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THE OSTRACODS IN THE PALAEOENVIRONMENTAL INTERPRETATION OF THE LATE LANGHIAN - EARLY SERRAVALLIAN SECTION OF RAS IL-PELLEGRIN (MALTA)

GIOACCHINO BONADUCE & DIANA BARRA

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Riassunto. La distribuzione degli ostracodi della sezione composita langhiano-serravalliana di Ras il Pellegrin (Malta) è stata studiata quantitativamente con lo scopo di definire l'evoluzione delle associazioni e delle condizioni paleoambientali. Sono stati esaminati 99 campioni raccolti ad una distanza stratigrafica di circa 1 m. Sono state identificate 78 specie la cui associazione dimostra un ambiente epibatiale corrispondente ad una profondità di circa 500-700 m. In particolare la quasi costante presenza del genere *Oblitacythereis* che caratterizza masse d'acqua giusto al di sopra della psicrosfera e l'assoluta assenza del genere psicrosferico *Agrenocythere* confermano questa interpretazione. La drastica riduzione sia della diversità semplice che dell'abbondanza di individui circa al limite tra le "Upper Globigerina Limestone" e le "Blue Clays" che diventa più accentuata al tetto della successione, a nostro avviso è correlabile con il decremento dell'ossigeno disciolto al fondo come anche confermato dalle Cytherellidae.

Abstract. The distribution of ostracods in the composed Langhian - Serravallian section of Ras il Pellegrin (Malta) has been studied quantitatively to define the evolution of both the assemblages and the palaeoenvironmental conditions. 99 samples have been examined at a stratigraphic distance of about 1 m. 78 species have been identified whose assemblages indicate an epibathyal environment and a sedimentation depth of 500-700 m. In particular, the almost continuous occurrence of the genus *Oblitacythereis*, which characterizes the water layer just above the psychrosphere, together with the absolute absence of the psychrospheric genus *Agrenocythere* confirm this interpretation. The sudden drop of both the simple diversity and abundance near the boundary "Upper Globigerina Limestone" - "Blue Clays" Formations, especially at the top of the succession, in our opinion may be due to the the decrease of dissolved bottom oxygen content as supported also by the Cytherellidae.

Introduction

The purpose of the present paper is to give a palaeoecological interpretation of the composed Ras il-Pellegrin section (Malta), ranging from the late Langhian to the early Serravallian (Fig. 1).

The biostratigraphy, based on planktonic foraminifera and calcareous nanno fossil events recognized by Foresi et al (2002) follows the scheme of Sprovieri et. al. (2002). The part of the section pertaining to the Globigerina Limestone Formation has been attributed to the *Praeorbulina glomerosa* Zone (MMi 4) pars (0-9.60 m) and to the *Orbulina suturalis - Globorotalia peripheroronda* Zone (MMi 5) pars (9.60-22 m). The sediments of the Blue Clays Formation has been assigned to the *O. suturalis - G peripheroronda* Zone (MMi 5) pars (0-16.97 m), *Dentoglobigerina altispira altispira* Zone (MMi 6) (16.97-52.82 m) and *Paragloborotalia partimlabiata* Zone (MMi 7) (52.82-68.75 m). The Langhian - Serravallian boundary has been placed approximately at the level of the disappearance of *Sphenolitus heteromorphus* (Rio et al. 1997) which occurs at 7.31 m above the "Blue Clays" base (Barra et al. 1999). A hiatus has been suggested to occur in the Langhian near the boundary between the "Upper *Globigerina* Limestone" and the "Blue Clays" (Sprovieri, pers. comm.).

Data on the deep water ostracods of the Mediterranean area, regarding the stratigraphic range here cited, are rare. The ostracods of the Ragusa area were doubtfully attributed to the Langhian by Ruggieri (1960). Oertli (1961) described the ostracod fauna of the Langhian type section of Bricco della Croce (Piedmont, Northern Apennines). Russo & Bossio (1976) afforded the study of the ostracod fauna of the Malta Archipelago in the Aquitanian - Messinian interval especially from a stratigraphic point of view, establishing 8 assemblages temptatively correlated with the foraminiferal plankton stratigraphy of Giannelli & Salvatorini (1972, 1974). Benson (1978) studied the distribution of the bathyal ostracods from the Burdigalian to the Pliocene in the D.S.D.P. Site 372 of the Alghero - Provençal Basin, while Ciampo (1981) studied the interval late Oligocene - Serravallian of Monte Cammarata and of the Ragusa area (Sicily). Most of the cited papers concentrate their attention on the stratigraphy and/or the systematics,

Dipartimento di Scienze della Terra, Università di Napoli "Federico II", Largo San Marcellino 10, 80138 Napoli, Italy. E-mail: dibarra@unina.it

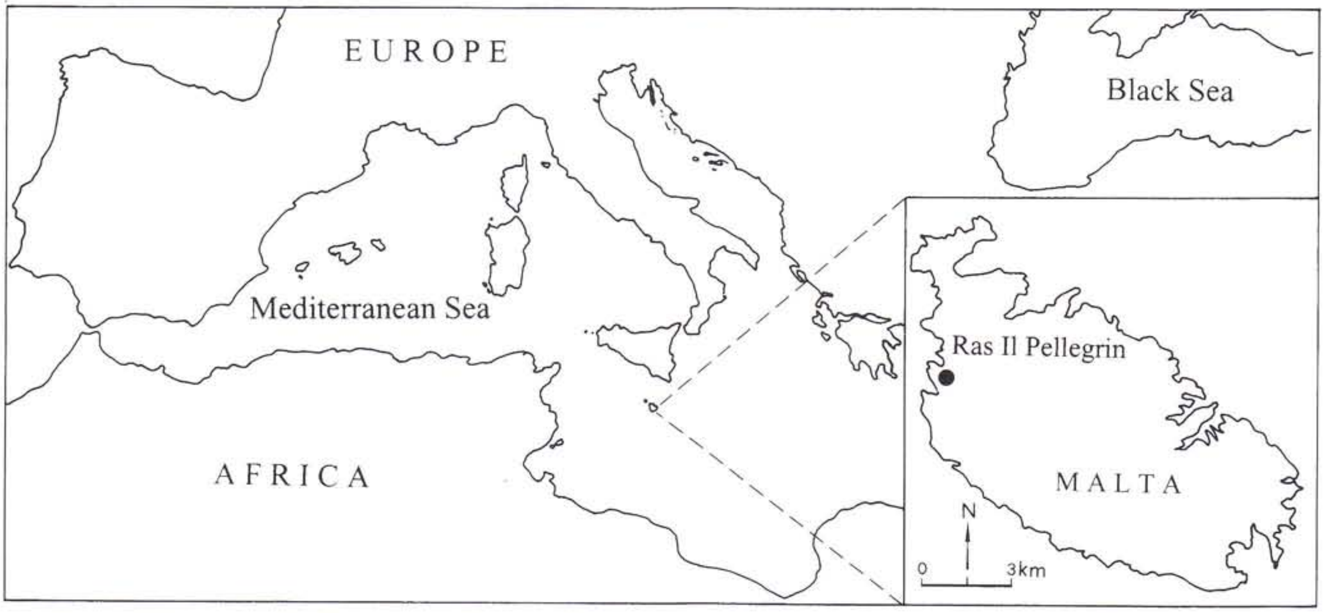

Fig. 1 - Location map of the Ras il-Pellegrin section.

with the description of a certain number of new species and only with generalized palaeoecological comments.

The scarceness of literature (as cited above) regarding the late Langhian and part of the Serravallian and the high number of species left in open nomenclature by previous Authors brought us to a revision of the systematics of the species found and to a greater definition of their palaeoecological interpretation describing 6 new species (Barra & Bonaduce 2001).

Material and methods

For the present study we examined quantitatively a total of 99 samples, spaced at a stratigraphic distance of about 1 m (Tab. 1). The material was kindly offered by Prof. G. Salvatorini (University of Siena). Most of the samples showed a weight of 200 g. The total picking of the ostracod fauna derived from the fraction > 125μm. Smaller samples were standardized to 200 g.

The number of specimens of each species has been obtained adding to the higher number between right or left valves the number of complete carapaces. The ostracod fauna found was constituted by 78 species, 53 of which have been identified or tentatively identified while the remaining 25 were left in open nomenclature because of the scarce or poorly preserved material. The complete list is reported in the systematic appendix.

For each sample the number of adult specimens and the number of species were taken into account and the quantitative stratigraphical distribution of all the species is reported in Tab. 2.

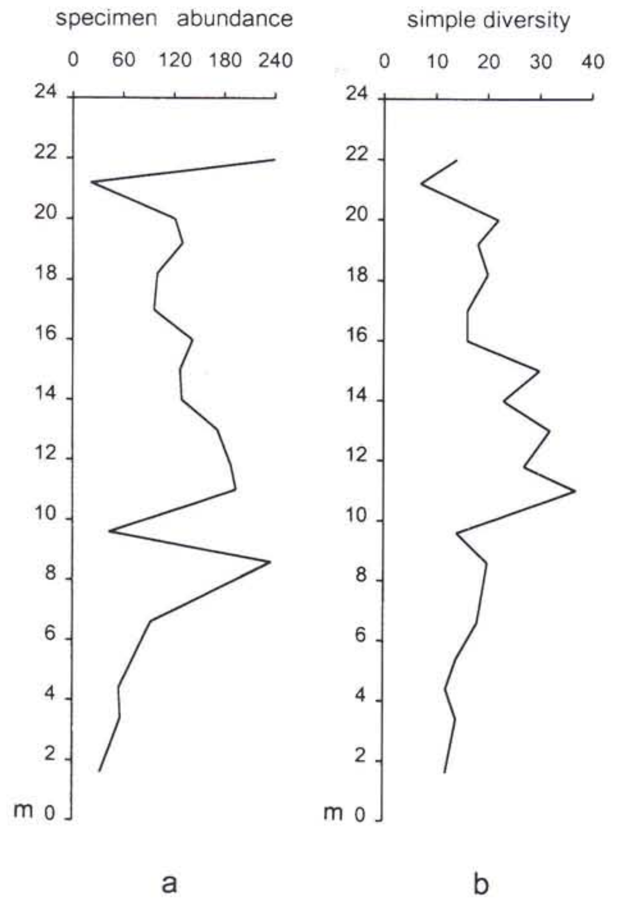

Fig. 2 - Number of specimens (a) and species (b) in the Upper Globigerina Limestone Formation; in x-axis represent the number of specimens.

UPPER GLOBIGERINA LIMESTONE		
SAMPLES	METERS	WEIGHT
ML 08	1.60	200
ML 017	3.40	130
ML 022	4.40	150
ML 027	5.40	150
ML 033	6.60	90
ML 043	8.60	200
ML 048	9.60	200
ML 055	11.00	200
ML 059	11.80	150
ML 065	13.00	200
ML 070	14.00	90
ML 075	15.00	150
ML 080	16.00	100
ML 085	17.00	100
ML 091	18.20	100
ML 096	19.20	80
ML 0100	20.00	150
ML 0106	21.20	200
ML 0110	22.00	50

BLUE CLAYS		
SAMPLES	METERS	WEIGHT
ML 1	0.00	200
ML 11	1.49	200
ML 21	3.02	200
ML 31	4.56	200
ML 41	6.09	200
ML 51	7.62	200
ML 61	9.15	200
ML 71	10.68	200
ML 81	12.22	200
ML 91	13.75	200
ML 101	15.28	200
ML 106	16.04	200
ML 111	16.81	200
ML 117	17.73	200
ML 121	18.34	200
ML 126	19.11	200
ML 131	19.88	200
ML 136	20.64	200
ML 141	21.41	200
ML 146	22.17	200
ML 151	22.94	200
ML 156	23.71	200
ML 161	24.47	200
ML 166	25.24	200
ML 176	26.77	200
ML 182	27.69	200
ML 186	28.30	200
ML 191	29.07	200

BLUE CLAYS		
SAMPLES	METERS	WEIGHT
ML 196	29.83	200
ML 201	30.60	200
ML 206	31.37	200
ML 211	32.13	200
ML 216	32.90	200
ML 221	33.66	200
ML 226	34.43	200
ML 231	35.20	200
ML 236	35.96	200
ML 241	36.73	200
ML 246	37.49	200
ML 251	38.26	200
ML 256	39.03	200
ML 261	39.79	200
ML 266	40.56	200
ML 271	41.32	200
ML 276	42.09	200
ML 281	42.86	200
ML 286	43.62	200
ML 291	44.39	200
ML 296	45.15	200
ML 301	45.92	200
ML 306	46.69	200
ML 311	47.45	200
ML 316	48.22	200
ML 321	48.98	200
ML 326	49.75	200
ML 331	50.52	200
ML 336	51.28	200
ML 341	52.05	200
ML 346	52.81	200
ML 351	53.58	200
ML 356	54.35	200
ML 500	54.61	50
ML 505	55.42	50
ML 510	56.19	50
ML 515	56.95	50
ML 520	57.71	50
ML 525	58.48	50
ML 530	59.25	50
ML 535	60.01	200
ML 540	60.78	50
ML 545	61.55	200
ML 550	62.31	50
ML 555	63.08	50
ML 560	63.85	200
ML 565	64.61	200
ML 570	65.37	200
ML 575	66.14	50
ML 580	66.91	200
ML 585	67.68	200
ML 590	68.44	200

Tab. 1 - List of the samples studied with meters and dry weights (in gram).

Data

Ostracod abundance and diversity in the "Upper Globigerina Limestone" Formation

The basal 7 samples (0-22 m) pertain to the *P. glomerosa* Zone and the following 12 samples to the *G. peripheroronda* Zone of the "Upper Globigerina Limestone" Formation. The segment studied was characterized by 69 species, 41 of which belonging to this biozone. The trends of the simple diversity and total specimen abundance per sample are plotted in Fig. 2. This segment is characterized by the highest diversity and abundance of all the studied section with an average of 119 specimens per sample. A first interval from the base up to 6.6 m shows an average value of 62 specimens per sample; a second interval (6.6 - 16 m), with higher abundance, 154 specimens per sample where a maximum of 236 specimens is reached (sample ML 043 at 8.6 m from the base) and a third and last interval with 119 specimens with a peak of 248 specimens (sample ML 0110 at 22 m from the base) (Fig. 2a).

The diagram representing the simple diversity (Fig. 2b) shows almost exactly the same trend of that described for the specimen abundance. We noted 19 species per sample in average, and higher diversity in the interval 11-15 m from the base with 30 species per sample in average. Only in two samples (ML 043 and ML 0110), in which the highest number of specimens has been found, a corresponding specific diversity has not been registered.

Distribution of ostracods in the Upper Globigerina Limestone Formation

The quantitative distribution of the most significative species is shown in Fig. 3. In the "Upper Globigerina Limestone" *Bairdoppilata conformis* (Te-rquem, 1878) appears the dominant species with higher abundance in the interval between 8.6 and 13 m. A similar distribution is shown by *Henryhowella sarsii profunda* Bonaduce, Barra & Aiello, 1999. *Australoecia posterocurva* Barra & Bonaduce, 2001, *Puricytheretta melitensis* Russo & Bossio, 1975, *Ruggieria caudoflexa* Barra & Bonaduce, 2001 and *Buntonia dertonensis* Ruggieri, 1954 are also present in this segment but less abundant and with strong fluctuations.

Acanthocythereis hystrix (Reuss, 1850), *Cytherella vulgata* Ruggieri, 1962, *Grinioneis pirata* (Ruggieri, 1960), *Ruggieria tetraptera* (Seguenza, 1880) and *Cytherella vulgatella* Aiello, Barra, Bonaduce & Russo, 1996 are better represented between 6.6 m to about 15 m. *Buntonia multicostata* Ruggieri, 1962, *Retibythere (B.) vandenboldi* (Ruggieri, 1960), *Krithe* spp. are almost esclusively to this interval while *Trachyleberidea lanceolata* Barra & Bonaduce, 2001 seems almost absent.

The genera *Cytherella* Jones, 1849 and *Parakrithe* van den Bold, 1958 occur in different samples with the highest number of species (9 and 11 respectively).

	AGE	LANGHIAN																																								
	FORMATIONS	Upper Globigerina Limestone																																										
	BIOZONES	*P. glomerosa* (MMi 4)						*Orbulina suturalis - Globorotalia peripheroronda* Zone (MMi 5)																																				
N°	SPECIES / SAMPLES	8	17	22	27	33	43	48	55	59	65	70	75	80	85	91	96	100	106	110	1	11	21	31	41	51	61	71	81	91	101	106	111	117	121	126	131	136	141	146	151	156	161	16
	meteres	1.6	3.4	4.4	5.4	6.6	8.6	9.6	11	11.8	13	14	15	16	17	18.2	19.2	20	21.2	22	0	1.49	3.02	4.56	6.09	7.62	9.15	10.68	12.22	13.75	15.28	16.04	16.81	17.73	18.34	19.11	19.88	20.64	21.41	22.17	22.94	23.71	24.47	25.2
1	*Acantocythereis hystrix*	1	1		1		26j	2	14j	17j	9j	1	12j	5j	1	3j	2	10j	6	7			2	7		1	8	11	4			3	2	3	1	16j	6j	9j	18	2	12j		5	3
2	*Henryhowella sarsii profunda*	3	5		4	4	34j	5	16j	10j	13j	2	2j	4j	1	3j	7j	14j	6j	9j	2j	3j	2	3j					1									6j	6j	1			2j	1
3	*Cytherella vulgata*	3		2			18j	6	14j	13j	5	6	9j	7j	6j	4j	2j	5	4	14j			1				1		4					6	6	7	4	3j	7j	2	5	4	10j	1
4	*Bairdoppilata conformis*	11	7	13	17j	12j	60j	13j	42j	31j	53j	13	27j	23j	12	8j	11j	20j						1					2			1		1					2		1	2	3	1
5	*Australoecia posterocurva*	1	3	2	5		4		3	2	8		5	7	9j	5	3	2																										
6	*Cytherella circumpuncata*	2	3			1	8j		5j	1	6j	3j		3j	1	2		3	1	4	1																				1			
7	*Parakrithe dactylomorpha*	1	4		1	1		2	3	5	1																1																3	
8	*Puricytheretta melitensis*	1	3	4	6	3	6		1	3	8	1	3	2	1j	2	1	5		1				1																				
9	*Xestoleberis prognata*	1			1				1	4		1		1		2	3	1	1																	1							1	
10	*Ruggieria caudoflexa*	2		5	2j	1	6		2	2	3	1j	1	5	1	2j		3					1	1																				
11	*Cytherella ? vandenboldi*	5	1	5	5	1			1		1			1	4j	1		1																										
12	*Buntonia multicostata*	2	1	2			2	2	6	3	2		1																															
13	*Oblitacythereis (P.) bossioi*		2			1		1	1												1							1											1		1			
14	*Buntonia dertonensis*		4	2		1	4		3		3	6	1		1	1	2	1									1											1					1	
15	*Grinioneis pirata*		1		3j	4	30j	3	12j	7	16j	5	3j	3j	1j	5	6	10	1																									
16	*Trachyleberidea lanceolata*	Trac	Trac	1	1	2	6						2	2	1	3	2	3																										
17	*Ruggieria tetraptera*			1j	1	1	10j	2	4	10	6	1	1j	2			1j			6	2			1	1		2	1	6					3	1	3	3	3	5	1	1		5j	
18	*Cytherella fovea*			3	5	2j		1			1																																	
19	*Retibythere (B.) vandenboldi*				2	1	4	1	2		5		3j			1																												
20	*Cytherella vulgatella*					4	8	3	13j	14j	8j	1		3j	1	2j	4j	3		10j	3j		2	5j		2	4j	7j	7			1		2	3	11	2j	7j	5	3	3	1	12j	1
21	*Parakrithe rotundata*					1	4		3		4	1	2	2	5	1	2	2		3														1										
22	*Eucythere curta*					1												2																										
23	*Parakrithe* sp. 1					1																																						
24	*Krithe iniqua*						1		24j	2	4	3j	1							1														2					1					
25	*Paijenborchella solitana*						2																																					
26	*Krithe compressa*						1		2j				3																															
27	*Paleocosta ocellata*						2		1																																			
28	*Cytherelloidea ? creutzburgi*							1	1	2	1	1		1		1				3																								
29	*Palmoconcha* sp. 1							1	1	1																																		
30	*Pseudopsammocythere kollmanni*								1			1																																
31	*Paracypris* sp. 1								3	2	2																																	
32	*Cytherella vandenboldi*								1											1																								
33	*Argilloecia spissa*								1		1		1			1	1	1																										
34	*Paijenborchella iocosa*								1	1	1	1	1				1	1																										
35	*Microcythere (?) sp. 1*								1								1																											
36	*Argilloecia kissamovensis*								4	2	1		1																															
37	*Chrysocythere paradisus*								1	3j	1	2j																																
38	*Propontocypris solida*								1	1																																		
39	*Argilloecia acuminata*								1																																			
40	*Microcythere (?) sp. 2*								1																																			
41	*Parakrithe ? iuliani*								2																																			
42	*Parakrithe* sp. 2								1																																			
43	*Eucytherura bicornuta*									1										1																								
44	*Parakrithe ambigua*									1	1				1		1																											
45	*Bairdoppilata profunda*									1	1j	1	4j																															
46	*Parakrithe* sp.									1																																		
47	*Platyleberis profunda*									1																																		
48	*Pterygocythereis siveteri*										1							1	2				1																					
49	*Argilloecia micra*										1																																	
50	*Incongruellina (Lixouria) marginata*										2	2												1																			1	
51	*Cytheropteron rectum*										1																																	
52	*Incongruellina (Lixouria) keiji*										2																																	
53	*Parakrithe ariminensis*											2	1					1						2				1																
54	*Parakrithe lamellosa*											2	1																															
55	*Parakrithe* sp. 3											1																																
56	*Bythocypris obtusata producta*												1j					1																										
57	*Pterygocythere (?) iblea*												1																															
58	*Cytherella cercinata*												2																															
59	*Krithe* sp. 1												1																															
60	*Macrocypris* sp. 1												2																															
61	*Macrocypris* sp. 2												2																															
62	*Paracypris* sp. 2												1																															
63	*Rectobuntonia hilaris*														2																								1		1			
64	*Anchistrocheles (?) sp.*															1																												
65	*Monoceratina praeoblita*															2																												
66	*Cytherella postdenticulata*																2			1																								
67	*Parakrithe dimorpha*																	1																										
68	*Occultocythereis ? dohrni*																			1																								
69	*Typhloeucytherura* sp. 1																			1																								
70	*Cytherella robusta*																											1																
71	*Xestoleberis ? glabrescens*																																						1					
72	*Pterygocythereis* sp.																																										1	
73	*Krithe* sp.																																											
74	*Krithe keyi*																																											
75	*Incongruellina (Lixouria)* sp.																																											
76	*Krithe undecimradiata*																																											
77	*Krithe* sp. 2																																											
78	*Argilloecia* sp.																																											

Tab. 2 - Stratigraphic distribution of the ostracod taxa in the Ras il-Pellegrin section (Malta); j = juveniles; the number before the species name s

Ostracod abundance and diversity in the "Blue Clays" Formation

A total of 80 samples have been studied in the "Blue Clays" for a total thickness of 68.44 m, 13 of which in the *Orbulina suturalis - Globorotalia peripheroronda* Zone (MMi 5), 46 in the *Dentoglobigerina altispira altispira* Zone (MMi 6) and 21 in the *Paragloborotalia partimlabiata* Zone (MMi 7). 37 species characterize these sediments, only 9 of which pertaining exclusively to the Serravallian interval of the section. Generally the assemblages of the Blue Clays are poor to very poor both in abundance and in diversity. Five samples mostly from the topmost part of the succession did not yield any ostracod. The average values correspond to 22 specimens and 6 species per sample respectively (Fig. 4 a-b).

A long interval (19.11 to 48. 22 m from the base of the Blue Clays) with a relatively higher abundance and diversity has been identified, even with strongly fluctuating values. An average of 28 specimens with 7 species per sample has been registered in this interval with 2 peaks at 27.54 m (71 specimens and 12 species) and at 34.43 m (67 specimens and 14 species). Very low values are recorded both above and below the cited interval: an average of 10 specimens and 4 species per sample in the interval from the base to 18.34 m and 12 specimens and 3 species from 54. 61 m to the top of the sections.

SERRAVALLIAN																																																						
Blu Clays																																																						
Dentoglobigerina altispira altispira Zone (MMi 6)																																		*Globorotalia partimlabiata* Zone (MMi 7)																				
182	186	191	196	201	206	211	216	221	226	231	236	241	246	251	256	261	266	271	276	281	286	291	296	301	306	311	316	321	326	331	336	341	346	351	356	500	505	510	515	520	525	530	535	540	545	550	555	560	565	570	575	580	585	590
27.54	28.15	29.07	29.83	30.60	31.37	32.13	32.90	33.66	34.43	35.20	35.96	36.73	37.49	38.26	39.03	39.79	40.56	41.32	42.09	42.86	43.62	44.39	45.15	45.92	46.69	47.45	48.22	48.98	49.75	50.52	51.28	52.05	52.81	53.58	54.35	54.61	55.42	56.19	56.95	57.71	58.48	59.25	60.01	60.78	61.55	62.31	63.08	63.85	64.61	65.22	66.14	66.91	67.68	68.44
17j	17j	5j	23j	3		10j	8j	4	10	13j		13j	3	4j	4	27j	21j	8		15j	29j	8j	24j	3	23j	16	33j	5	4	2	6		16	7	19	2	2			2			3		13j	2				3		3		4
1j			1j			3j	1	4	10j	6j			3				1			4j		2j				6	2																				1							1
14	3		6			3j	1	2	8j	7j	1	2		4	2	5	5	3	1	1	4	1	5j	1	6	6	5	1		1	5		3	1	2	1			3			1		1	3	4	3	2		2		3	1	
12	1		2			2	7	2	9j	6	4	1			1		1	1			1		1				1									1								2	2		3	2				1		
																																														1								
2	1		1							1j						1							1								1																							
																							2			1	4	1																										
1										1																																												
4			1																																																			
6j			1					1	4	1					1		3			3	5		1		5	1	1																											2
1																							1																															
8		3	2	1		2	3j	3	3	4	3	2	1			2j	4	3	1	2			1	2	4	1	2			1	3		5		3	1	1	1	1		1		2	1	6	1		7		2	1	1	1	2
4									2														1		2																													
	2	3	5j	2		3j	3j	4	7j	3		3	2	4j	1	2	6j			3	5		12j		3								1			1					1				1	3	2	3		1	1	1	2	
		3												2	1	2				1		1			1	1	5								2																			
	2	2	4	1		3		3	2	2	2											3	1	2	7																											1		
																							1																															
																						1									1																							
								1	2							1			1												1																							
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the correspondence with the species appendix.

Distribution of ostracods in the "Blue Clays" Formation

In the "Blue Clays" *Acanthocythereis hystrix* is constantly present and frequently dominant followed by *Cytherella vulgatella* with a trend very similar to that shown by the total number of specimens. *Cytherella vulgata* and *Ruggieria tetraptera* are generally registered in the studied segment even with lower abundance per sample and with evident fluctuations (Fig. 5).
Bairdoppilata conformis, Henryhowella sarsii profunda, Oblitacythereis (Paleoblitacytereis) bossioi Dall'Antonia, 2000, *Krithe iniqua* Abate, Barra, Aiello & Bonaduce, 1993 and various species of *Parakrithe*, scarcely represented up to about 20 m, occur with a relative abundance from 20 to 50 m, while they are pratically absent above in the succession (Fig. 5).

Palaeobathymetry

A reduced number of species with defined bathymetric range occurs in the studied section.

Henryhowella sarsii profunda, one of the more abundant taxa, occurs in the bathyal of both the Mediterranean and Atlantic from Miocene to Recent as pointed out by Bonaduce et al. (1999).

The following species are exclusively represented in the Langhian part of the section: *Krithe compressa* (Seguenza 1880) (synonym *Krithe* sp. 5 Whatley & Quanhong 1993) which has been found alive deeper than 900 m in the South China Sea (Whatley & Quan-

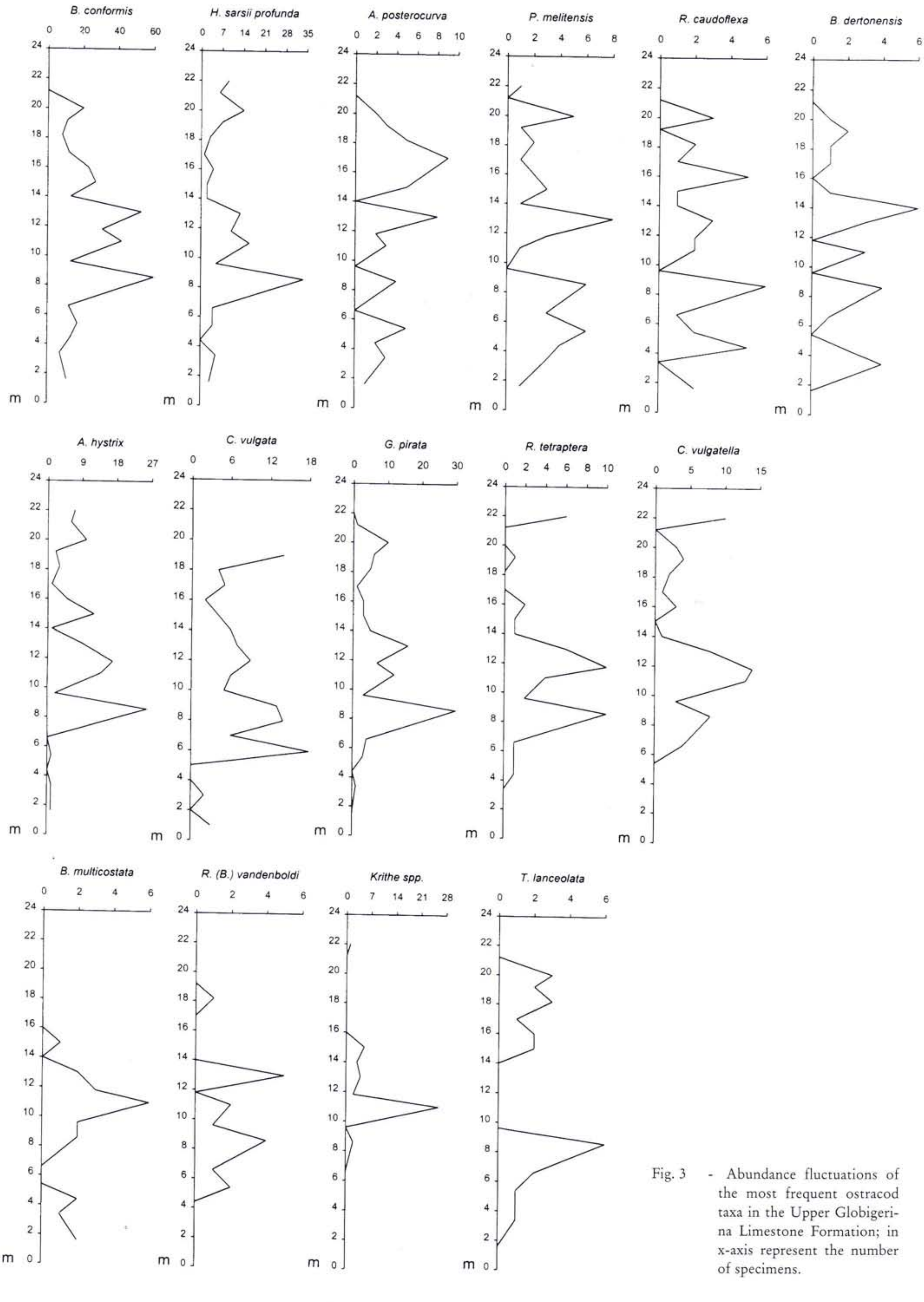
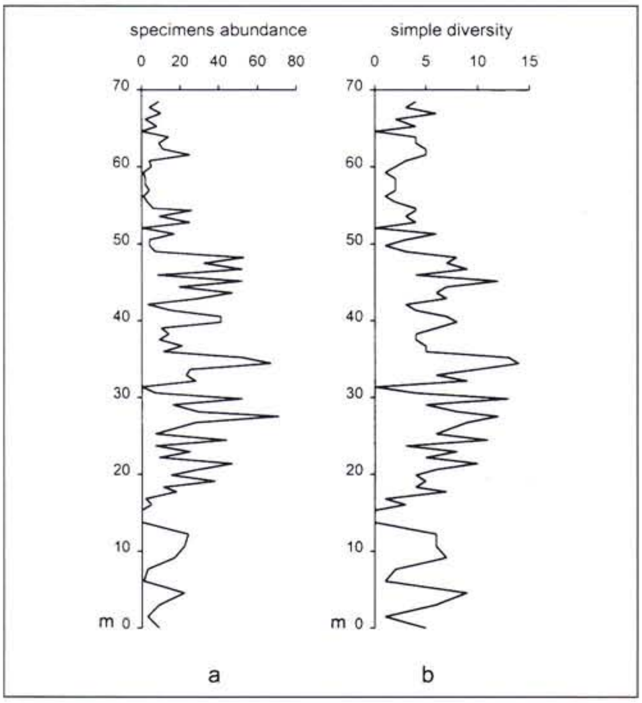


Fig. 3 - Abundance fluctuations of the most frequent ostracod taxa in the Upper Globigerina Limestone Formation; in x-axis represent the number of specimens.



hong 1993), *Paijenborchella iocosa* Kingma 1948 "slender form" as reported by Barra et al. (1998) and by Aiello et al. (2000) found in Recent bathyal setting of the South China Sea deeper than 500 m (Keij 1966) and *Platyleberis profunda* (Breman 1975) which occurs in the Recent of the Gulfs of Naples and Taranto deeper than 200 m, in the Caribbean Sea at 720 m, in the upper bathyal assemblage of Ain el Beida (Tortonian - Messinian of Morocco) and in the bathyal Holocene of the Alboran Sea (Abate et al. 1994). *Cytherella robusta* Colalongo & Pasini 1980 (= *Cytherella* sp. B Cronin 1983), found in Recent sediments of the Florida Straits from 500 to 1000 m depth, appears very rare in *O. suturalis - G. peripheroronda* Zone.

Together with the previous species, some others, represented almost exclusively in the fossil record also allow us to confirm a deep marine environment. They are *Krithe iniqua, Krithe undecimradiata* Ruggieri, 1974, *Argilloecia kissamovensis* Sissingh 1972, *Parakrithe dimorpha* Bonaduce, Ciampo & Masoli, 1976 and *Xestoleberis prognata* Bonaduce & Danielopol, 1988,

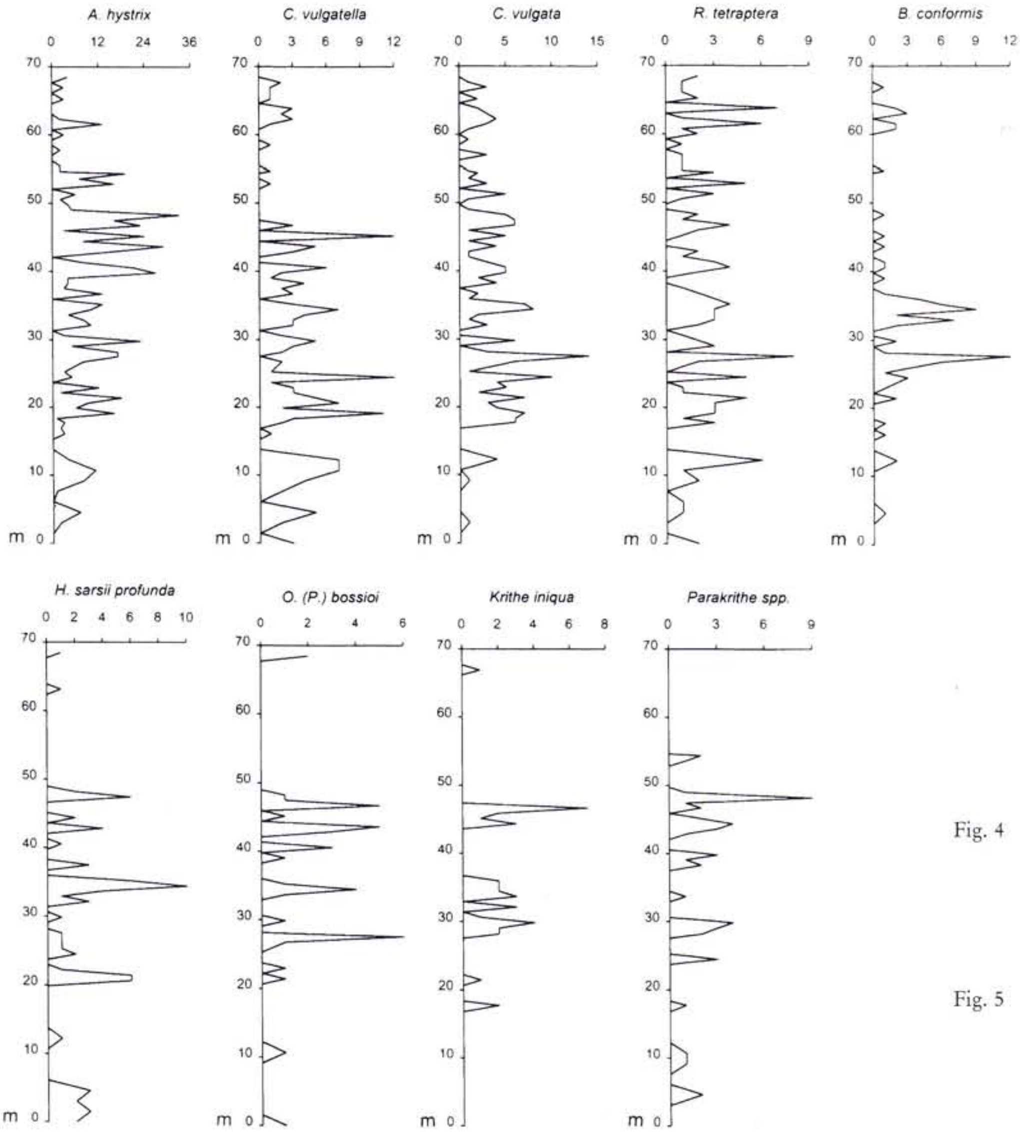


Fig. 4 - Number of specimens (a) and species (b) in the "Blue Clays" Formation; in x-axis represent the number of specimens.

Fig. 5 - Abundance fluctuations of the most frequent ostracod taxa in the "Blue Clays" Formation; in x-axis represent the number of specimens.

Exclusive of U.G. Limestone	Exclusive of Blue Clays	In common of U.G.L. and B.C.
Anchistrocheles (?) sp.	*Argilloecia* sp.	*Acantocythereis hystrix*
Argilloecia acuminata	*Cytherella robusta*	*Argilloecia micra*
Argilloecia kissamovensis	*Incongruellina (L.)* sp.	*Australoecia posterocurva*
Argilloecia spissa	*Krithe keyi*	*Bairdoppilata conformis*
Bairdoppilata profunda	*Krithe undecimradiata*	*Buntonia dertonensis*
Buntonia multicostata	*Krithe* sp. 2	*Bythocypris obtusata producta*
Chrysocythere paradisus	*Krithe* sp.	*Cytherella circumpunctata*
Cytherella cercinata	*Pterygocythereis* sp.	*Cytherella fovea*
Cytherella postdenticulata	*Xestoleberis ? gabrescens*	*Cytherella vulgata*
Cytherella vandenboldi		*Cytherella vulgatella*
Cytherella ? vandenboldi		*Eucytherura bicornuta*
Cytherelloidea ? creutzburgi		*Henryhowella sarsii profunda*
Cytheropteron rectum		*Incongruellina (L.) marginata*
Eucythere curta		*Krithe iniqua*
Grinioneis pirata		*Oblitacythereis (P.) bossioi*
Incongruellina (L.) keiji		*Paijenborchella solitaria*
Krithe compressa		*Paracypris* sp. 1
Krithe sp. 1		*Parakrithe ariminensis*
Macrocypris sp. 1		*Parakrithe dactylomorpha*
Macrocypris sp. 2		*Parakrithe lamellosa*
Microcythere (?) sp. 1		*Parakrithe rotundata*
Microcythere (?) sp. 2		*Pseudopsammocythere kollmanni*
Monoceratina praeoblita		*Pterygocythere* (?) *iblea*
Occultocythereis ? dohrni		*Pterygocythereis siveteri*
Paijenborchella iocosa		*Puricytheretta melitensis*
Paleocosta ocellata		*Rectobuntonia hilaris*
Palmoconcha sp. 1		*Ruggeria caudoflexa*
Paracypris sp. 2		*Ruggeria tetraptera*
Parakrithe ambigua		*Xestoleberis prognata*
Parakrithe dimorpha		
Parakrithe ? iuliani		
Parakrithe sp. 1		
Parakrithe sp. 2		
Parakrithe sp. 3		
Parakrithe sp.		
Platyleberis profunda		
Propontocypris solida		
Retibythere (B.) vandenboldi		
Trachyleberidea lanceolata		
Typhloeucytherura sp. 1		
Typhloeucytherura sp. 2		

Tab. 3 - List of the species exclusive of the "Upper Globigerina Limestone", the "Blue Clays" and in common with both formations.

Tab. 4 - Stratigraphic range in the Mediterranean of species previously known in literature whose occurrences in the section enlarge their stratigraphic distribution.

SPECIES	STRATIGRAPHICAL RANGE		
	PRESENT PAPER	PREVIOUS DATA	REFERENCES
Argilloecia kissamovensis	Langhian	Tortonian - Pliocene	Sissingh 1972; Bonaduce & Sprovieri 1985; Ciampo 1992; Barra et al. 1996
Argilloecia micra	Langhian - Serravallian	Early Pleistocene - Recent	Bonaduce et al. 1976; Barra et al. 1993
Argilloecia spissa	Langhian	Pliocene (from M Pl 5) - Early Pleistocene	Barra et al. 1996
Bairdoppilata conformis	Langhian - Serravallian	Late Pliocene - Holocene	Aiello et al. 2000
Buntonia multicostata	Langhian	Tortonian - Messinian	Ruggieri 1962; Dieci & Russo 1965; Ruiz & Gonzalez-Regalado 1996
Cytherella circumpunctata	Langhian - Serravallian	Messinian - Pleistocene	Aiello et al. 1996
Cytherella postdenticulata	Langhian	Langhian	Oertli 1961
Cytherella robusta	Serravallian (*G. peripheroronda* Zone)	Pliocene - Pleistocene	Aiello et al. 1996
Cytherella vulgata	Langhian - Serravallian	Tortonian	Ruggieri 1962; Aiello et al. 1996
Cytherella vulgatella	Langhian - Serravallian	Tortonian - Recent	Aiello et al. 2000
Cytheropteron rectum	Langhian	Pleistocene	Colalongo & Pasini 1980
Krithe compressa	Langhian	Tortonian - base Holocene	Aiello et al. 2000
Krithe iniqua	Langhian - Serravallian	Pliocene	Barra et al. 1998; Aiello et al. 2000
Krithe undecimradiata	Serravallian (*D. altispira* Zone)	Tortonian - Pliocene (M Pl 5 biozone)	Aiello et al. 2000
Paijenborchella solitaria	Langhian - Serravallian	Tortonian - Middle Pliocene	Ruggieri 1962; Sissingh,1972
Paleocosta ocellata	Langhian	Langhian	Ciampo 1981
Parakrithe ambigua	Langhian	Tortonian - Recent	Aiello et al. 1993
Parakrithe ariminensis	Langhian - Serravallian	Tortonian - Pliocene	Aiello et al. 1993
Parakrithe dactylomorpha	Langhian - Serravallian	Tortonian	Ruggieri 1962; Dieci & Russo 1965; Ciampo 1982
Parakrithe dimorpha	Langhian	Middle Tortonian - Recent	Aiello et al. 1993
Parakrithe lamellosa	Langhian - Serravallian	Pliocene	Aiello et al. 1993
Parakrithe rotundata	Langhian - Serravallian	Pliocene - Pleistocene	Aiello et al. 1993
Platyleberis profunda	Langhian	Pliocene - Recent	Abate et al. 1994
Rectobuntonia hilaris	Langhian - Serravallian	Tortonian - Messinian	Ciampo 1980; Ciampo 1984
Xestoleberis prognata	Langhian - Serravallian	Late Miocene - Pliocene	Ruiz & Gonzalez Regalado 1996; Bonaduce & Danielopol 1988; Abate et al. 1994; Barra et al. 1998

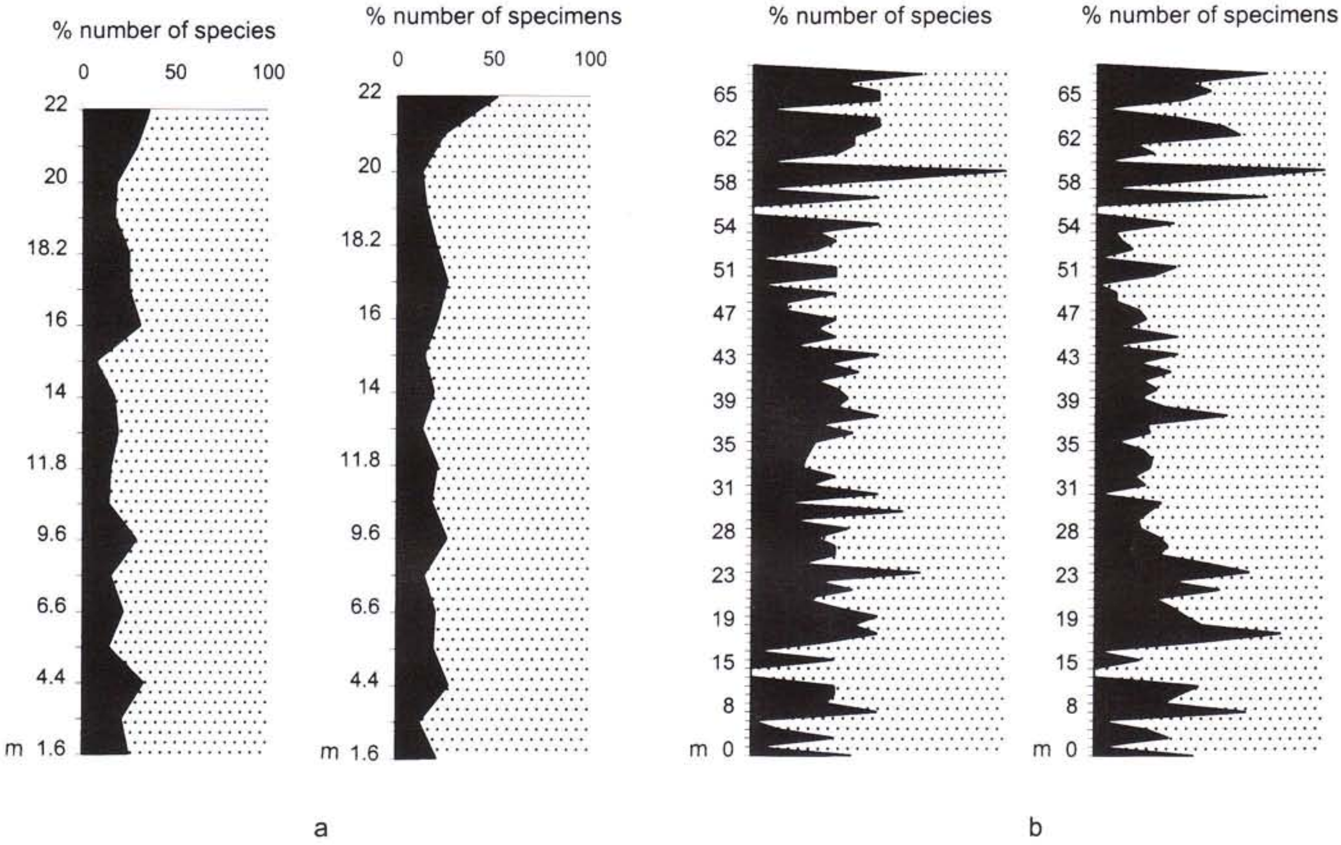


Fig. 6 - Percentages of Cytherellidae in the "Upper Globigerina Limestone" Formation (a) and in the "Blue Clays" Formation (b).

which have been found in the early Zanclean (from M Pl 2 Biozone upwards) of the Capo Rossello area (Sicily) (Barra et al. 1998) and in the Pliocene Monte Narbone Formation of Monte S. Nicola (Gela, Sicily) (Aiello et al. 2000; Bonaduce et al. 2000) associated with *Agrenocythere pliocenica* (Seguenza, 1880), species pertaining to a typically psychrospheric genus able to live in oceanic water masses generally deeper than 1000 m (Benson 1973)..

The occurrence all along the most part of the section of *Oblitacythereis (P.) bossioi* (= *O. (Paleoblitacythereis) ruggierii* sensu Benson 1977) which colonizes the deep water in thermospheric environment just above the psychrosphere (Benson 1977), associated with the previously cited species, confirms a paleobathymetry of 500-700 m or even a little more.

The finding of *Agrenocythere* Benson, 1972 in other Mediterranean areas in the Langhian - Serravallian (e.g. Benson 1978) demonstrates the occurrence of the psychrosphere in the basin at the bottom of deeper environments. The absence of this taxon in our section is due to a shallower depth of sedimentation instead of a drastic change in the Atlantic - Mediterranean connections as suggested by Gebhardt (1999).

Our interpretation agrees with that of Russo & Bossio (1976) for the Malta area.

Meaning of the distribution of the Cytherellidae

In the Upper Globigerina Limestone and the "Blue Clays" Formations the Cytherellidae are generally well represented both in abundance and diversity.

In the Langhian part of the Upper Globigerina Limestone they reach in average 21 % of the total assemblages with almost constant values (Fig. 6a). In the Blue Clays sediments the Cytherellidae represent in average 28 % of the assemblage with 2 intervals, from 17.7 m to 30.6 m and from 54.6 m to the top of the studied section in which they reach respectively percent values of 35 % and 40 % in average (Fig. 6b).

This family is mostly represented by deep-water species. It has been considered, through the study of the anatomy of the respiratory organs, to be able to survive and reproduce during periods of kenoxia or reduced oxygen values (Whatley 1992). Their reproductive strategy allows also to the juveniles to survive during dysaerobic episodes (Boomer & Whatley 1992) while most of the other species of the assemblages are the early victims of the oxygen depletion.

In the minimum oxygen zone of modern oceans platycopid ostracods tend to dominate (Cronin 1983; Dingle et al. 1989). Different studies suggest that a preponderance of platycopids often characterizes stratigraphical intervals which are considered to be representative of dysaerobic conditions: in the Cenomanian/Turonian from Southern England (Jarvis et al. 1988; Horne et al. 1990), in the Cenomanian from Basque Basin (Rodriguez Lazaro et al. 1998), in Late Albian - Early Cenomanian from Navarra, Spain (Lopez-Horgue et al. 1999), in British Liassic (Boomer & Whatley 1992), in Spanish Middle and Upper Liassic (Whatley et al. 1994), in the Early Callovian of the central - western Argentina (Ballent & Whatley 2000).

Consequently, the constant relative abundance of Cytherellidae throughout the succession seems to indicate O2 depauperated bottom waters; the increase in platycopid percentages could be interpreted as a result of a moderately, in the "Upper Globigerina Limestone", to strongly reduced dissolved oxygen in several levels of the Blue Clays Formation.

An oxygen depletion in dissolved oxygen during Serravallian is suggested also by the concomitant decrease in overall ostracod species diversity; in agreement with Boomer & Whatley (1992), with increasing dysaerobia, more and more species, unable to obtain adequate oxygen supply to survive, become locally extinct. In fact, of the total 78 species which characterize the whole succession, only 29 species occur both in the "Upper Globigerina Limestone" and "Blue Clays" while 41 of them are represented exclusively in the Upper Globigerina Limestone (Tab. 3).

Stratigraphic comments on some species

The stratigraphic distribution of all the species identified throughout the section is shown in Tab. 2. Some previously known species, found in this section enlarge their stratigraphic distribution as summarized in Tab. 4.

Of the new species recently described from the section (Barra & Bonaduce 2001) *Australoecia posterocurva, Monoceratina praeoblita, Ruggeria caudoflexa* and *Trachyleberidea lanceolata* seem esclusive of the Langhian while *Cytherella fovea* and *Eucytherura bicornuta* occur also in the Serravallian and exclusively in the *D. altispira altispira* Zone.

The findings of *Cytherella postdenticulata* from Langhian of Piedmont (Oertli 1961) and of *Paleocosta ocellata* from the Langhian of Sicily (Ciampo 1981) and in the Langhian of the investigated section seem to characterize this stratigraphic interval.

Conclusions

The genus *Oblitacythereis* Benson 1977, which usually characterizes the thermospheric layer just above the psychrosphere, occurs in Ras il-Pellegrin section together with a typical deep-water assemblage, thus allowing us to define a sedimentation depth of about 500-700 m, above the boundary between the psychrosphere and the overlying thermosphere.

The high diversity and specimen abundance in MMi 5 and those of many single species (see previous diagrams) demonstrate the relatively high content of dissolved oxygen.

The "Blue Clays", on the other side, show a general drop of oxygen values which become even more evident in the top 20 m of the succession. In our opinion these data demonstrats the decrease of oxygen, possibly due to the increase of the organic productivity in the water column related to sluggish circulation.

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Systematic appendix

All the studied ostracod species are listed below in alphabetical order for genera and species. The number at the left refers to the order followed in Tab. 2.

(1) *Acanthocythereis hystrix* (Reuss, 1850)
(64) *Anchistrocheles* (?) sp.
(39) *Argilloecia acuminata* G.W. Müller, 1894
(36) *Argilloecia kissamovensis* Sissingh, 1972
(49) *Argilloecia micra* Bonaduce, Ciampo & Masoli, 1976
(33) *Argilloecia spissa* Barra, Aiello & Bonaduce, 1996
(78) *Argilloecia* sp.
(5) *Australoecia posterocurva* Barra & Bonaduce, 2001
(4) *Bairdoppilata conformis* (Terquem ,1878)
(45) *Bairdoppilata profunda* Aiello, Barra & Bonaduce, 2000
(14) *Buntonia dertonensis* Ruggieri, 1954
(12) *Buntonia multicostata* Ruggieri, 1962
(56) *Bythocypris obtusata* (Sars 1866) *producta* (Seguenza, 1880)
(37) *Chrysocythere paradisus* Doruk, 1973
(58) *Cytherella cercinata* Aiello, Barra, Bonaduce & Russo, 1996
(6) *Cytherella circumpunctata* Ciampo, 1976
(18) *Cytherella fovea* Barra & Bonaduce, 2001
(66) *Cytherella postdenticulata* Oertli, 1961
(70) *Cytherella robusta* Colalongo & Pasini, 1980
(32) *Cytherella vandenboldi* Sissingh, 1972
(11) *Cytherella ? vandenboldi* Sissingh, 1972
(3) *Cytherella vulgata* Ruggieri, 1962
(20) *Cytherella vulgatella* Aiello, Barra, Bonaduce & Russo, 1996
(28) *Cytherelloidea ? creutzburgi* Sissingh, 1972
(51) *Cytheropteron rectum* Colalongo & Pasini, 1980
(22) *Eucythere curta* Ruggieri, 1975
(43) *Eucytherura bicornuta* Barra & Bonaduce, 2001
(15) *Grinioneis pirata* (Ruggieri, 1960)
(2) *Henryhowella sarsii profunda* Bonaduce, Barra & Aiello, 1999
(50) *Incongruellina (Lixouria) marginata* (Terquem, 1878)
(52) *Incongruellina (Lixouria) keiji* Sissingh, 1972
(26) *Krithe compressa* (Seguenza, 1880)
(24) *Krithe iniqua* Abate, Barra, Aiello & Bonaduce, 1993
(74) *Krithe keyi* Breman, 1978

(76) *Krithe undecimradiata* Ruggieri, 1974
(59) *Krithe* sp. 1
(77) *Krithe* sp. 2
(73) *Krithe* sp.
(75) *Incongruellina (Lixouria)* sp.
(60) *Macrocypris* sp. 1
(61) *Macrocypris* sp. 2
(40) *Microcythere* (?) sp. 1
(35) *Microcythere* (?) sp. 2
(65) *Monoceratina praeoblita* Barra & Bonaduce, 2001
(13) *Oblitacythereis (Paleoblitacythereis) bossioi* Dall'Antonia, 2000
(68) *Occultocythereis ? dohrni* (Puri, 1963)
(34) *Paijenborchella iocosa* Kingma, 1948
(25) *Paijenborchella solitaria* Ruggieri, 1962
(26) *Paleocosta ocellata* Ciampo, 1981
(29) *Palmoconcha* sp. 1
(31) *Paracypris* sp. 1
(62) *Paracypris* sp. 2
(44) *Parakrithe ambigua* Ciampo, 1980
(53) *Parakrithe ariminensis* (Ruggieri, 1967)
(7) *Parakrithe dactylomorpha* Ruggieri, 1962
(67) *Parakrithe dimorpha* Bonaduce Ciampo & Masoli, 1976
(41) *Parakrithe ? iuliani* Aiello, Barra, Abate & Bonaduce, 1993
(54) *Parakrithe lamellosa* Aiello, Barra, Abate & Bonaduce, 1993
(21) *Parakrithe rotundata* Aiello, Barra, Abate & Bonaduce, 1993
(23) *Parakrithe* sp. 1
(42) *Parakrithe* sp. 2
(55) *Parakrithe* sp. 3
(46) *Parakrithe* sp.
(47) *Platyleberis profunda* (Breman, 1975)
(38) *Propontocypris solida* Ruggieri, 1952
(30) *Pseudopsammocythere kollmanni* Carbonnel, 1966
(57) *Pterygocythere* (?) *iblea* Ruggieri, 1960
(48) *Pterygocythereis siveteri* Athersuch, 1978
(72) *Pterygocythereis* sp.
(8) *Puricytheretta melitensis* Russo & Bossio, 1975
(63) *Rectobuntonia hilaris* Ciampo, 1984
(19) *Retibythere (Batibythere) vandendoldi* (Ruggieri, 1960)
(10) *Ruggieria caudoflexa* Barra & Bonaduce, 2001
(17) *Ruggieria tetraptera* (Seguenza, 1880)
(16) *Trachyleberidea lanceolata* Barra & Bonaduce, 2001
(69) *Typhloeucytherura* sp. 1
(71) *Xestoleberis ? glabrescens* (Reuss, 1850)
(9) *Xestoleberis prognata* Bonaduce & Danielopol, 1988

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