previous study of the ostracod

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assemblages of the Montalbano Jonico succession (Maiorano et al., 2008) concerns the IM-5 agosto section. This mid-Pleistocene part of the Montalbano Jonico composite section includes sapropel 19 (insolation cycle 90, ~954 ka). The results of that investigation showed the sensitivity of ostracod assemblages to paleoenvironmental factors, in particular bathymetry and dissolved oxygen levels in bottom waters.

The aim of the present paper is to describe the composition and variation of the ostracod assemblages recovered from sediments of the Montalbano section (Basilicata Region, Southern Italy; Fig. 1) at the Early–Middle Pleistocene boundary, and to investigate the relationship with paleoenvironmental changes during the considered time span. The Montalbano Jonico succession (MJS) has been

regarded as a potential candidate for the Middle Pleistocene GSSP (Ciaranfi and D'Alessandro, 2005; Ciaranfi et al., 2010; Maiorano et al., 2010).

2. Materials and methods

Ostracod assemblages from 40 silty-clay samples, pertaining to the sampling of the Montalbano Jonico section described and dated in Ciaranfi et al. (2010), Maiorano et al. (2010) and Marino et al. (2015), have been studied. The astronomical calibration of the section has been provided using the sapropel pattern, the Ar/Ar age of selected volcanoclastic layers, biostratigraphic constraints based on calcareous plankton, and oxygen isotope records (Ciaranfi et al.,

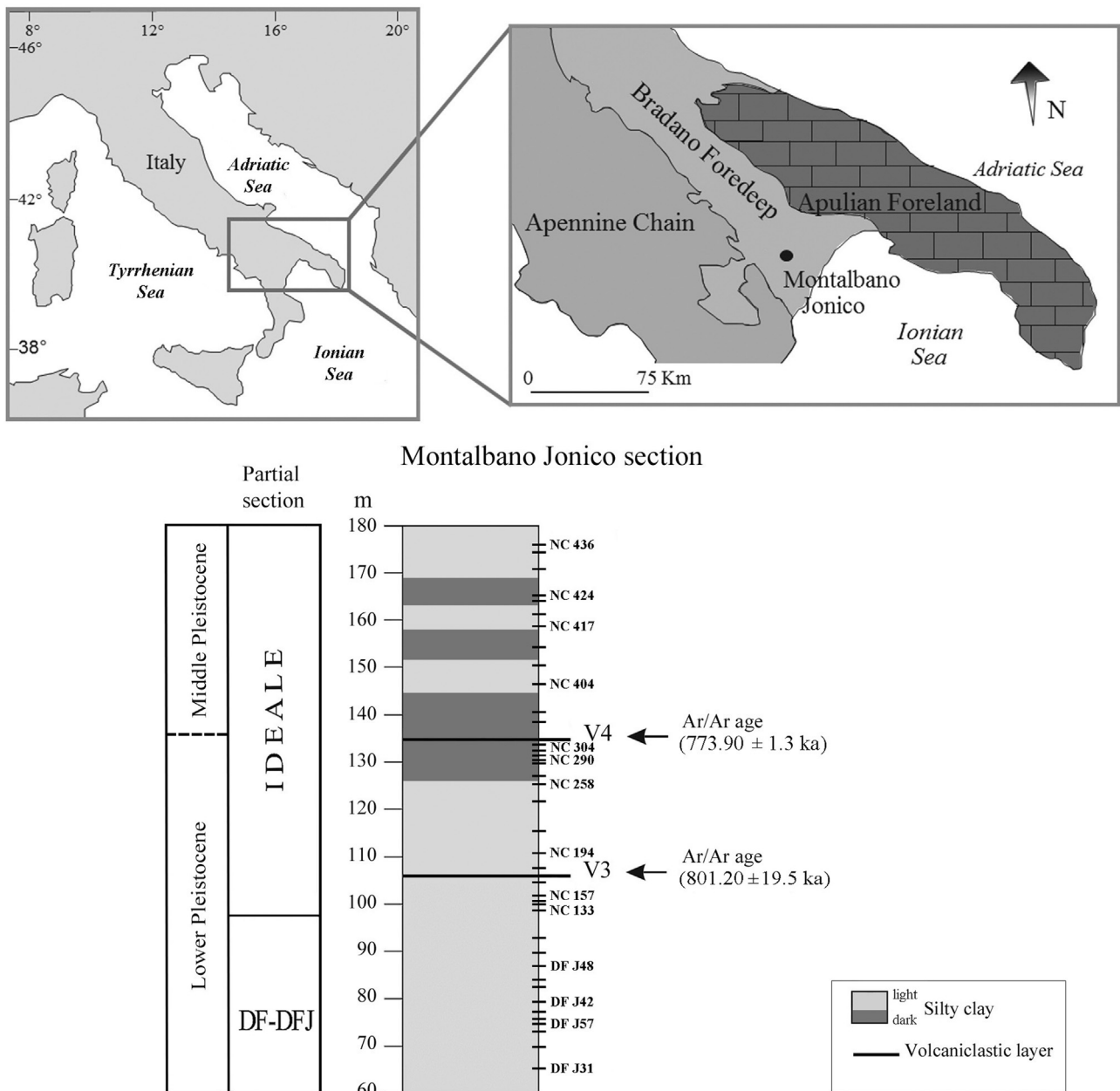


Fig. 1. Location, lithology and chronostratigraphy of the Montalbano Jonico section (following Marino et al. 2015); dashes on the right side of the lithological column indicate the location of samples examined.

2010; Maiorano et al., 2010; Marino et al., 2015). The samples (Table 1) range from 65.10 to 176.10 m (864.00–740.54 ka), and belong to the uppermost part of the Lower Pleistocene and to the lower part of the Middle Pleistocene (MIS 21–18), and consequently span the Matuyama/Brunhes paleomagnetic boundary (MBB) that is located within MIS 19. Marino et al. (2015) suggest that the MBB at the Montalbano Jonico section should be placed between the volcanoclastic layer V4 (773.9 ± 1.3 ka) and MIS 19.2 (771.84 ka). Detailed stratigraphic studies on the Montalbano Jonico succession carried out by a number of authors (Marino et al. 2015, and references therein) have provided an extensive reference data set. The ages of samples are reported to two decimal places following Marino et al. (2015).

The sediment samples (300 g dry), disaggregated in boiling water with sodium carbonate and washed through 230 and 120 mesh sieves (63 μ m and 125 μ m respectively), were examined under a reflected light microscope. All the ostracod remains, both adult and young instars, were picked from the coarsest fraction (>125 μ m). The total number of valves (TNV) and minimum number of individuals (MNI) were then counted. The TNV includes all the recovered juvenile and adult valves. The MNI has been calculated by adding the greater number between right and left adult valves to the number of adult carapaces; juveniles are not

considered. When only young instars occur, the number of specimens equals one.

Taxa have been identified according to the modern literature, with special regard to the Mediterranean area (including Müller, 1894; Ruggieri, 1950, 1952, 1975; 1976, 1978; Pucci, 1955; Mistretta, 1967; Schornikov, 1969; Ciampo, 1972, 1976; Sissingh, 1972; Bonaduce et al., 1976, 1998, 1999; Whatley and Masson, 1979; Colalongo and Pasini, 1980; Aruta and Ruggieri, 1983; Abate et al., 1993; Aiello et al., 1993, 1996a; 1996b, 1996c; 2000; Coles et al., 1994; Barra et al., 1996; Barra and Bonaduce, 1996; Aiello and Szczechura, 2004). Paleocological reconstructions are based on available data based on both living and extinct species.

Autochthonous and allochthonous specimens have been discriminated. The features of ostracod shells allow more reliable allochthonicity/autochthonicity analyses than, for example, with the generally more robust foraminifer tests. This appraisal is based upon the following features: the state of preservation of the valves (poor preservation generally indicates allochthonous specimens), the co-occurrence of different development stages (autochthonous species are frequently characterized by juveniles and adult valves), presence of dimensionally selected instars (*i.e.* different taxa represented by adult and/or juvenile valves with the same dimension suggest size sorting due to transport), and on the available distribution data (*e.g.* Whatley, 1988; Boomer et al., 2003; Coimbra et al., 2006; D'Amico et al., 2013).

Table 1

Height (m of the section) and age of studied samples in the Montalbano Jonico section (following Ciaranfi et al., 2010; Maiorano et al., 2010; Marino et al., 2015).

Sample	m	Age (ka)
NC 436	176.10	740.54
NC 434	174.00	741.42
NC 430	170.10	743.05
NC 424	165.10	745.14
NC 423	164.20	745.51
NC 420	161.60	746.60
NC 417	158.30	749.91
NC 413	154.60	753.61
NC 409	151.10	757.12
NC 404	146.40	761.83
NC 400	140.20	768.04
NC 320	138.50	769.74
NC 304	134.20	774.07
NC 299	132.50	775.94
NC 293	131.00	777.59
NC 290	130.30	778.36
NC 284	129.30	779.47
NC 271	127.00	782.00
NC 258	125.00	783.54
NC 250	122.30	785.62
NC 219	115.80	790.65
NC 194	111.65	794.00
NC 179	107.90	798.62
NC 168	105.10	802.02
NC 157	102.20	805.43
NC 145	100.04	807.55
NC 139	99.40	808.72
NC 133	98.50	809.78
DF J71	93.70	815.42
DF J50	89.80	820.00
DF J48	87.20	823.00
DF J46	84.60	826.00
DF J44	82.00	829.00
DF J42	79.40	834.50
DF J40	76.80	840.00
DF J39	75.50	843.71
DF J57	74.70	846.00
DF J38	73.20	848.63
DF J55	70.30	853.72
DF J31	65.10	864.00

2.1. Paleobathymetry

Paleobathymetric variations have been estimated by calculating the assemblage paleodepth on the basis of the following distribution data and considerations.

- Presence of the genus *Aurila*. In Neogene Mediterranean shallow marine deposits, the genus *Aurila* is generally highly differentiated, showing a considerable number of species (*e.g.* Uliczny, 1969; Aruta and Ruggieri, 1983; Dall'Antonia et al., 2005; Faranda et al., 2008). It declines during the Upper Pleistocene (Ruggieri, 1976). In the studied sediments only two species are well represented, *Aurila bradleyana* and *Aurila cimbaeformis*. This low diversity suggests that sedimentation occurred constantly below the infralittoral zone.

A. bradleyana: this Pliocene–Pleistocene species shows a close resemblance to *Aurila convexa* (indeed *A. bradleyana* could be considered a subspecies of *A. convexa*), presently living in Atlantic and Mediterranean shallow marine waters (Athersuch et al., 1989 and references therein). We hypothesize, also on the basis of fossil records, that *A. bradleyana* had the same depth distribution as *A. convexa*. The latter species has been recorded in the Mediterranean at a maximum depth of 1894 m below sea level (mbsl) (Puri et al., 1969), and considered autochthonous up to 122 mbsl (Bonaduce and Masoli, 1970; Bonaduce et al., 1976; Breman, 1976; Lachenal, 1989 and references therein).

A. cimbaeformis: this extinct species shows a distribution very similar to that of *A. bradleyana* and very probably had the same ecological features.

- Distribution of Leptocytheridae: The genera *Leptocythere* and *Callistocythere* are typical of infra-circalittoral environments. The most abundant species of *Leptocythere* are *Leptocythere multipunctata* and *Leptocythere bacescoi*. The former is a fossil species, the latter lives in the Mediterranean in the depth range 0–135 mbsl (*e.g.* Rome, 1964; Puri et al., 1964; Uffnerde, 1972; Bonaduce et al., 1976; Breman, 1976).

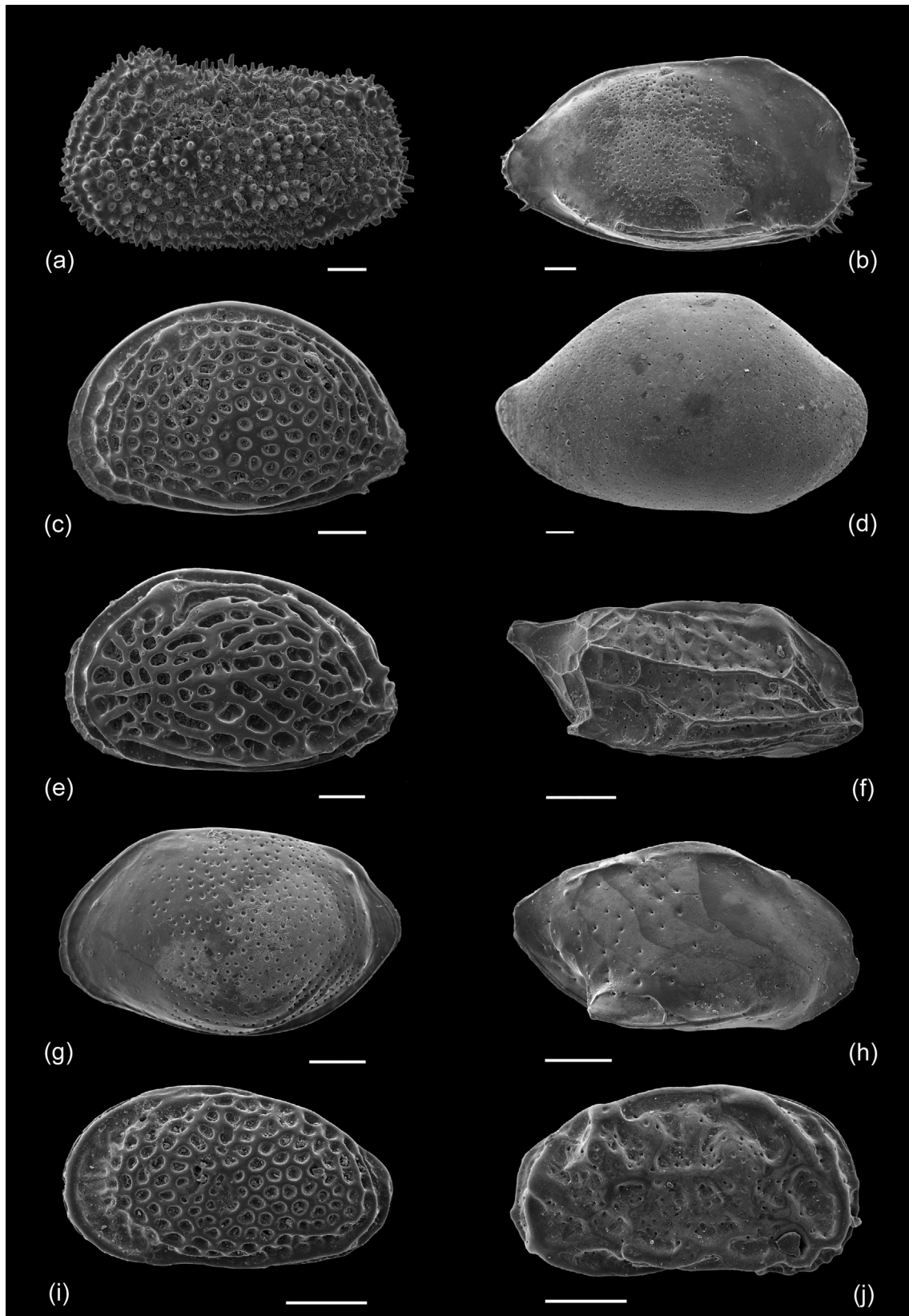


Fig. 2. (a) *Henryhowella sarsii* (G.W. Müller 1894), LV, sample DF J42, ABMC 2014-003. (b) *Bosquetina dentata* (G.W. Müller 1894), RV, sample NC 271, ABMC 2014-001. (c) *Aurila bradleyana* Ruggieri 1976, LV, sample NC 139, ABMC 2014-007. (d) *Bairdoppilata conformis* (Terquem 1878), RV, sample NC 417, ABMC 2014-002. (e) *Aurila (Cimbaurila) cimbaeformis* (Seguenza 1883), LV, sample NC 436, ABMC 2014-024. (f) *Semicytherura ruggierii* (Pucci 1955), RV, sample NC 420, ABMC 2014-012. (g) *Palmoconcha subrugosa* (Ruggieri 1967), LV, sample DF J44, ABMC 2014-018. (h) *Cytheropteron ruggierii* Pucci 1955, RV, sample DF J42, ABMC 2014-023. (i) *Leptocythere bacescoi* (Rome 1942), LV, sample NC 179, ABMC 2014-016. (j) *Callistocythere macilenta* Ciampo 1976, RV, sample NC 219, ABMC 2014-006. LV = lateral view of left valve; RV = lateral view of right valve. Scale bar corresponds to 100 μ m.

The extinct species *Callistocythere macilenta* is very similar to its possible descendent *Callistocythere littoralis*, and we consider that the depth data of the latter species can be attributed to the former. *C. littoralis* occurs up to 135 m (e.g. Puri et al., 1964; Barbeito-Gonzalez, 1971; Bonaduce et al., 1976, 1977; Aiello et al., 2006).

- Loxoconchidae: two species of *Sagmatocythere*, *S. versicolor* and *Sagmatocythere concentrica*, are well represented in the Montalbano Jonico section. The first is widely distributed on the shelf (e.g. Puri et al., 1964; Bonaduce et al., 1976, 1977, 1979; Breman, 1976, Peypouquet and Nachite, 1984) with maximum

abundances between 20 and 170 mbsl. *S. concentrica* is a typical circalittoral–upper bathyal species with an optimum depth ranging from 125 to 170 mbsl (e.g. Bonaduce et al., 1976; Breman, 1976). *Palmoconcha subrugosa* has been recorded in the Bay of Naples (Puri et al., 1964; as *Loxoconcha* n. sp. A) and the Adriatic Sea (Bonaduce et al., 1976; as *Loxoconcha* aff. *L. agilis*) from the infralittoral up to 170 mbsl.

- Genus *Cytheropteron*. The genus is typical of circalittoral–bathyal environments. *Cytheropteron ruggierii* is the only species not rare in the infralittoral zone of the Mediterranean (Bonaduce et al., 1976; Aiello and Barra, unpublished data). The

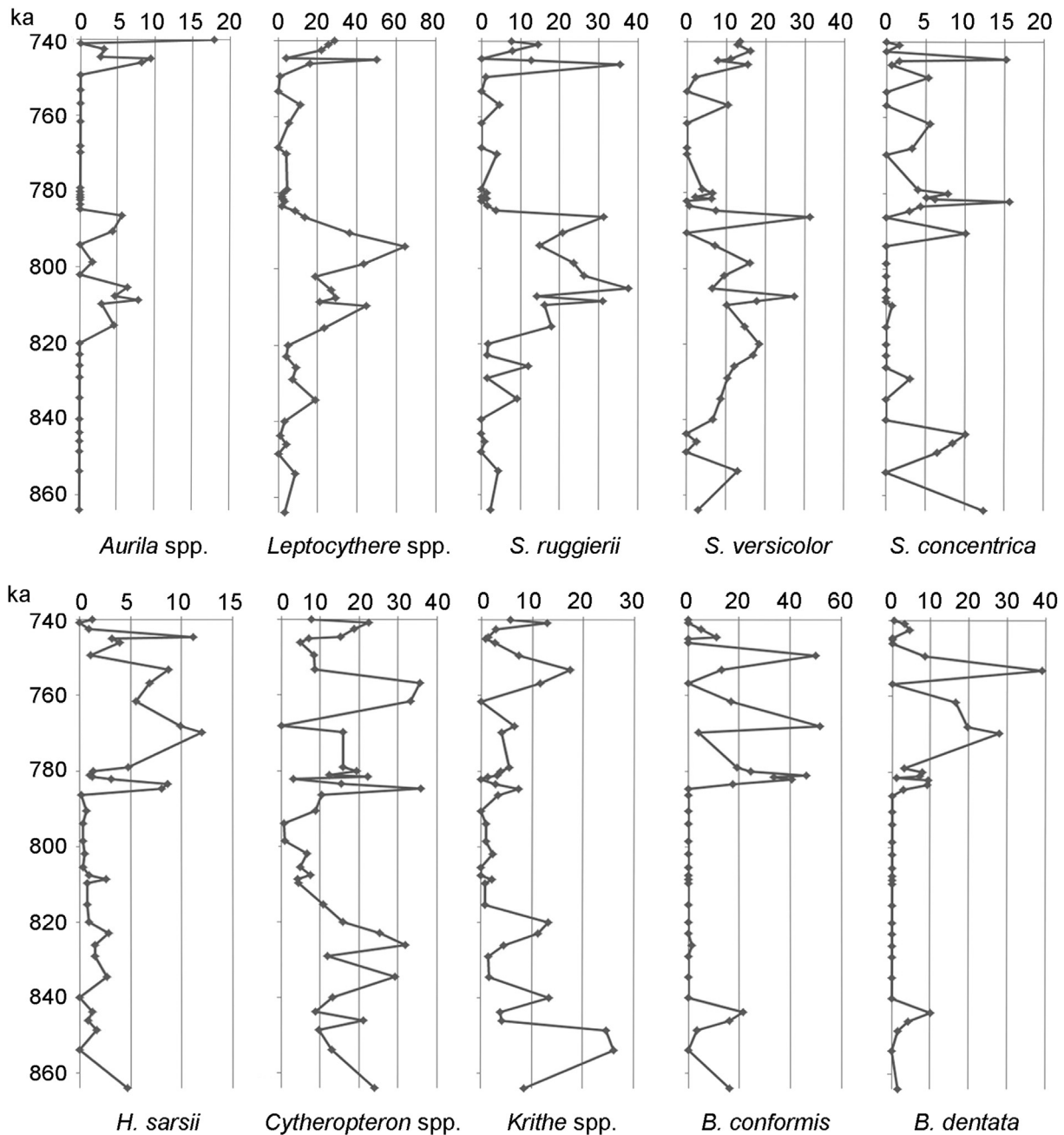


Fig. 3. Relative abundance, based on the minimum number of individuals (MNI), of *Aurila* spp., *Leptocythere* spp., *Semicytherura ruggierii*, *Sagmatocythere versicolor*, *S. concentrica*, *Krithe* spp., *Cytheropteron* spp., *Henryhowella sarsii*, *Bairdoppilata conformis*, and *Bosquetina dentata*.

simple diversity data indicates that the co-occurrence of four species of *Cytheropteron* is recorded below 70 mbsl. *C. zinzulusae*, rare in the Montalbano Jonico section, is an outer shelf–bathyal species living below 110 mbsl (Bonaduce et al., 1976; Breman, 1976).

- *Bosquetina dentata*: this is a lower infralittoral–upper bathyal species. High abundances are recorded in the depth interval 120–170 mbsl (Bonaduce et al., 1976).
- Genus *Krithe*: the genus is typical of bathyal–abyssal environments. *Krithe praetexta* generally occurs in the depth range 50–500 mbsl (e.g. Bonaduce et al., 1976; Athersuch et al., 1989).

The co-occurrence of two to three *Krithe* species is recorded at depths greater than 150–200 mbsl (Breman, 1976; Whatley and Zhao, 1993; Coles et al., 1994; Carmo and Sanguinetti, 1995). *Krithe compressa* lives below 160 mbsl (Whatley and Zhao, 1993; Coles et al., 1994; Ayress et al., 1999).

- *Eucytherura mistrettai*: this species is very rare above 70 mbsl, with its optimum between 70 and 200 mbsl (Bonaduce et al., 1976; Breman, 1976).
- *Bairdoppilata conformis*; the species is present below 70 mbsl, and common in the depth interval 110–200 mbsl (Bonaduce et al., 1976; Breman, 1976).

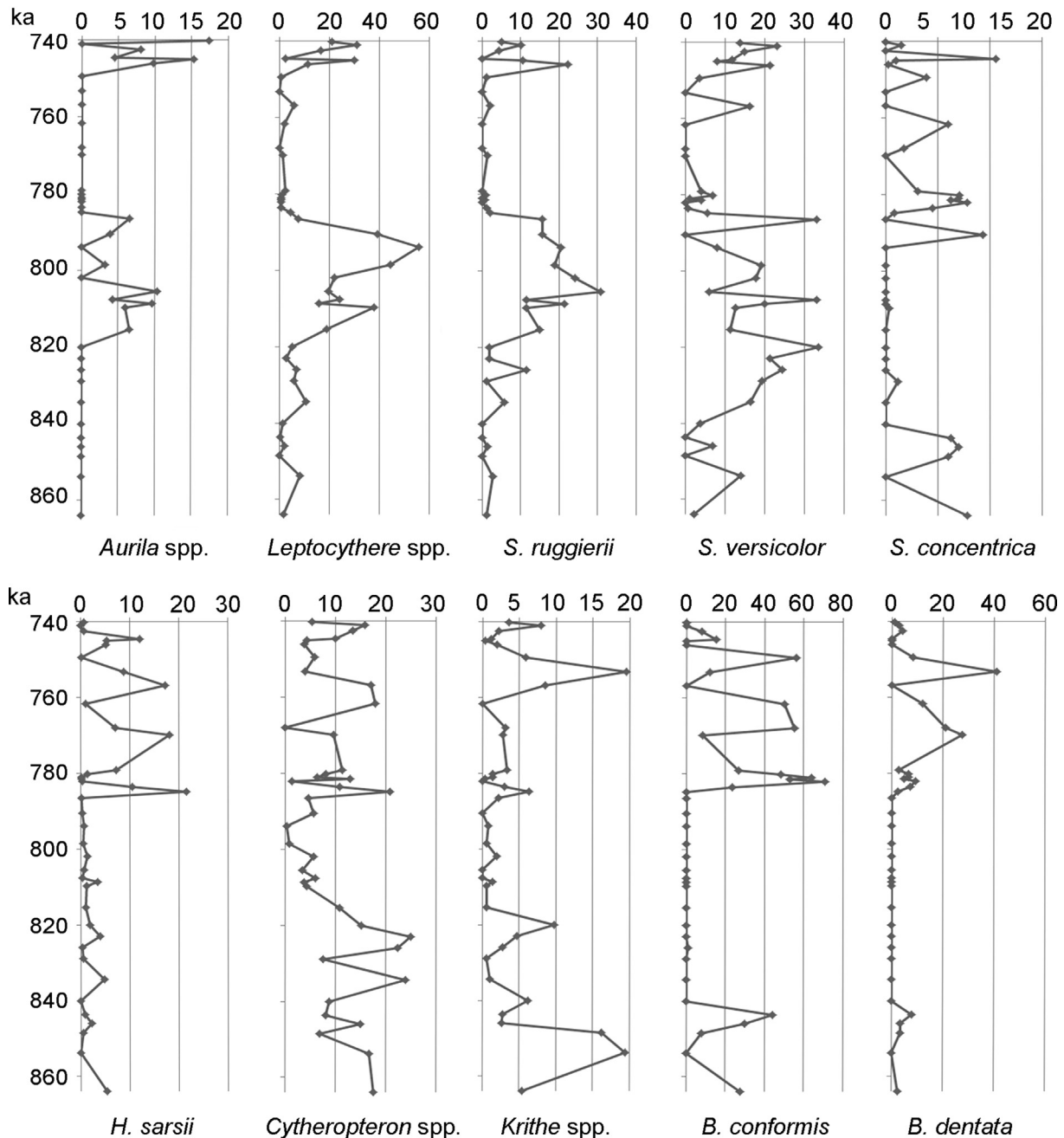


Fig. 4. Relative abundance, based on the total number of valves (TNV), of *Aurila* spp., *Leptocythere* spp., *Semicytherura ruggierii*, *Sigmatocythere versicolor*, *S. concentrica*, *Krithe* spp., *Cytheropteron* spp., *Henryhowella sarsii*, *Bairdoppilata conformis*, and *Bosquetina dentata*.

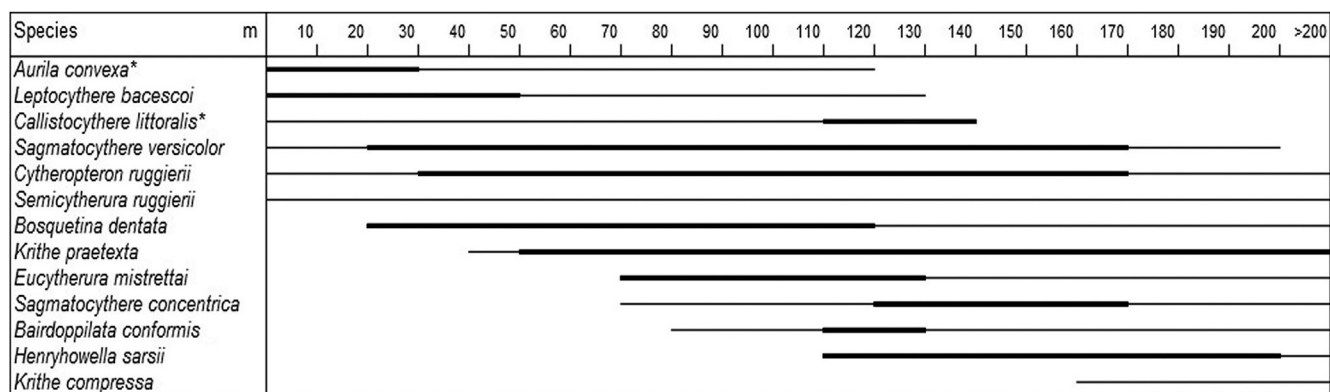


Fig. 5. Bathymetry data of selected ostracod taxa recorded in the Montalbano Jonico section. Thick lines indicate optimum depth of the species. It is assumed that the living species marked with an asterisk, *Aurila convexa* and *Callistocythere littoralis*, have depth distributions similar to the extinct species *Aurila bradleyana* and *Callistocythere macilenta* (see text).

- *Henryhowella sarsii*: this species lives at depths greater than 110 mbsl (Bonaduce et al., 1998, 1999).

2.2. Bottom water oxygen conditions

An attempt has been made to reconstruct the paleo-oxygen levels following the method of Maiorano et al. (2008). It is based on the evidence that ostracod assemblage composition depends upon oxygen levels, especially in bathyal environments (Peypouquet, 1977; McKenzie et al., 1989; Whatley, 1991; Whatley and Zhao, 1993; van Harten, 1995; Corbari, 2004). Ostracod assemblages are very poor and scarcely diversified when O_2 is < 3 ml/l (Peypouquet, 1977) and ostracod life is not possible in “anoxic” (sensu van Harten, 1987) environments. Consequently abundance and simple diversity are two main factors for evaluating bottom dissolved paleo-oxygen. Following observations on the relationship between infaunal/epifaunal benthic foraminifers and bottom water oxygen levels (Stefanelli, 2004 and references therein), Maiorano et al. (2008) proposed the use of the infaunal/epifaunal ostracod ratio, calculated by dividing *Krithe* and *Parakrithe* (K + P) by *Cytheropteron* and *Henryhowella* (C + H) abundances. The mode of life of *Krithe* has been inferred from shell structure (e.g. Coles et al., 1994) and directly observed by Majoran and Agrenius (1995). The genus *Parakrithe* shows very similar features and it is assumed to be infaunal. *Henryhowella* is considered epifaunal on the basis of both the structure of the carapace and indirect observations (Kempf and Nink, 1993; Didié and Bauch, 2002). *Cytheropteron* is characterized by alae generally interpreted as typical of taxa crawling over bottom sediments (Elofson, 1941). Abundance and diversity values and the infaunal/epifaunal ratio indicate aerobic and kenoxic (Cepek and Kemper, 1981; Whatley, 1990) phases. Aerobic phases are mainly characterized by high diversity and abundance and low values of the infaunal/epifaunal ratio; kenoxic phases generally show low diversity and abundance values and high infaunal/epifaunal ratios; the “ostracod barren” deposits, devoid of autochthonous ostracod remains, are characterized by dysaerobic foraminifer assemblages. We tested the method in circalittoral paleoenvironments.

The studied specimens are housed in the Aiello Barra Micropaleontological Collection (A.B.M.C.), Dipartimento di Scienze della

Terra, dell’Ambiente e delle Risorse, Università degli Studi di Napoli Federico II.

3. Results

Ostracod assemblages studied from the Montalbano Jonico section include 138 species in 54 genera (Appendix 1). Selected species are illustrated in Fig. 2. No samples were barren of ostracods. Both autochthonous and mixed (sensu Fagerstrom, 1964: “a fossil assemblage containing large numbers of specimens which belonged to the same ecological community; however, the assemblage also contains many specimens transported from other contemporaneous communities or derived from the erosion of pre-existing rocks”) assemblages occur. Most samples yielded mixed assemblages (including both autochthonous and allochthonous specimens). Five assemblages, from samples DFJ40, NC290, NC320, NC404, NC413, consist exclusively of autochthonous shells. Allochthonous specimens appear to be displaced from shallower marine environments or, in rare cases, from non-marine, continental waters. The occurrence of valves reworked from older sediments was not recorded.

The allochthoneity/autochthoneity analysis distinguished four groups of taxa (Appendix 1):

- 1 Non-marine taxa, including *Candona* sp. and *Cyprideis torosa*, very rare, allochthonous (Tables 2 and 3);
- 2 Fifteen shallow-marine species, pertaining to the genera *Carinocythereis*, *Caudites*, *Cistacythereis*, *Costa*, *Loxoconcha*, *Paradoxostoma*, *Pontocythere*, *Procytherideis*, *Urocythereis* and *Xestoleberis*, consistently allochthonous (i.e. transported from shallow marine waters; Tables 2 and 3);
- 3 A third group comprises six species assigned to *Aurila*, *Paracytheridea* and *Pterygocythereis*, that show, alternatively, allochthonous or autochthonous features (Tables 2–5);
- 4 The remaining 115 species are autochthonous (Tables 4 and 5).

Paleoecological reconstructions, considering only autochthonous taxa, are based on assemblage composition and relative abundance and diversity values (Tables 6 and 7). The most abundant species are reported in Table 8. Relative abundance trends of the most significant taxa are reported in Figs. 3–4. Bathymetrical data of the selected taxa are summarized in Fig. 5.

Table 2
Allochthonous ostracod taxa (MNI: minimum number of individuals), * indicates juvenile specimens.

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00
<i>Aurila bradleyana</i>	*	*	*	*			*	1*	*	*	*						*		*
<i>Aurila (C.) cimbaeformis</i>	*						*										1*		*
<i>Aurila</i> sp. 1											*								
<i>Aurila</i> sp.							*	*									*		*
<i>Candona</i> sp. 1				1															
<i>Carinocythereis carinata</i>	*						*				*				*	*	1*	*	*
<i>Caudites calceolatus</i>				*										4					
<i>Cistacythereis turbida</i>							*				*	*	*	*			1*		*
<i>Costa batei</i>			1*	*			*				*				*	1*			
<i>Costa edwardsi</i>	*																		
<i>Cyprideis torosa</i>																	*		
<i>Loxoconcha ovulata</i>																			
<i>Loxoconcha</i> sp.																			
<i>Paracytheridea triquetra</i>			1				4*	*		1	*				4*	*			1*
<i>Paradoxostoma</i> aff. <i>P. simile</i>																			
<i>Pontocythere turbida</i>	1*			*	*		1*	1*		*	*	*	*	*	*	*	*	*	3*
<i>Procytherideis retifera</i>														*					
<i>Procytherideis subspiralis</i>					*														
<i>Pterygocythereis jonesii</i>											1								
<i>Urocythereis favosa</i>	1			*			1*	*		1		1							
<i>Xestoleberis communis</i>	*	*					3*	1*		1*	*	8*	1	*	*		1*	1	1
<i>Xestoleberis parva</i>		*																	
<i>Xestoleberis</i> sp. 1																			

Table 3
Allochthonous ostracod taxa (TNV: total number of valves).

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00
<i>Aurila bradleyana</i>	6	1	1	8			89	9	19	2	8						94		43
<i>Aurila (C.) cimbaeformis</i>	4						27				12						26		7
<i>Aurila</i> sp. 1											2								
<i>Aurila</i> sp.							31	5											6
<i>Candona</i> sp. 1				1															
<i>Carinocythereis carinata</i>	5						1				1				6	4	3	5	2
<i>Caudites calceolatus</i>				1										4					
<i>Cistacythereis turbida</i>							4				1	8	3	16		18	2		1
<i>Costa batei</i>				5	1		3					8			2	3			
<i>Costa edwardsi</i>	1																		
<i>Cyprideis torosa</i>																	1		
<i>Loxoconcha ovulata</i>																			
<i>Loxoconcha</i> sp.																			
<i>Paracytheridea triquetra</i>			1				11	1		1	3			20	2				4
<i>Paradoxostoma</i> aff. <i>P. simile</i>																			
<i>Pontocythere turbida</i>	5			3	1		14	3		1	1	32	1	4	4	19	10	9	6
<i>Procytherideis retifera</i>														4					
<i>Procytherideis subspiralis</i>					1														
<i>Pterygocythereis jonesii</i>											1								
<i>Urocythereis favosa</i>	1			1			2	1		1									
<i>Xestoleberis communis</i>	3	1					15	3		2	6	16	1	4		1	4	1	1
<i>Xestoleberis parva</i>		1																	
<i>Xestoleberis</i> sp. 1																			

3.1. Cluster analysis

Statistical analysis was performed using the free software PAST version 3.01 (Hammer et al., 2001). Cluster analysis was applied to ostracod assemblage data using the Morisita similarity coefficient, considering both the minimum number of individuals (MNI) and the total number of valves (TNV), which gave results consistent with the paleoecological trends observed throughout the section.

Cluster analysis revealed, both for MNI and TNV, two significant clusters (A and B), divided into subclusters (A1, A2, B1, B2) (Figs. 6–7). In spite of some minor differences between the MNI

and TNV clustering, the results allow the definition of four intervals within the section that have well-defined features.

Interval I – (65.10–89.80 m, 864.00–820.00 ka). The basal part of the section yielded assemblages characterized by *Krithe* spp. and *Cytheropteron* spp., *H. sarsii*, *E. mistrettai* and *S. concentrica*. These taxa indicate an outer shelf paleoenvironment. Samples are grouped by cluster analysis in the subcluster A1. Cluster analysis includes three samples (DF J31, DF J57, DF J39) belonging to this interval in the subcluster B1, due to the high abundance of *B. conformis* and *B. dentata*. The genus *Aurila*, typical of infralittoral/upper circalittoral waters, is not present.

NC 219	NC 250	NC 258	NC 271	NC 284	NC 290	NC 293	NC 299	NC 304	NC 320	NC 400	NC 404	NC 409	NC 413	NC 417	NC 420	NC 423	NC 424	NC 430	NC 434	NC 436
115.80	122.30	125.00	127.00	129.30	130.30	131.00	132.50	134.20	138.50	140.20	146.40	151.10	154.60	158.30	161.60	164.20	165.10	170.10	174.00	176.10
790.65	785.62	783.54	782.00	779.47	778.36	777.59	775.94	774.07	769.74	768.04	761.83	757.12	753.61	749.91	746.60	745.51	745.14	743.05	741.42	740.54
		*	*			*	*	*				2*		*					*	
		*				*	*	*		*		*		*					*	
			1*																	
			1*																	
*	1		1				*	*							1*					2*
*	2*		*				*	*							*					
			1			*									1			1		
								*												*
					2		*	*								*	1			2
*			1												*	*		1	*	2*
						2		*							*					2*
		1						*	*							*				
												1			2		*			
															*					

NC 219	NC 250	NC 258	NC 271	NC 284	NC 290	NC 293	NC 299	NC 304	NC 320	NC 400	NC 404	NC 409	NC 413	NC 417	NC 420	NC 423	NC 424	NC 430	NC 434	NC 436
115.80	122.30	125.00	127.00	129.30	130.30	131.00	132.50	134.20	138.50	140.20	146.40	151.10	154.60	158.30	161.60	164.20	165.10	170.10	174.00	176.10
790.65	785.62	783.54	782.00	779.47	778.36	777.59	775.94	774.07	769.74	768.04	761.83	757.12	753.61	749.91	746.60	745.51	745.14	743.05	741.42	740.54
		6	27			2	21	31				70		8					20	
		5	6	1		2	11	17		1		1		1					3	
			26									1								
			3																	
1	2		1				1	4						2						4
3	20	1	1					1						1						
			1			2												1		
								1												6
																	1			2
			1												2			1		4
1					4		1	4						4	2			2		4
						2									2					
		1					4	1				1			2			1		
															2					
															2					

Interval II – The second interval (93.70–122.30 m, 815.42–785.62 ka) shows high abundances of the genus *Lepocythere*, including *L. bacescoi*, typical of infralittoral to upper circalittoral waters. Assemblages are characterised by *Aurila* spp., *Sagmatocythere versicolor* and *Semicytherura ruggierii*. The genera *Cytherofteron* and *Krithe* are each mainly represented by a single species, *C. ruggierii* and *Krithe praetexta*. *B. conformis* and *B. dentata* are not present, *H. sarsii* is rare, and *E. mistrettai* very rare. All samples pertain to the subcluster A2 and represent a lower circalittoral (upper part) paleoenvironment.

Interval III – This part of the section (125.00–158.30 m, 783.54–749.91 ka) is better defined by the cluster analysis on the

total number of valves (TNV) than with the minimum number of individuals (MNI). It includes samples of cluster B (subclusters B1 and B2). The assemblages are dominated by *B. conformis*, *B. dentata* and *H. sarsii*. The genus *Cytherofteron* includes generally two or more species, and *E. mistrettai* and *S. concentrica* are common. *L. bacescoi* is rare and the genus *Aurila* does not occur. Inferred paleodepths indicate an outer shelf paleoenvironment.

Interval IV – The uppermost sediments (161.60–176.10 m; 746.60–740.54 ka) are characterized by the species *L. bacescoi*, *S. ruggierii*, *S. versicolor* and the genus *Aurila*. Assemblages are grouped by cluster analysis in subcluster A2 together with the second interval samples, indicating a similar lower circalittoral

Table 4
Autochthonous ostracod taxa (MNI: minimum number of individuals) * indicates juvenile specimens.

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194	
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65	
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00	
<i>Aglaocypris</i> sp.																				
<i>Argilloecia acuminata</i>	2*			4*	2*		1*				1					1*				
<i>Argilloecia fatua</i>	2*	1	1	1																
<i>Argilloecia gonzalesi?</i>																				
<i>Argilloecia pseudoreticolata</i>																				
<i>Argilloecia robusta</i>				*																
<i>Argilloecia</i> sp. 1					1															
<i>Argilloecia</i> sp.																				
<i>Aurila bradleyana</i>												40*		28*	8*	14*			2*	
<i>Aurila</i> (C.) <i>cimbaeformis</i>												8*	3*	32*	*	4*			2*	
<i>Aurila</i> sp. 1																				
<i>Aurila</i> sp.													*						*	
<i>Bairdoppilata conformis</i>	21*		2*	19*	17*				*											
<i>Bosquetina dentata</i>	2*		*	5*	8*															
<i>Buntonia sublatissima</i>																				1
<i>Callistocythere</i> aff. <i>C. abjecta</i>		1																		
<i>Callistocythere adriatica</i>	1*																			
<i>Callistocythere macilenta</i>				*	1*		20*	4*	2*	1*		16*	7*	12*	2*	5*	19*	13*	9*	
<i>Callistocythere</i> aff. <i>C. rastrifera</i>							3*						1*			1	2	1*		
<i>Callistocythere</i> sp. 1							3							4		1	1			
<i>Callistocythere</i> sp. 2							1							4						
<i>Callistocythere</i> sp. 3														4						
<i>Callistocythere</i> sp. 4																				
<i>Callistocythere</i> sp.		*									*									
<i>Cluthia keiji</i>	2	1		1	2		2				1									
<i>Cytherella vulgatella</i>	4*		3*	4	4*		1												1*	1*
<i>Cytherois carcinitica</i>												8								
<i>Cytherois fischeri</i>														8						1
<i>Cytherois</i> aff. <i>C. succinoides</i>																		*		
<i>Cytherois</i> sp. 1																				
<i>Cytherois</i> sp. 2												8								
<i>Cytheroma variabilis</i>																				
<i>Cytheromorpha</i> aff. <i>C. nana</i>																				
<i>Cytheropteron ionicum</i>	4*		2	11*				1												1
<i>Cytheropteron monoceros</i>	5*			2			3*									1	1			
<i>Cytheropteron ruggierii</i>	9*	2*	1	6*	4*	3	54*	6*	18*	11*	12*	88*	6*	32*	16*	5*	5*			
<i>C. aff. C. sagittaeferum</i>			1	3*	1*											1*	1	1*	1	
<i>Cytheropteron sulcatum</i>												*				7*	5*	2*		
<i>Cytheropteron volantium</i> ssp. 1	13*	1*	2	3*	2*	1	30*	1	3	7*	6	8*					1*			
<i>Cytheropteron zinzulusae</i>												*					1			
<i>Cytherura curta</i>	1						2								4					
<i>Cytherura levireticulata</i>																				
<i>Dopseucythere mediterranea</i>			1																	
<i>Eucythere curta</i>							2*		*	*			1*						2*	
<i>Eucytherura complexa</i>	4*			10*	1*															
<i>Eucytherura</i> aff. <i>E. gibbera</i>																	1			
<i>Eucytherura mistrettai</i>	1*		1	2	3		1		1		*							*		
<i>Eucytherura patercoli</i>	1																			
<i>Eucytherura</i> sp. 1							1						1				4			
<i>Eucytherura</i> sp. 2							2													
<i>Eucytherura</i> sp. 3																2*				
<i>Eucytherura</i> sp. 4																				
<i>Hemicytherura deflorei</i>				*			4*			1		8				1	1			
<i>Hemicytherura videns</i>	*				1			*												1*
<i>Henryhowella parthenopea</i>																				
<i>Henryhowella sarsii</i>	6*		1	1*	1*		8*	*	*	2*	*	8*	*	20*	*	*		1*	1*	*
<i>Kangarina abyssicola</i>							*	*												
<i>Krithe compressa</i>		3						1	2	4	6*	8*								
<i>Krithe marialuisae</i>				1		1			1	4	5*									
<i>Krithe</i> aff. <i>K. minima</i>														4						
<i>Krithe monostercensis</i>		1																		
<i>Krithe praetexta</i>	11*	2	15*	4*	3*	3	5*				4*		1	12*			5*	3*	2*	
<i>Krithe</i> sp. 1																				1
<i>Leptocythere bacescoi</i>		1		1			10*	1			1	8	10*	12	2*	12*	13*	13*	26	
<i>Leptocythere crepidula</i>				1			2						1			4*				
<i>Leptocythere macella</i>				1			2			1						2				
<i>Leptocythere multipunctata</i>	4*	1*		2	1	1	35*	3*	6	2*	5*	224*	48*	144*	58*	56*	25*	94*	158*	
<i>Leptocythere ramosa</i>							7*	1*				8	2*	4*	2	2*	2*	20*	4	
" <i>Leptocythere</i> " sp. 1																				
<i>Loxococoncha gibberosa</i>							1*						1*		*		3*	2*	2*	
<i>Loxococoncha minima</i>												16								
<i>Macromckenziea ligustica</i>	1																			
<i>M. aff. M. ligustica</i>																				
<i>Microcytherura angulosa</i>	1			*														1*	1	1
<i>Microcytherura fulva</i>												8								
" <i>Microcytherura</i> " sp. 1					1				1						2					
<i>Neocytherideis subulata</i>																1	*			
<i>Pachycaudites</i> sp.	*											*								
<i>Palmoconcha subrugosa</i>	1*	2*	22*	10*	11*	18*	25*	31*	9*	20*	39*	56*	3*	32*	20*	3*	1*	1		
<i>Palmoconcha turbida</i>	1*					*	2*	2*	5	1*		16*	2*	4*	6*	9*	2*	3*		

Table 4 (continued)

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194	
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65	
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00	
<i>Palmoconcha</i> sp. 1												*								
<i>Paracypris</i> sp. 1																				
<i>Paracytheridea triquetra</i>													1			1*	8*	1		1
<i>Paracytherois agigensis</i>								1							4					1
<i>Paracytherois rara</i>																				
<i>Paracytherois striata</i>			2																	
<i>Parakrithe ambigua</i>	1			5*	2															
<i>Parakrithe dimorpha</i>					1															
<i>Parakrithe rotundata</i>																				
<i>Phlyctocythere pellucida</i>																				
<i>Platyleberis?</i> sp. 1				*																
<i>Polycope frequens?</i>																				
<i>Polycope tuberosa</i>											1									
<i>Pontocypris acuminata</i>			*		*							*								
<i>Pontocypris</i> aff. <i>P. frequens</i>												*								
<i>Pontocypris pallida</i>	*												*							
<i>Propontocypris succinea</i>																				
<i>Propontocypris</i> sp. 1																				
<i>Propontocypris</i> sp.																				
<i>Pterygocythereis jonesii</i>	*		*																	
<i>Pterygocythereis siveteri</i>																				
<i>Sagmatocythere concentrica</i>	16*		4	10*	8*			2					*							
<i>Sagmatocythere littoralis</i>								1				1*								
<i>Sagmatocythere</i> aff. <i>S. littoralis</i>	1																			
<i>Sagmatocythere moncharmonti</i>				2	2								64*							
<i>Sagmatocythere versicolor</i>	4*	3*		3*		2	26*	7*	8*	12*	21*	152*	14*	136*	58*	18*	20*	47*	21*	
<i>Sagmatocythere</i> sp.		*									*									
<i>Sclerochilus</i> aff. <i>S. dubowsky</i>												1								
<i>Sclerochilus gewemuelleri</i>		1*																		
<i>Sclerochilus</i> sp. 1																				
<i>Sclerochilus</i> sp.													8							
<i>Semicytherura acuticostata</i>						2							8	1						3*
<i>Semicytherura alifera</i>						1*							1			2*				1*
<i>Semicytherura dispar</i>	1					1*	1*				*	8	2		2					1
<i>Semicytherura inversa</i>																				
<i>Semicytherura mediterranea</i>						2*														1
<i>Semicytherura quadridentata</i>	*					1						16								1
<i>Semicytherura rara</i>	1				1	10				2		8	4	28*	6	16*	14*	8*	8*	
<i>Semicytherura rarecostata</i>						2						3								
<i>Semicytherura ruggierii</i>	3*	1		1*		27*	*		8*	1*	2*	184*	22*	236*	30*	106*	55*	69*	43*	
<i>Semicytherura</i> sp. 1										1										

(upper part) paleoenvironment. Some samples contain the outer shelf to bathyal species *K. compressa* and show high diversity for the genus *Cytheropteron*. The sample NC 434 (174.00 m, 741.42 ka) has to be considered as anomalous (cluster B1 in MNI, B2 in TNV) due to the abundance of *B. dentata* and *E. mistrettai*, suggesting a peak in water depth.

3.2. Paleobathymetry

The distributional data of the species characterizing the ostracofaunas recorded in the study section indicate the influence of bathymetric variations on the assemblage composition. Sedimentation took place in the circalittoral zone. We excluded the possibility of deposition in infralittoral environments due to the lack of autochthonous specimens belonging to typical shallow-water genera such as *Carinocythereis*, *Pontocythere*, and *Urocythereis* (Tables 2 and 3), widespread in Neogene–modern Mediterranean waters, and here represented by scattered, mainly juvenile, displaced valves.

All assemblages indicate deposition within the Lower Circalittoral Subzone (LCS) described by Sgarrella and Moncharmont Zei (1993), and based on Mediterranean benthic foraminiferal data distribution. The upper and lower limits of the LCS are placed, respectively, at 80–100 mbsl and 150–200 mbsl. The presence of species characteristic of deep, mainly bathyal environments, such as *K. compressa*, indicates that the section reaches

a maximum paleodepth corresponding to the circalittoral/bathyal boundary.

The approach used to estimate paleobathymetry is outlined in Figs. 5 and 8. Fig. 5 shows distribution data for the most abundant species present in the Montalbano Jonico section. Fig. 8 shows the percentage abundance of taxa characterizing one of the shallowest (upper part of LCS) assemblages (sample NC 157, 102.20 m) and two “deep” (outer shelf, lower part of LCS) assemblages (NC 284, 129.30 m, and DF J46, 84.60 m). The ostracod assemblage for the sample NC 284 is dominated by *B. conformis*, *B. dentata* and *H. sarsii*, and the assemblage of DF J46 consists mainly of species belonging to *Krithe* and *Cytheropteron*.

Paleobathymetric ranges have been inferred for each sample from distributional data of living and fossil species. Analysis of the assemblage composition allowed the discrimination of 12 groups of assemblages. The main features of the assemblages are outlined as follows.

Group A: autochthonous specimens of *Aurila bradleyana*, *Aurila cimbaeformis* and *L. bacescoi* co-occur. The relative abundance of *A. bradleyana* ranges from 0.68 to 6.56% (MNI) and from 3.11 to 20.20% (TNV), *A. cimbaeformis* from 0.18 to 4.20% (MNI) and from 0.56 to 6.83% (TNV), and *L. bacescoi* from 0.66 to 4.44% (MNI) and from 0.16 to 3.37% (TNV). The sum of the percentages of *Aurila* spp. and *L. bacescoi*, here named “Infra–Circalittoral Taxa Abundance” (ICTA), ranges from 5.43 to 10.68% (MNI) and from 9.29 to 23.48% (TNV). *B. conformis* and *B. dentata* are not present, rare specimens of

Table 5
Autochthonous ostracod taxa (TNV: total number of valves).

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194	
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65	
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00	
<i>Aglaocypris</i> sp.																				
<i>Argilloecia acuminata</i>	5			10	5		3				1					4				
<i>Argilloecia fatua</i>	5	1	1	2																
<i>Argilloecia gonzalesi?</i>																				
<i>Argilloecia pseudoreticolata</i>																				
<i>Argilloecia robusta</i>				3																
<i>Argilloecia</i> sp. 1					2															
<i>Argilloecia</i> sp.																				
<i>Aurila bradleyana</i>												288		236	34	179			36	
<i>Aurila</i> (C.) <i>cimbaeformis</i>												48	14	128	12	5			34	
<i>Aurila</i> sp. 1																				
<i>Aurila</i> sp.													30						5	
<i>Bairdoppilata conformis</i>	123		9	112	113				1											
<i>Bosquetina dentata</i>	11		4	13	20															
<i>Buntonia sublatissima</i>																				1
<i>Callistocythere</i> aff. <i>C. abjecta</i>		1																		
<i>Callistocythere adriatica</i>	5																			
<i>Callistocythere macilenta</i>				3	2		123	11	6	7		56	22	44	8	46	60	52	48	
<i>Callistocythere</i> aff. <i>C. rastrifera</i>							7						3			2	3	3		
<i>Callistocythere</i> sp. 1							5							8		2	1			
<i>Callistocythere</i> sp. 2							1							4						
<i>Callistocythere</i> sp. 3																				
<i>Callistocythere</i> sp. 4																				
<i>Callistocythere</i> sp.		4									6									
<i>Cluthia keiji</i>	2	1		1	3		3				1									
<i>Cytherella vulgatella</i>	58		10	8	18		1												2	2
<i>Cytherois carcinitica</i>												8								
<i>Cytherois fischeri</i>														8						1
<i>Cytherois</i> aff. <i>C. succinoides</i>																			2	
<i>Cytherois</i> sp. 1																				
<i>Cytherois</i> sp. 2												8								
<i>Cytheroma variabilis</i>																				
<i>Cytheromorpha</i> aff. <i>C. nana</i>																				
<i>Cytheropteron ionicum</i>	11		3	26				1												1
<i>Cytheropteron monoceros</i>	9			3			7									1	1			
<i>Cytheropteron ruggierii</i>	28	4	1	11	14	5	199	11	30	37	32	224	16	72	32	11	25			
<i>C. aff. C. sagittaeferum</i>			1	7	3											2	1	2	1	
<i>Cytheropteron sulcatum</i>												8				17	10	7		
<i>Cytheropteron volantium</i> ssp. 1	30	2	3	9	4	2	61	1	3	16	10	40				2				
<i>Cytheropteron zinzulusae</i>												8				1				
<i>Cytherura curta</i>	1						2								4					
<i>Cytherura levireticulata</i>																				
<i>Dopseucythere mediterranea</i>			2																	
<i>Eucythere curta</i>							5			1	1		2						4	
<i>Eucytherura complexa</i>	8			19	3															
<i>Eucytherura</i> aff. <i>E. gibbera</i>																		2		
<i>Eucytherura mistrettai</i>	2		1	2	4		1		1		1								1	
<i>Eucytherura patercoli</i>	1																			
<i>Eucytherura</i> sp. 1							1						1						4	
<i>Eucytherura</i> sp. 2							2													
<i>Eucytherura</i> sp. 3																3				
<i>Eucytherura</i> sp. 4																				
<i>Hemicytherura deflorei</i>				1			9			1		8				1	1			
<i>Hemicytherura videns</i>	1				1			1												2
<i>Henryhowella parthenopea</i>																				
<i>Henryhowella sarsii</i>	48		1	16	4		107	2	1	17	10	56	9	132	4	12	19	10	9	
<i>Kangarina abyssicola</i>							2	1												
<i>Krithe compressa</i>		3						1	3	6	9	16								
<i>Krithe marialuisae</i>				1		1			1	4	11									
<i>Krithe</i> aff. <i>K. minima</i>														1						
<i>Krithe monosteracensis</i>		1																		
<i>Krithe praetexta</i>	24	3	19	9	7	4	12				7		2	24				14	6	5
<i>Krithe</i> sp. 1																				1
<i>Leptocythere bacescoi</i>		1		1			21	1			1	8	21	20	4	24	48	39	42	
<i>Leptocythere crepidula</i>				2			3						1			9				
<i>Leptocythere macella</i>				2			2			1						3				
<i>Leptocythere multipunctata</i>	8	2		2	1	1	79	7	10	5	13	464	113	268	124	135	104	418	377	
<i>Leptocythere ramosa</i>							14	2				16	4	12	2	4	5	59	4	
" <i>Leptocythere</i> " sp. 1																				
<i>Loxococoncha gibberosa</i>						4							4			2	11	6	5	
<i>Loxococoncha minima</i>												16								
<i>Macromckenziea ligustica</i>	1																			
<i>M. aff. M. ligustica</i>																				
<i>Microcytherura angulosa</i>	1			1													3	1	2	
<i>Microcytherura fulva</i>												8								
" <i>Microcytherura</i> " sp. 1					1				1							2				
<i>Neocytherideis subulata</i>																	1	1		
<i>Pachycaudites</i> sp.	1											16								
<i>Palmoconcha subrugosa</i>	2	4	49	38	27	63	133	84	30	60	68	96	10	92	46	5	7	1		
<i>Palmoconcha turbida</i>	2					1	24	5	7	4		160	10	22	51	18	13	22		

NC 219	NC 250	NC 258	NC 271	NC 284	NC 290	NC 293	NC 299	NC 304	NC 320	NC 400	NC 404	NC 409	NC 413	NC 417	NC 420	NC 423	NC 424	NC 430	NC 434	NC 436
115.80	122.30	125.00	127.00	129.30	130.30	131.00	132.50	134.20	138.50	140.20	146.40	151.10	154.60	158.30	161.60	164.20	165.10	170.10	174.00	176.10
790.65	785.62	783.54	782.00	779.47	778.36	777.59	775.94	774.07	769.74	768.04	761.83	757.12	753.61	749.91	746.60	745.51	745.14	743.05	741.42	740.54
			75			8	5	2	1					16	1 6			3		2
			14 2			4		4										4		
	1		2		2	2		1												
25 18	297 24														179 24	150 34	10 6	85 13		254 58
															3					
		15 1	361 110	99 13	272 24	366 38	143 19	103 11	6 20	125 48	25 6		6 21	143 21			27	47 24	4	8
102	8	14	15			6	8	39		1		3		3	24	8	5	69	5	28
								2	1						4					
	2																			
				1	2	4	2	3										1		
		3	81 3	8	30	12	11	6	1	1	2	3		1						
1	1																			
			1																	
		2	8												2					
		6	18		10	2	2	4			2		2	8	6	10	12	1		
8	85	100	113	2	32	28	14	23	2		5	39		5	24	10	2	67	11	34
		2	2				1	7							2					
24	26	3	4		4	4		1						1	1	2			2	
	3	12	30		18	2	6	5	4		1	20		1	3	2	2	12	9	14
						2														
						2														
			21			6		4						1			1			
		1	33	1	10	2		7						1	1		12		1	
	1																			
		1													5			1		2
																		1		
3	5 5	1 258	328 6	1	2	2	8 1	56	26	32	1	121 1	9	1	110	64 2 2	43	9		12
								11 2		1				15	5	2		7	5	2
	54	38	47		2	8	4		2	6			10		15		2	6	6	30
17	4	3	1		2		2	3 2							4 2			7	3 2	18
200 1	175 6	21 2	8	1	2	2 2	1	4		1	21			2	112	180	4	94	38	172
			3		10							2			4					
					2												4	2		14
															1					
1 8	447 76	47 5	122	2	14	26	26	43 1	4	6	1 2	28 18	2	9 4	20 19	4 10	4 1	8 9	2 2	24 30

(continued on next page)

Table 5 (continued)

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00
<i>Palmoconcha</i> sp. 1											1								
<i>Paracypris</i> sp. 1																			
<i>Paracytheridea triquetra</i>													1			3	15	1	
<i>Paracytherois agigensis</i>								1						4					1
<i>Paracytherois rara</i>																			
<i>Paracytherois striata</i>			2																
<i>Parakrithe ambigua</i>	2			11	2														
<i>Parakrithe dimorpha</i>					1											1			
<i>Parakrithe rotundata</i>																	1	1	
<i>Phlyctocythere pellucida</i>																			
<i>Platyleberis?</i> sp. 1				1															
<i>Polycopse frequens?</i>																			
<i>Polycopse tuberosa</i>											2								
<i>Pontocypris acuminata</i>			3		1								24						
<i>Pontocypris</i> aff. <i>P. frequens</i>												8							
<i>Pontocypris pallida</i>	1																		
<i>Propontocypris succinea</i>																			
<i>Propontocypris</i> sp. 1																			
<i>Propontocypris</i> sp.																			
<i>Pterygocythereis jonesii</i>	1		1											4			20	1	
<i>Pterygocythereis siveteri</i>																			
<i>Sagmatocythere concentrica</i>	35		7	26	16			2					1						
<i>Sagmatocythere littoralis</i>								2			2								
<i>Sagmatocythere</i> aff. <i>S. littoralis</i>	1																		
<i>Sagmatocythere moncharmonti</i>				2	4								224						
<i>Sagmatocythere versicolor</i>	10	5		25		3	184	33	36	45	93	288	46	376	178	53	126	221	60
<i>Sagmatocythere</i> sp.		1									1								
<i>Sclerochilus</i> aff. <i>S. dubowsky</i>											1								
<i>Sclerochilus gewemuelleri</i>		2																	
<i>Sclerochilus</i> sp. 1																			
<i>Sclerochilus</i> sp.												8							
<i>Semicytherura acuticostata</i>							5					8	1				7		
<i>Semicytherura alifera</i>							2						1			4	3		1
<i>Semicytherura dispar</i>	1						3	2			1	8	3			3		1	
<i>Semicytherura inversa</i>																			1
<i>Semicytherura mediterranea</i>							5									2		1	
<i>Semicytherura quadridentata</i>	1						1					24						1	
<i>Semicytherura rara</i>	1				1		19			2		8	7	36	8	26	24	13	14
<i>Semicytherura rarecostata</i>							2					40							
<i>Semicytherura ruggierii</i>	5	1		5			63	2	17	4	5	384	42	400	62	273	171	218	154
<i>Semicytherura</i> sp. 1										1									

Table 6
Ostracod abundance and diversity index values based on MNI (minimum number of individuals).

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00
Taxa S	34	16	17	31	24	8	36	19	14	16	22	30	24	20	14	30	31	28	22
Individuals (100 g)	43	8	20	39	26	10	99	22	22	27	38	344	45	254	71	93	69	98	97
Dominance D	0.08	0.08	0.20	0.07	0.10	0.39	0.09	0.24	0.14	0.15	0.18	0.12	0.18	0.17	0.19	0.20	0.12	0.19	0.34
Shannon H	2.98	2.67	2.09	2.99	2.69	1.40	2.78	2.08	2.22	2.22	2.24	2.59	2.28	2.16	1.97	2.24	2.63	2.08	1.65
Equitability J	0.84	0.96	0.74	0.87	0.85	0.67	0.78	0.71	0.84	0.80	0.72	0.76	0.72	0.72	0.75	0.66	0.76	0.62	0.54

Table 7
Ostracod abundance and diversity index values based on TNV (total number of valves).

Samples	DF J31	DF J55	DF J38	DF J57	DF J39	DF J40	DF J42	DF J44	DF J46	DF J48	DF J50	DF J71	NC 133	NC 139	NC 145	NC 157	NC 168	NC 179	NC 194
Height (m)	65.10	70.30	73.20	74.70	75.50	76.80	79.40	82.00	84.60	87.20	89.80	93.70	98.50	99.40	100.04	102.20	105.10	107.90	111.65
Age (ka)	864.00	853.72	848.63	846.00	843.71	840.00	834.50	829.00	826.00	823.00	820.00	815.42	809.78	808.72	807.55	805.43	802.02	798.62	794.00
Taxa S	34	16	17	31	24	8	37	19	14	16	22	31	25	21	14	31	32	28	23
Individuals (100 g)	148	12	39	124	86	27	372	57	49	70	92	859	122	625	179	295	237	386	252
Dominance D	0.13	0.08	0.22	0.13	0.22	0.63	0.11	0.29	0.17	0.17	0.20	0.10	0.15	0.14	0.19	0.17	0.13	0.21	0.31
Shannon H	2.55	2.60	2.02	2.63	2.15	0.89	2.55	1.78	2.03	2.07	2.09	2.60	2.39	2.24	1.96	2.22	2.47	1.98	1.66
Equitability J	0.72	0.94	0.71	0.77	0.68	0.43	0.71	0.60	0.77	0.74	0.67	0.76	0.74	0.74	0.74	0.65	0.71	0.59	0.53

Table 8
Ostracod species with maximum relative abundances. MNI: minimum number of individuals; TNV: total number of valves.

Species	Number of samples	Max % MNI	Max % NTV
<i>Aurila bradleyana</i>	12	14.7%	28.3%
<i>Bairdoppilata conformis</i>	18	51.6%	70.7%
<i>Bosquetina dentata</i>	19	39.1%	41.2%
<i>Callistocythere macilenta</i>	29	13.8%	10.1%
<i>Cytheropteron ruggierii</i>	36	27.7%	20.4%
<i>Cytheropteron volantium</i> n. ssp. 1	30	13.8%	7.6%
<i>Eucytherura mistrettai</i>	17	11.1%	6.7%
<i>Henryhowella sarsii</i>	37	12%	43%
<i>Krithe compressa</i>	12	13%	4.3%
<i>Krithe marialuisae</i>	9	11.5%	8.6%
<i>Krithe praetexta</i>	27	24.6%	19.6%
<i>Leptocythere multipunctata</i>	36	54.3%	49.9%
<i>Palmoconcha subrugosa</i>	39	60%	78.8%
<i>Sagmatocythere concentrica</i>	21	15.6%	10.6%
<i>Sagmatocythere versicolor</i>	32	31.3%	33.6%
<i>Semicytherura ruggierii</i>	30	37.7%	30.8%

A. cimbaeformis is 1.39% (MNI) and 3.35% (TNV). CBTA: 50% (MNI) and 57.54% (TNV). Inferred paleodepth range: 120–150 mbsl.

Group F: The genus *Aurila* and *K. compressa* are not present. The relative abundance of *L. bacescoi* ranges from 0.31 to 1.30% MNI and from 0.06 to 0.67% TNV, *B. conformis* from 16.10 to 33.54% (MNI) and from 23.31 to 53.02% TNV, *B. dentata* from 1.24 to 9.26% (MNI) and from 3.49 to 7.10% (TNV), *H. sarsii* from 0.85 to 8.64% (MNI) and from 0.39 to 21.17 % (TNV), *S. concentrica* from 4.32 to 8.47% (MNI) and from 4.45 to 7.07 % (TNV); CBTA ranges from 35.59 to 45.45% (MNI) and from 48.12 to 66.67% (TNV). Group F includes the samples DF J57 at 74.70 m, NC 271 at 127.00 m, NC 290 at 130.30 m, and NC 299 at 132.50 m. Inferred paleodepth range: 130–150 mbsl.

Group G includes only sample NC 258 at 125.00 m. The genus *Aurila* and the species *K. compressa* and *B. conformis* are not present. The relative abundance of *L. bacescoi* is 1.46% (MNI) and 0.5% (TNV), *B. dentata* is 2.92% (MNI) and 2.5% (TNV), *H. sarsii* is 8.03 (MNI) and 43% (TNV), and *S. concentrica* is 2.92% (MNI) and 0.83% (TNV). CBTA: 21.90% (MNI) and 52.83% (TNV). Inferred paleodepth range: 130–150 mbsl.

Group H: The genus *Aurila* and the species *B. conformis* and *B. dentata* are not present. The species *L. bacescoi* and *K. compressa* co-occur. The relative abundance of *H. sarsii* is lower than 1.49% (MNI) and 3.61% (TNV), few specimens of *E. mistrettai* occur in sample DF J50 at 89.80 m [0.88% (MNI), 0.36% (TNV)], *S. concentrica* is present in sample DF J44 at 82.00 m [2.99% (MNI), 1.18% (TNV)]. The relative abundance of *L. bacescoi* ranges from 0.88 to 4.35 % (MNI) and from 0.36 to 2.78 % (TNV). Group H includes the samples DF J55 at 70.30 m, DF J44 at 82.00 m, and DF J50 at 89.80 m. CBTA ranges from 5.97 to 26.09% (MNI) and from 2.94% to 19.44% (TNV). Inferred paleodepth range: 130–150 mbsl.

Group I includes only sample NC 304 at 134.20 m. The genus *Aurila* is not present. The relative abundance of *B. conformis* is 19.05% (MNI) and 26.61% (TNV), *K. compressa* 3.97% (MNI) and 2.84% (TNV), *L. bacescoi* 1.59% (MNI) and 0.77% (TNV), *B. dentata* 3.17% (MNI) and 2.84% (TNV), *E. mistrettai* 2.38% (MNI) and 1.81% (TNV), *H. sarsii* 4.76% (MNI) and 14.47% (TNV), and *S. concentrica* 3.97% (MNI) and 3.10% (TNV). CBTA: 38.89% (MNI) and 52.20% (TNV). Inferred paleodepth range: 130–160 mbsl.

Group J: The genus *Aurila* and the species *K. compressa* and *L. bacescoi* are not present. CBTA ranges from 39.34 to 78.26% (MNI) and from 35.04 to 90.20% (TNV). Group J includes the samples DF J31 at 65.10 m, DF J38 at 73.20 m, DF J39 at 75.50 m, NC 284 at

129.30 m, NC 293 at 131.00 m, NC 320 at 138.50 m, NC 404 at 146.40 m, and NC 413 at 154.60 m. The samples DF J40 at 76.80 m [CBTA: 13.33% (MNI) and 6.25% (TNV)] and NC 409 at 151.10 m [CBTA: 18.39% (MNI) and 43.02% (TNV)] are included in Group J due to the strong resemblance of the assemblage composition. Inferred paleodepth range: 140–160 mbsl.

Group K: The genus *Aurila* and the species *L. bacescoi* are not present. The relative abundance of *K. compressa* ranges from 3.03 to 5.63 % (MNI) and from 2.04 to 2.84% (TNV). CBTA ranges from 9.09 to 14.08% (MNI) and from 4.76 to 12.80% (TNV). Group K includes the samples DF J46 at 84.60 m and DF J48 at 87.20 m. Inferred paleodepth range: 140–170 mbsl.

Group L: The genus *Aurila* and the species *L. bacescoi* are not present. The relative abundance of *K. compressa* ranges from 1.10 to 7.45% (MNI) and from 0.44 to 5.88% (TNV). CBTA ranges from 73.40 to 91.21 % (MNI) and from 74.90 to 95.15 % (TNV). Group L includes the samples NC 400 at 140.20 m and NC 417 at 158.30 m. Inferred paleodepth range: 170–200 mbsl.

The paleobathymetry trend (Fig. 9) has been defined by considering the main part of the assemblage variations as dependent on water depth changes. The trend fits well with both the benthic $\delta^{18}\text{O}$ trend (Maiorano et al., 2010; Marino et al. 2015) and with the sea level curve of Bintanja and van de Wal (2008), and shows a strong correlation between climatic phases and sea level (Fig. 9).

The lower part of the section (subcluster A1 and B1), deposited in an outer shelf environment, can be linked to the high sea level typical of MIS 21.

The shallowing indicated by the upper LCS ostracod assemblages recorded in the second interval (subcluster A2) is related to the climatic cooling of MIS 20. In the third interval (subclusters B1 and B2), the rise in sea level resulting from the warm climate of MIS 19 induced the replacement of upper LCS assemblages with open shelf ostracods.

The section ends with a new shallowing (subcluster A2) corresponding to the cold phase MIS 18, including a brief deepening episode at 741.42 ka. This last interval shows the unexpected presence of autochthonous specimens of *Aurila* spp. (mainly infralittoral and upper circalittoral) and *Krithe compressa*, a species generally living below 160 m. The co-occurrence of taxa with different ecological preferences may be interpreted to represent an upward migration of outer shelf to bathyal taxa during upwelling episodes, inducing the mixing of upper bathyal and middle circalittoral waters (e.g. Borne, 1995).

3.3. Bottom-water oxygen conditions

Among the main factors influencing the composition of ostracod assemblages, dissolved oxygen levels play a role that depends on the general context of the paleoenvironmental trend. For example, the assemblages of the Calabrian IM-5 Agosto section (Maiorano et al., 2008), deposited within the upper bathyal zone, show a close relationship with paleo-oxygen levels, leading to the complete loss of ostracods during anoxic–dysoxic phases. In the studied part of the section, the sediments were deposited in lower circalittoral paleoenvironments, and the ostracod assemblages largely reflect the paleobathymetric variations. Consequently, the data seem inadequate to reconstruct a continuous paleo-oxygen curve. Nonetheless, the previously adopted methodology (Maiorano et al., 2008) that considers the infaunal/epifaunal ratio together with simple diversity and abundance, yielded some meaningful results.

- a The lack of barren samples indicates that bottom waters did not reach the low-oxygen levels of an anoxic–dysoxic environment.

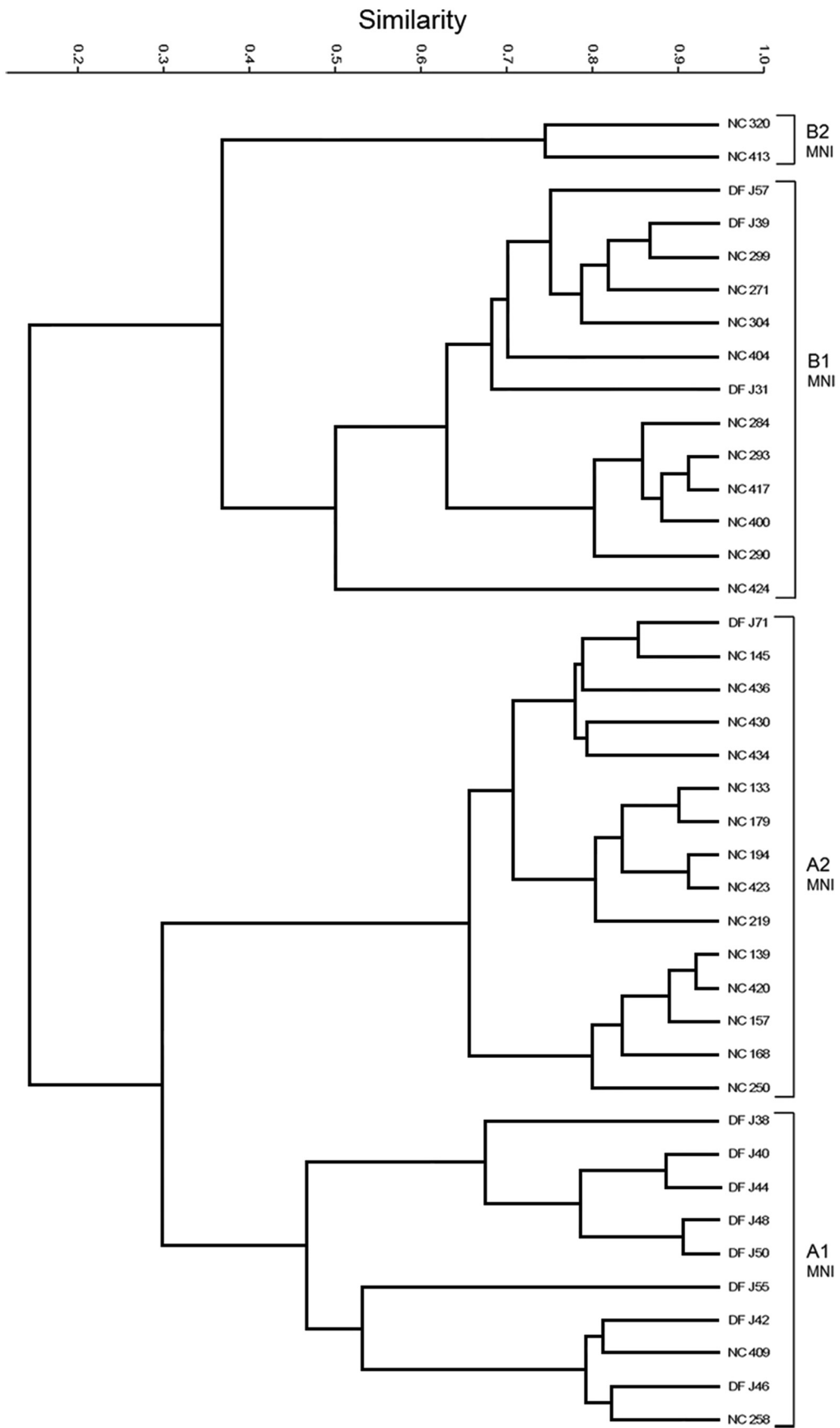


Fig. 6. Dendrogram based on a cluster analysis of the minimum number of individuals (MNI).

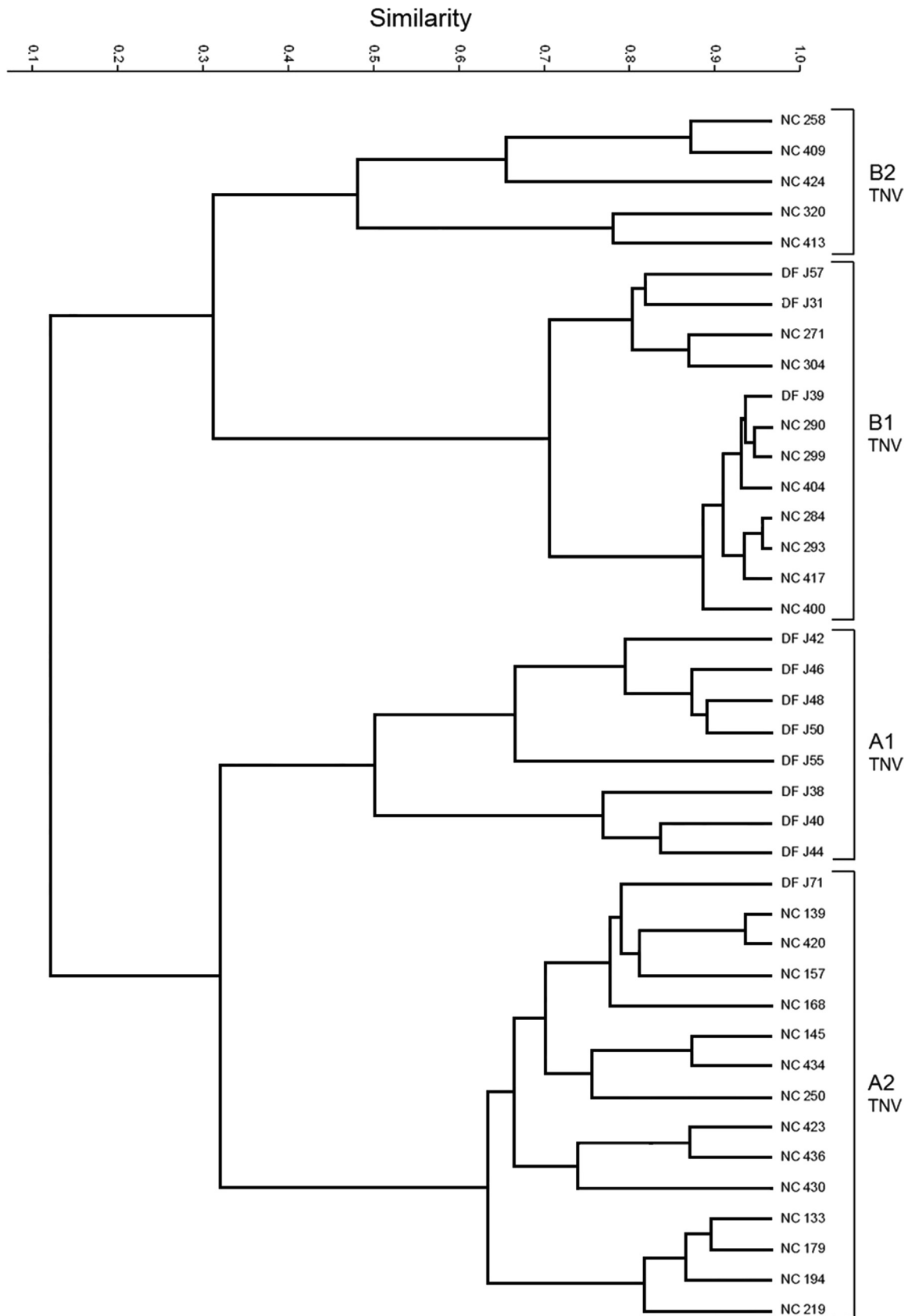


Fig. 7. Dendrogram based on a cluster analysis of the total number of valves (TNV).

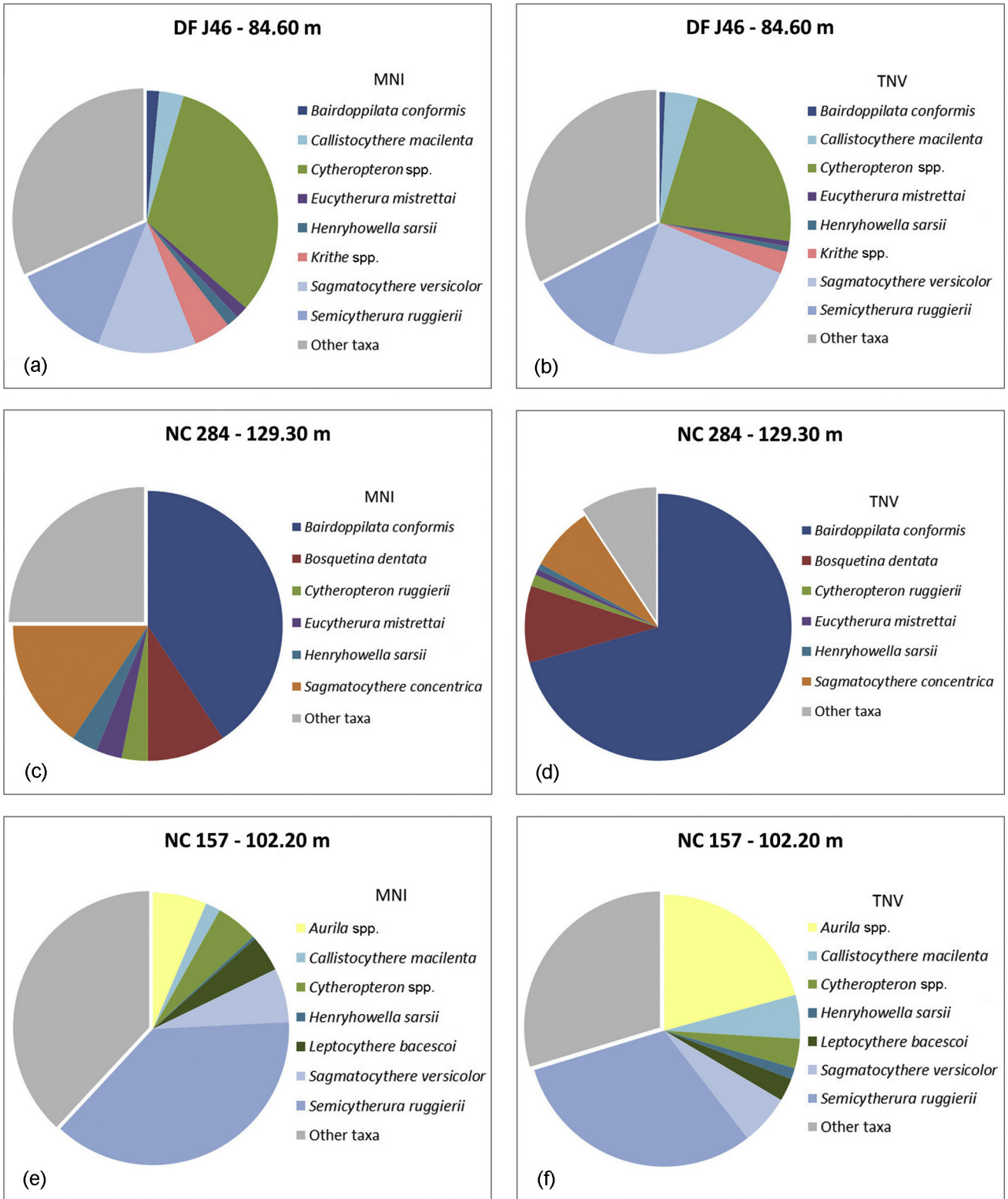


Fig. 8. Relative abundances of selected taxa in three samples belonging to different clusters. (a) Sample DFJ46 MNI. (b) Sample DFJ46 TNV (cluster A1, outer shelf paleoenvironment, cold phase MIS 21). (c) Sample NC284 MNI. (d) Sample NC 284 TNV (cluster B1, outer shelf paleoenvironment, warm phase MIS 19). (e) Sample NC 157 MNI. (f) Sample NC 157 TNV (cluster A2, upper LCS paleoenvironment, cold phase MIS 20).

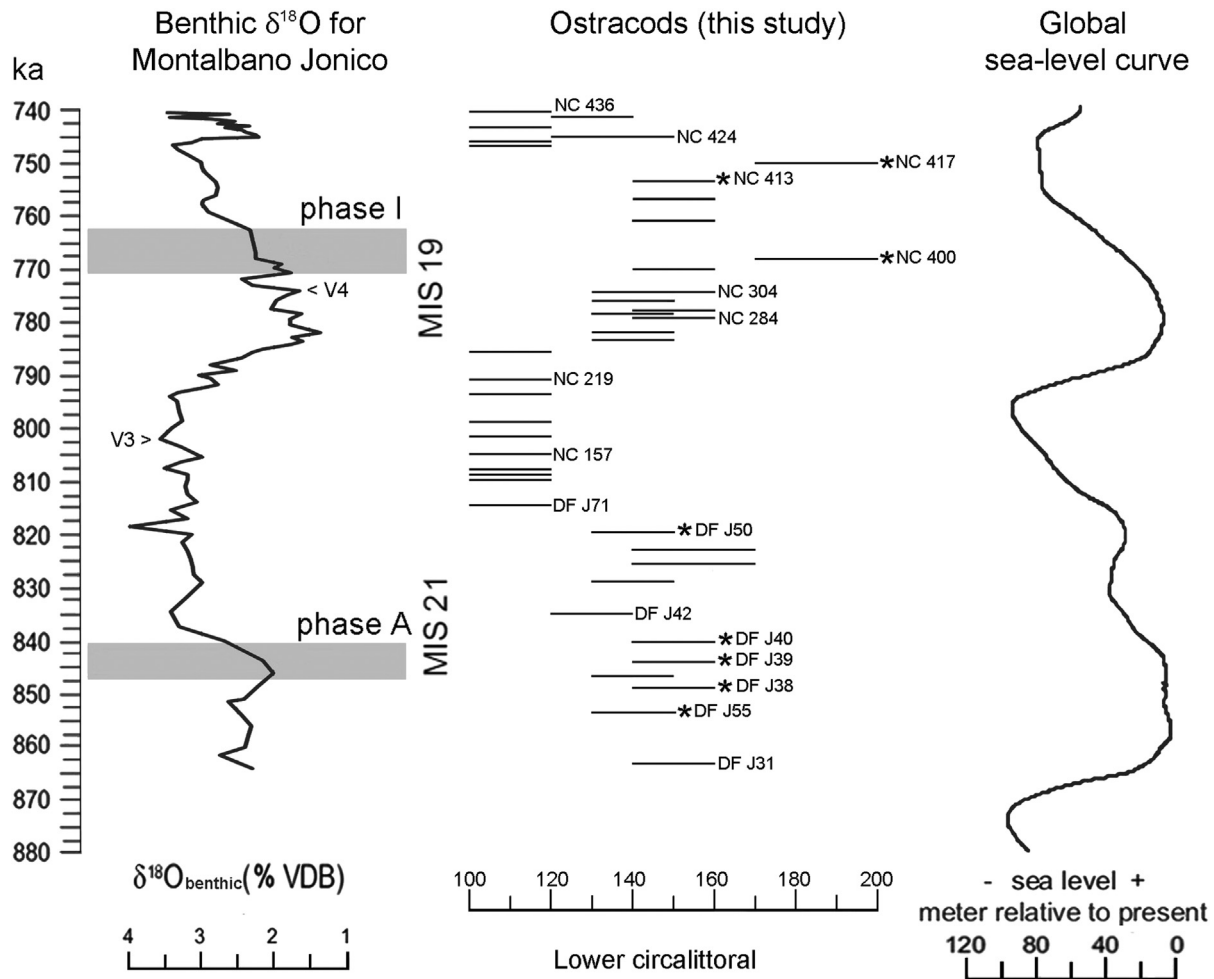


Fig. 9. Paleocological events through the Montalbano Jonico section and paleobathymetry trends compared with the benthic $\delta^{18}\text{O}$ curve (Marino et al. 2015) and global sea level curve (Bintanja and van de Wal, 2008). The asterisks indicate kenoxic ostracod assemblages. V3 and V4: volcaniclastic layers; Phase A: MIS 21.3 warm-humid phase; Phase I: MIS 19.1 warm-humid phase (following Marino et al. 2015).

b Some samples show high infaunal/epifaunal ratios, ranging from 0.7 to 2, coinciding with low values of simple diversity ranging from 7 to 24. The data are reported in Table 9.

The samples indicating low-oxygen bottom waters (*i.e.* “kenoxic” *sensu* Maiorano et al., 2008) mostly belong to the first and the third part of the section, related to the warm intervals MIS 21 and MIS 19 (indicated by asterisks in Fig. 9). These layers most likely represent phases of moderate stratification of the water column linked to interglacial phases frequently represented, in deep paleoenvironments, by the deposition of sapropel layers (*e.g.* Olausson, 1961; Ryan, 1972; review and references in Cramp and O’Sullivan, 1999).

Table 9
Infaunal/epifaunal ratio, species richness and abundance (number of specimens/100 g) values of kenoxic assemblages recorded in the Montalbano Jonico section.

Sample	m	Age (ka)	MIS	Infaunal/epifaunal ratio	Taxa S	Ab. MNI	Ab. TNV
NC 417	158.30	749.91	19	0.94	20	44	255
NC 413	154.60	753.61	19	0.92	7	23	51
NC 400	140.20	768.04	19	0.24	10	91	227
DF J50	89.80	820.00	21	0.53	22	113	277
DF J40	76.80	840.00	21	0.75	8	30	80
DF J39	75.50	843.71	21	0.42	24	79	257
DF J38	73.20	848.63	21	2.00	17	61	117
DF J55	70.30	853.72	21	1.14	16	23	36

Samples with the lowest simple diversity, low abundance and high infaunal/epifaunal ratios are DFJ40 (76.8 m, 840.00 ka) and NC 413 (154.6 m, 753.61 ka) which can be considered as representing minimum paleo-oxygen levels (Fig. 10). Furthermore, these assemblages show very low Shannon H diversity and high Dominance D values (Tables 6 and 7).

Given that the relationships between climatic events and bottom water paleo-oxygen conditions, as well as the dating of related sediments, are not completely defined at this time, we suggest some possible correlations that require confirmation through further investigations. The kenoxic assemblages recorded in the cold phase MIS 21, with the exception of sample DF J50, fall within 854–840 ka, which includes the warm-humid phase (“phase A”) recorded by Marino et al. (2015), corresponding to MIS 21.3 and dated at about 846 ka by Marino et al. (2015).

Murat (1999), describing the sapropel levels recovered at ODP leg 161 Site 976 (Alboran Sea), recognized a 0.94 m thick layer (key bed number 620) with total organic carbon (TOC) max. = 1.58%, dated 835.38 ka. This sapropel has been related to insolation cycle (i-cycle) 80, dated at 841 ka (Laskar et al., 1993; de Kaenel et al., 1999; Lourens, 2004; Reale and Monechi, 2005; Joannin et al., 2011). Consequently, the minimum-oxygen ostracod assemblage occurring in sample DF J40 (840.00 ka) could reflect the insolation maximum of i-cycle 80 in an open shelf environment, approximately coeval with sapropel deposition in deep Mediterranean waters.

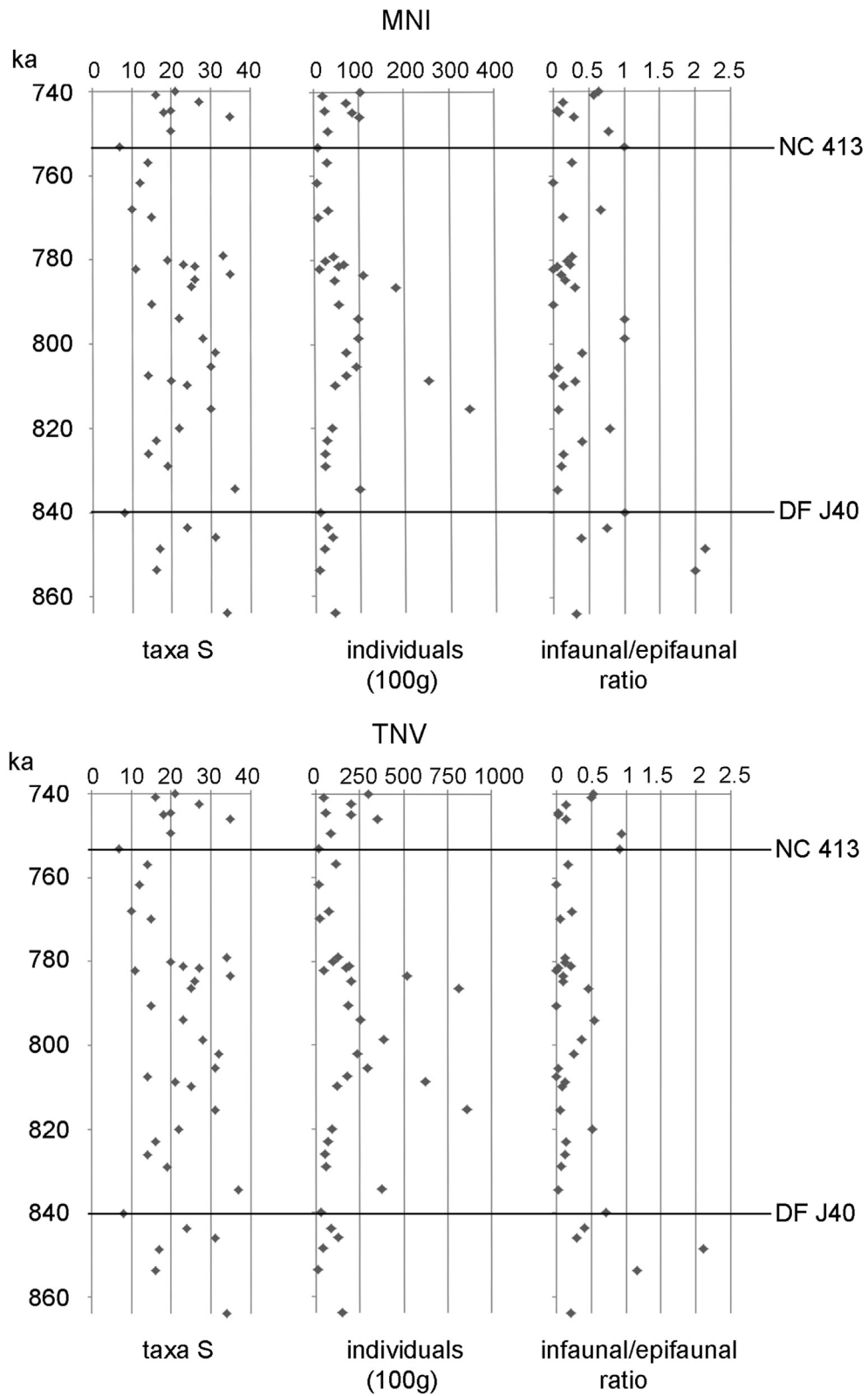


Fig. 10. Simple diversity (taxa S), abundance (individuals per 100 g), and infaunal/epifaunal ratios for the studied interval, highlighting the minimum paleo-oxygen levels recorded in samples DFJ40 and NC413. MNI = minimum number of individuals, TNV = total number of valves.

The kenoxic assemblages of samples NC 413 (753.61 ka) and NC 417 (749.91 ka) are associated with the assemblages of the underlying deposits (NC 409, 757.12 ka; NC 404, 761.83 ka; NC 400, 768.04 ka) that show low simple diversity (10–14) and low abundance (MNI: 18–91; NTV: 50–351), thus indicating a kenoxic interval that corresponds approximately with the increase of arboreal mesothermic taxa recorded by Marino et al. (2015; “warm phase I”, 768 ka) associated with the warm and humid phase of MIS 19.1 (dated 765 ka in Bassinot et al., 1994; de Kaenel et al., 1999; 766 ka in Wei et al., 2003; 772 ka in Langereis et al., 1997; Capraro et al., 2005). A certain correspondence with the insolation maximum of cycle 72 (dated 765 ka; Laskar et al., 1993; de Kaenel et al., 1999) is noted.

4. Conclusions

The sensitivity of ostracods to environmental changes allows recognition of paleoecological trends in the studied part of the Montalbano Jonico succession, ranging from 864.00 to 740.54 ka. Assemblage compositions show close connections with the evolution of paleobathymetry that, in turn, is linked to climate phases recorded around the Lower–Middle Pleistocene (Matuyama–Brunhes) boundary. Quantitative taxonomic analysis and cluster analysis indicate four paleobathymetric–paleoclimatic

Table 10
Intervals of the study section resulting from paleoecological considerations and cluster analysis, and positions of the hypothesized kenoxic levels and upwelling episodes.

Sample	m	Age (ka)	Interval	Events
NC 436	176.10	740.54	IV <i>Semicytherura ruggierii</i> ,	- upwelling
NC 434	174.00	741.42	<i>Sagmatocythere versicolor</i> ,	
NC 430	170.10	743.05	<i>Aurila</i> spp. (~MIS 18)	- upwelling
NC 424	165.10	745.14		
NC 423	164.20	745.51		- upwelling
NC 420	161.60	746.60		
NC 417	158.30	749.91	III <i>Bairdoppilata conformis</i> ,	- kenoxic
NC 413	154.60	753.61	<i>Bosquetina dentata</i> ,	- kenoxic
NC 409	151.10	757.12	<i>Henryhowella sarsii</i> (~MIS 19)	
NC 404	146.40	761.83		
NC 400	140.20	768.04		- kenoxic
NC 320	138.50	769.74		
NC 304	134.20	774.07		
NC 299	132.50	775.94		
NC 293	131.00	777.59		
NC 290	130.30	778.36		
NC 284	129.30	779.47		
NC 271	127.00	782.00		
NC 258	125.00	783.54		
NC 250	122.30	785.62	II <i>Leptocythere</i> spp.,	
NC 219	115.80	790.65	<i>Aurila</i> spp. (~MIS 20)	
NC 194	111.65	794.00		
NC 179	107.90	798.62		
NC 168	105.10	802.02		
NC 157	102.20	805.43		
NC 145	100.04	807.55		
NC 139	99.40	808.72		
NC 133	98.50	809.78		
DF J71	93.70	815.42		
DF J50	89.80	820.00	I <i>Krithe</i> spp.,	- kenoxic
DF J48	87.20	823.00	<i>Cytheropteron</i> spp.,	
DF J46	84.60	826.00	<i>Henryhowella sarsii</i> (~MIS 21)	
DF J44	82.00	829.00		
DF J42	79.40	834.50		
DF J40	76.80	840.00		- kenoxic
DF J39	75.50	843.71		- kenoxic
DF J57	74.70	846.00		
DF J38	73.20	848.63		- kenoxic
DF J55	70.30	853.72		- kenoxic
DF J31	65.10	864.00		

intervals (Table 10). The lowest part of the section, deposited in the lower part of LCS, is related with the warm phase MIS 21. The overlying sediments have yielded assemblages characteristic of the upper part of the LCS, due to the lowered sea level of MIS 20. The third part, including the Lower–Middle Pleistocene boundary, shows a deepening in outer shelf waters during the warm phase of MIS 19. Above this, a new shallowing is recorded, resulting in upper LCS sediments associated with MIS 18. The paleobathymetric trends show a close correlation with the sea level reconstruction as defined by Bintanja and van de Wal (2008). The presence of upwelling episodes has been inferred from the co-occurrence of autochthonous infra-to circalittoral and circalittoral to bathyal taxa. A secondary factor influencing ostracod assemblages is the dissolved oxygen level in bottom waters. Two major kenoxic events have been recognized. The first, occurring within the warm phase MIS 21, can be related to the substage 21.3. The second is associated with the substage MIS 19.1. Dysoxic–anoxic phases, typical of sapropel deposition, have not been recorded.

Acknowledgements

The authors thank David Horne (Queen Mary University of London) and editors Martin Head and Norm Catto, whose comments and suggestions greatly improved the manuscript. We especially acknowledge Maria Marino and Neri Ciaranfi (Università degli Studi di Bari) who provided the samples and Roberto de' Gennaro (Cisag, Università di Napoli Federico II) who took the SEM micrographs. We are particularly grateful to Tania Alfeo for the valuable scientific contribution during the starting phase of this investigation.

Appendix 1. List of ostracod taxa recorded in the present study. Numbers in parentheses indicate autochthonous/allochthonous groups (see text).

- (4) *Aglaiocypris* sp.
- (4) *Argilloecia acuminata* G.W. Müller 1894
- (4) *Argilloecia fatua* Barra et al. 1996
- (4) *Argilloecia gonzalesi*? Barra et al. 1996
- (4) *Argilloecia pseudoreticolata* Barra et al. 1996
- (4) *Argilloecia robusta* Bonaduce et al. 1976
- (4) *Argilloecia* sp. 1
- (4) *Argilloecia* sp.
- (3) *Aurila bradleyana* Ruggieri 1976
- (3) *Aurila* (*Cimbourila*) *cimbaeformis* (Seguenza 1883)
- (3) *Aurila* sp. 1
- (3) *Aurila* sp.
- (4) *Bairdoppilata conformis* (Terquem 1878)
- (4) *Bosquetina dentata* (G.W. Müller 1894)
- (4) *Buntonia sublatissima* (Neviani 1906)
- (4) *Callistocythere* aff. *C. abjecta* Schornikov 1966
- (4) *Callistocythere adriatica* Masoli 1968
- (4) *Callistocythere macilenta* Ciampo 1976
- (4) *Callistocythere* aff. *C. rastrifera* (Ruggieri 1953)
- (4) *Callistocythere* sp. 1
- (4) *Callistocythere* sp. 2
- (4) *Callistocythere* sp. 3
- (4) *Callistocythere* sp. 4
- (4) *Callistocythere* sp.
- (1) *Candona* sp. 1
- (2) *Carinocythereis carinata* (Roemer 1838)
- (2) *Caudites calceolatus* (O.G. Costa 1853)
- (2) *Cistacythereis turbida* (G.W. Müller 1894)
- (4) *Cluthia keiji* Neale 1975
- (2) *Costa batei* (Brady 1866)

- (2) *Costa edwardsi* (Roemer 1838)
 (1) *Cyprideis torosa* (Jones 1850)
 (4) *Cytherella vulgatella* Aiello, Barra, Bonaduce and Russo 1996
 (4) *Cytherois carcinitica* Marinov 1964
 (4) *Cytherois fischeri* (Sars 1866)
 (4) *Cytherois* aff. *C. succinoides* Dubowsky 1939
 (4) *Cytherois* sp. 1
 (4) *Cytherois* sp. 2
 (4) *Cytheroma variabilis* G.W. Müller 1894
 (4) *Cytheromorpha* aff. *C. nana* Bonaduce et al. 1976
 (4) *Cytheropteron ionicum* Colalongo and Pasini 1980
 (4) *Cytheropteron monoceros* Bonaduce et al. 1976
 (4) *Cytheropteron ruggierii* Pucci 1955
 (4) *Cytheropteron* aff. *C. sagittaeferum* Aiello and Szczechura 2004
 (4) *Cytheropteron sulcatum* Bonaduce et al. 1976
 (4) *Cytheropteron volantium* Whatley and Masson 1979 ssp. 1
 (4) *Cytheropteron zinzulusae* Bonaduce et al. 1976
 (4) *Cytherura curta* Colalongo and Pasini 1980
 (4) *Cytherura levireticulata* Colalongo and Pasini 1980
 (4) *Dopseucythere mediterranea* (Bonaduce, Masoli, Pugliese and McKenzie 1980)
 (4) *Eucythere curta* Ruggieri 1975
 (4) *Eucytherura complexa* (Brady 1866)
 (4) *Eucytherura* aff. *E. gibbera* G.W. Müller 1894
 (4) *Eucytherura mistrettai* Sissingh 1972
 (4) *Eucytherura patercoli* Mistretta 1967
 (4) *Eucytherura* sp. 1
 (4) *Eucytherura* sp. 2
 (4) *Eucytherura* sp. 3
 (4) *Eucytherura* sp. 4
 (4) *Hemicytherura defiorei* Ruggieri 1953
 (4) *Hemicytherura videns* (G.W. Müller 1894)
 (4) *Henryhowella parthenopea* Bonaduce et al. 1999
 (4) *Henryhowella sarsii* (G.W. Müller 1894)
 (4) *Kangarina abyssicola* (G.W. Müller 1894)
 (4) *Krithe compressa* (Seguenza 1880)
 (4) *Krithe marialuisae* Abate et al. 1993
 (4) *Krithe* aff. *K. minima* Coles et al. 1994
 (4) *Krithe monosteracensis* (Seguenza 1880)
 (4) *Krithe praetexta* (Sars 1866)
 (4) *Krithe* sp. 1
 (4) *Leptocythere bacescoi* (Rome 1942)
 (4) *Leptocythere crepidula* Ruggieri 1950
 (4) *Leptocythere macella* Ruggieri 1975
 (4) *Leptocythere multipunctata* (Seguenza 1883)
 (4) *Leptocythere ramosa* (Rome 1942)
 (4) “*Leptocythere*” sp. 1
 (4) *Loxoconcha gibberosa* Terquem 1878
 (2) *Loxoconcha ovulata* (O.G. Costa 1853)
 (2) *Loxoconcha* sp.
 (4) *Loxoconchidea minima* Bonaduce et al. 1976
 (4) *Macromckenziea ligustica* (Bonaduce et al. 1977)
 (4) *Macromckenziea* aff. *M. ligustica* Bonaduce et al. 1976
 (4) *Microcytherura angulosa* (Seguenza 1880)
 (4) *Microcytherura fulva* (Brady and Robertson 1874)
 (4) “*Microcytherura*” sp. 1
 (4) *Neocytherideis subulata* (Brady 1868)
 (4) *Pachycaudites* sp.
 (4) *Palmoconcha subrugosa* (Ruggieri 1967)
 (4) *Palmoconcha turbida* (G.W. Müller 1912)
 (4) *Palmoconcha* sp. 1
 (4) *Paracypris* sp. 1
 (3) *Paracytheridea triquetra* (Reuss 1850)
 (4) *Paracytherois agigensis* Caraion 1963
 (4) *Paracytherois rara* G.W. Müller 1894
 (4) *Paracytherois striata* G.W. Müller 1894
 (2) *Paradoxostoma* aff. *P. simile* G.W. Müller 1894
 (4) *Parakrithe ambigua* Ciampo 1980
 (4) *Parakrithe dimorpha* Bonaduce et al. 1976
 (4) *Parakrithe rotundata* Aiello et al. 1993
 (4) *Phlyctocythere pellucida* (G.W. Müller 1894)
 (4) *Platyleberis?* sp. 1
 (4) *Polycope frequens?* G.W. Müller 1894
 (4) *Polycope tuberosa* G.W. Müller 1894
 (4) *Pontocypris acuminata* (G.W. Müller 1894)
 (4) *Pontocypris* aff. *P. frequens* (G.W. Müller 1894)
 (4) *Pontocypris pallida* (G.W. Müller 1894)
 (2) *Pontocythere turbida* (G.W. Müller 1894)
 (2) *Procytherideis retifera* Ruggieri 1978
 (2) *Procytherideis subspiralis* (Brady, Crosskey and Robertson 1874)
 (4) *Propontocypris succinea* (G.W. Müller 1894)
 (4) *Propontocypris* sp. 1
 (4) *Propontocypris* sp.
 (3) *Pterygocythereis jonesii* (Baird 1850)
 (4) *Pterygocythereis siveteri* Athersuch 1978
 (4) *Sagmatocythere concentrica* (Bonaduce et al. 1976)
 (4) *Sagmatocythere littoralis* (G.W. Müller 1894)
 (4) *Sagmatocythere* aff. *S. littoralis* (G.W. Müller 1894)
 (4) *Sagmatocythere moncharmonti* (Ciampo 1972)
 (4) *Sagmatocythere versicolor* (G.W. Müller 1894)
 (4) *Sagmatocythere* sp.
 (4) *Sclerochilus* aff. *S. dubowsky* Marinov 1962
 (4) *Sclerochilus gewemuelleri* Dubowsky 1939
 (4) *Sclerochilus* sp. 1
 (4) *Sclerochilus* sp.
 (4) *Semicytherura acuticostata* (G.O. Sars 1866)
 (4) *Semicytherura alifera* Ruggieri 1959
 (4) *Semicytherura dispar* (G.W. Müller 1894)
 (4) *Semicytherura inversa* (Seguenza 1880)
 (4) *Semicytherura mediterranea* (G.W. Müller 1894)
 (4) *Semicytherura quadridentata* (Hartmann 1953)
 (4) *Semicytherura rara* (G.W. Müller 1894)
 (4) *Semicytherura rarecostata* Bonaduce et al. 1976
 (4) *Semicytherura ruggierii* (Pucci 1955)
 (4) *Semicytherura* sp. 1
 (2) *Urocythereis favosa* (Roemer 1838)
 (2) *Xestoleberis communis* G.W. Müller 1894
 (2) *Xestoleberis parva* G.W. Müller 1894
 (2) *Xestoleberis* sp. 1

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