Atti Soc. tosc. Sci. nat., Mem., Serie A, 111 (2006)
pagg. 67-74, figg. 5, tab. 1, tav. 1

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PREMILINARY STRATIGRAPHICAL INVESTIGATIONS ON THE MIOCENE SUCCESSIONS OF THE PORTO TORRES BASIN (NORTHERN SARDINIA, ITALY)

Abstract - The following is a brief report on a preliminary micropalaeontological research carried out on the Miocene succession of the Porto Torres Basin (Northwestern Sardinia, Italy). Planktonic foraminifers and ostracods from 12 samples collected in the northeastern side of the basin within marls and marly chaotic beds of unknown – dubitatively Langhian – age have been analyzed. From a biostratigraphic viewpoint assemblages unquestionable allowed us to refer the investigated succession to the upper Burdigalian. The ostracod palaeoecological analysis indicates a depositional setting referable to the intermediate part of the outer neritic zone. In addition, since from a general ostracod standpoint the Mediterranean lower Miocene is relatively unexplored, the new biostratigraphic data obtained from this study are discussed.

Key words - Miocene, Biostratigraphy, Paleoecology, Foraminifera, Ostracoda, Northwestern Sardinia, Italy.

Riassunto - *Indagini stratigrafiche preliminari sulle successioni mioceniche del Bacino di Porto Torres (Sardegna settentrionale, Italia)*. Questa breve nota costituisce uno studio micropaleontologico preliminare sulla successione miocenica affiorante nel Bacino di Porto Torres nelle Sardegna nord-occidentale. Sono stati campionati tre affioramenti nei dintorni di Sennori, costuiti da marne e strati caotici marnosi supposti di età langhiana, per lo studio dei Foraminiferi planctonici e degli Ostracodi. Per quanto concerne lo studio biostratigrafico i dodici campioni raccolti hanno fornito associazioni a Foraminiferi planctonici indicative della Zona a *Globigerinoides trilobus* del Burdigaliano superiore. Le analisi paleoecologiche condotte sugli Ostracodi ed il rapporto plankton/benthos individuano nella parte intermedia della piattaforma esterna l'ambiente relativo ai sedimenti investigati. Questo studio risulta di particolare utilità per la ricostruzione dell'evoluzione dei bacini intracratonici terziari del Blocco Sardo-Corso. Per quanto riguarda gli Ostracodi i dati raccolti risultano particolarmente significativi in quanto per l'area mediterranea gli studi di questi organismi in associazioni del Miocene inferiore, ed in particolare del Burdigaliano, sono scarsi.

Parole chiave - Miocene, Biostratigrafia, Paleoecologia, Foraminiferi, Ostracodi, Sardegna nord-occidentale, Italia.

Introduction

Marine and lacustrine deposits of Miocene age are widespread in Sardinia, ranging from lower Aquitanian to Messinian. In northern Sardinia the Upper Oligocene-Aquitanian deposits are coeval to the calcaline volcanic activity, so that, often, they result in tuffite beds that fill E-W to ENE oriented strike-slip basins (Oggiano *et al*., 1995). Other deposits are essentially carbonates and remarkably younger as their sedimentation started in the upper Burdigalian and, probably, ended in the lower Messinian. These latter deposits post-date both the onset of the huge volume volcanic products and the drifting of the Sardinia-Corsica block. Accordingly, also the basins hosting the post-Burdigalian succession are younger and show a different structural frame: they consist of several NNW-trending half grabens, which display an *en echelon* array from the north to the south of the Island (the so called Sardinian Rift; Cherchi & Montadert, 1982). Hence in Sardinia, during the Miocene, an almost continuous record of depositional events occurred in different sedimentary environments and at different palaeogeographic locations (before and after drifting respectively). Succession investigated in the present work belong to the Porto Torres Basin, which generated in middle-late Burdigalian time during the final stage of the Sardinia drifting, as consequence of the opening of the Balearic back-arc basin (Malinverno & Ryan, 1986; Barroul *et al*., 2004).

Study area and materials

The Porto Torres Basin is a NNW oriented half-graben well detected offshore by seismic profiles (Thomas & Gennessaux, 1986); southward this half graben is connected to the Logudoro basin by mean of an E-W trending transfer zone (Fig. 1; Funedda *et al*., 2000). To the east the basin is bounded by a major fault that caused the uplift of the andesitic massif of Osilo, whereas to the west the basin shallows toward the Nurra structural high, where the Miocene deposits directly lap on the Mesozoic carbonate shelf. The on-land succession of the Porto Torres basin, after the Pliocene uplift, underwent a general northwestward tilting and suffered strong erosion.

The stratigraphical frame of the Porto Torres basin is partially comparable to that of the well-known, adjacent, Logudoro basin (Martini *et al*., 1992; Funedda *et al*., 2000), where two main sequences were evidenced by Mazzei & Oggiano (1990). In the Logudoro basin the first sequence started in the late Burdigalian time;

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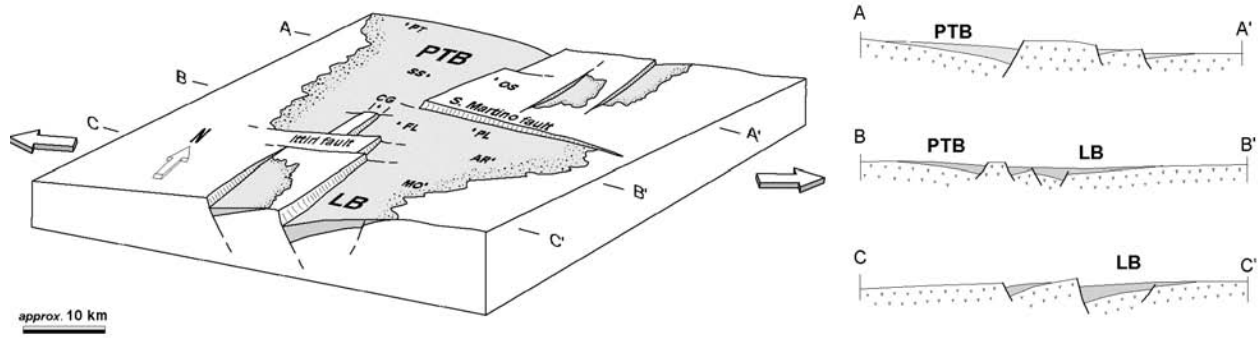

Fig. 1 - Schematic block-diagram of the relation between the Porto Torres and the Logudoro basins during upper Burdigalian (After Funedda *et al.*, 2000).

its base consists of quartz-feldspatic sands and conglomerates, sometimes arranged into Gilbert-type deposits. These fluvial-marine sediments pass into shelf limestone, which in turn is capped by marls. On the marls pertaining to the first sequence, along an erosive or non-depositional surface, a second sequence made up of grainstones and boundstones, sometimes with chaotic aspect, rests. The age of the sequence is unknown; according to Pomesano Cherchi (1971) and Mazzei & Oggiano (1990) it is supposed of Tortonian-early Messinian age.

The Porto Torres Basin shows a similar stratigraphical succession. The relations between the first and the second sequence are well exposed in the southern boundary of the Basin, near Sassari. Here the base of the second sequence is characterised by at least 50 metres of slumped beds, megabreccias and olistostromes rich of algal balls.

With the aim to get additional biostratigraphic and palaeoecological data on the sedimentary succession of the Porto Torres Basin, a preliminary and exploratory sampling for micropalaeontological investigations has been carried out.

The samples were collected in the northeastern side of the Porto Torres Basin (Fig. 2) within the marly unit belonging to the first sequence (Fig. 3) and within the muddy matrix of the chaotic beds, which with a position typical of olistostrome, rest on the marls or are interlayered in their upper part (Fig. 4).

On the whole 12 samples have been collected. Approximately 200 g of each sample were used for foraminifers and ostracods analyses. The washed residues of the samples revealed the common presence of abundant planktonic foraminifers and diversified ostracod faunas. Only a single sample (OG 8) is barren of fossils. The microfauna is moderately to well preserved.

BIOSTRATIGRAPHICAL ANALYSIS

Planktonic foraminifers

Planktonic foraminifers are always present in the studied samples (except for OG 8). Benthic foraminifers (The P/B ratio is always greater than 1), rests of echinoids, molluscs and fishes commonly occur in many samples.

Planktonic assemblages are dominated by the genus *Globigerinoides* and include abundant representatives of *Dentoglobigerina* and *Globoquadrina*. Particularly the following species have been recorded: *Dentoglobigerina altispira*, *D. baroemoenensis*, *D. langhiana*, *Globigerina praebulloides*, *Globigerinella obesa*, *G. praesiphonifera*, *Globigerinita glutinata*, *Globigerinoides altiaperturus*, *G. quadrilobatus*, *G. sacculifer*, *G. subquadratus*, *Globigerinoides trilobus*, *Globoquadrina dehiscens*, *Globorotalia peripheroronda*, *G. praescitula*, *Paragloborotalia siakensis*, *Tenuitellinata angustiumbilicata*, *Turborotalita quinqueloba*.

The most relevant features of the foraminiferal assemblages are:

- the concomitant occurrence throughout the examined succession of *Globigerinoides* species, notably *G. quadrilobatus* and *G. sacculifer* which appear within the N6 Zone of Blow (1969) and *Globigerinoides altiaperturus* which disappears within the N7 Zone (Kennett & Srinivasan, 1983; Bolli & Saunders, 1985; Iaccarino, 1985);
- the absence of representatives of *Catapsidrax* and notably *C. dissimilis* whose last occurrence marks the N6/N7 boundary;
- the absence of *Praeorbulina* (no typical specimens or doubtful forms have been recovered) which First Occurrence is known to marks N7/N8 boundary (Berggren *et al*., 1995; Foresi *et al*., 2002).

All together these data unquestionably indicate the N7 Zone or the *Globigerinoides trilobus* Zone of the Iaccarino & Salvatorini (1982) or Foresi *et al*. (2002) planktonic foraminiferal zonal scheme, that is a late Burdigalian age (Fig. 5).

Ostracods

The abundance and diversity of ostracods are low in the lower sampled levels and tend to increase upwards apart for the uppermost sample. Mean values of the abundance and species diversity are about 50 and 13 respectively, but among the 12 examined samples three

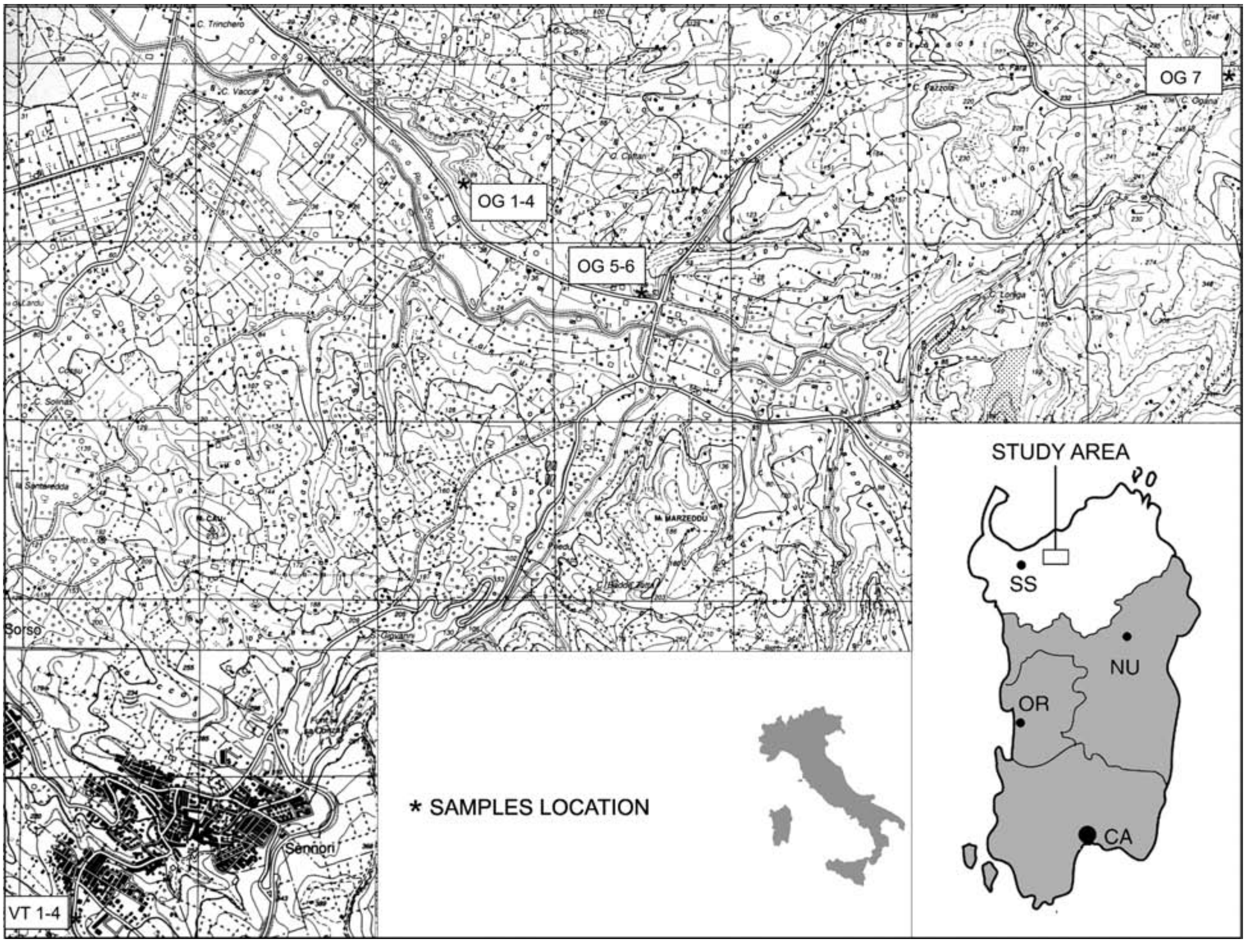

Fig. 2 - Location map of the sampling area.

samples (OG4 and particularly VT 1, VT 2) yielded an extremely rich and diversified fauna. Faunal composition is fairly homogeneous throughout the investigated succession.
A total of 58 species belonging to 33 genera have been recognized. On the whole 6 species are left in open nomenclature and some specimens mainly of the genera *Aurila*, *Callistocythere*, *Cytherella*, *Loxoconcha*, *Paracypris*, *Sagmatocythere* could not be specifically identified owing to poor preservation or immaturity. The numerical distribution of recovered species is given in Table 1.
From a bio-chronostratigraphic viewpoint it must be noted that lower Miocene faunas of Western and Central Europe have been object of several studies (Gebhardt, 2003 *cum bibl*.; Ducasse & Chuzac, 1996, 1997 *cum bibl*.) but shelf ostracods of the Mediterranean have so far been poorly investigated (Carbonnel, 1969; Coutelle & Yassini, 1973; Gökçen, 1985; Dall'Antonia & Bossio, 2001). In addition previous studies on coeval faunas from Italy focused mainly on bathyal assemblages, such as Ruggieri (1960), Oertli (1961), Russo (1966), Ciampo (1981) and Bonaduce & Russo (1985) which represent the only published research on the Lower Miocene of Sardinia.
Taking into account these remarks, analysis of known occurrences of the identified taxa highlighted that most of them appear to be long-ranging species widely distributed within the Cenozoic (e.g. *Bairdia conformis*, *Cnestocythere truncata*, *Costa punctatissima*, *C. tricostata*, *Henryhowella asperrima*, *Paracytheridea triquetra*, *Ruggieria tetraptera*) or spanning at least the entire Miocene (e.g. *Carinovalva rotundata*, *Cytherella postdenticulata*, *C. vandenboldi*).
Nevertheless it must be emphasized that recovered assemblages include also three species whose known distribution suggest an lower-early Miocene age for the investigated succession. These significant species are:

- *Pokornyella deformis* (Reuss, 1850): known from the early-middle Miocene of Central-Eastern Europe (Reuss, 1850; Bonaduce *et al*., 1986; Gross, 2006).
- *Pterigocythereis* gr. *cornuta* (Roemer, 1838): reported from the Oligocene and lower Miocene of Europe (Guernet, 1990).

Fig. 3 - Sampled beds of the marly unit in the eastern part of the Porto Torres Basin.

Fig. 4 - Cahotic bed of the upper part of the marly unit. Notice the megabreccia element enveloped by fine muddy matrix (Sennori village).

– *Puricytheretta melitensis* Russo and Bossio, 1976: known from the upper Burdigalian-lower Serravallian of Malta Islands and Southern Italy (Russo & Bossio, 1976; Dall'Antonia & Bossio, 2001; Dall'Antonia, 2003) and the Badenian of Central Tethys (Brestenská & Jirícek, 1978).

Furthermore it is interesting to note that the present study allowed to extend the stratigraphical range of a number of species which are listed below:

– *Aurila bullapunctata* Uliczny, 1969: so far reported from the Pliocene of Cephalonia (Uliczny, 1969; Mostafawi & Matzke-Karasz, 2006) and the Lower Pleistocene of Italy (Ruggieri, 1973, 1980; Dall'Antonia *et al*., 2005). It is worth of mention that Ruggieri (1973) reported the occurrence of a form very similar to Uliczny's species from the upper Miocene of Central Italy (Ruggieri, 1973, p. 163).

– *Loxocorniculum quadricornis* (Ruggieri 1962): know from the middle Miocene (Serravallian) of Aegean Islands and Tremiti Islands (Sissingh, 1972; Dall'Antonia, 2003) and upper Miocene (Tortonian) of North Italy and of Sicily (Dieci & Russo, 1965; Ruggieri, 1962; Ciampo, 1980), Messinian of Maltese Islands (Russo & Bossio, 1976).

– *Heliocythere vejhonensis* (Prochazka, 1893): known only from the middle Miocene (Badenian) of Central-Eastern Europe and the upper Miocene (Tortonian-Messinian) of Spain, Italy and dubitably Algeria (see Bonaduce *et al*., 1988).

– *Nonurocythereis seminula* (Seguenza, 1880): reported from the middle Miocene (Langhian-Serravallian) of Aquitaine (Ducasse & Cahuzac, 1996, 1997) and the upper Miocene of Italy (e.g. Seguenza, 1980; Ruggieri & Russo, 1980) and Greece (Mostafawi, 1990).

– *Paracytheridea grignonensis* Keji, 1957: known from the Eocene and Oligocene of France (Ducasse *et al*., 1985).

– *Sagmatocythere gibbosofoveolata* (Seguenza, 1880): so far reported from the upper Miocene (Tortonian) of Southern Calabria (Seguenza, 1880 and Ruggieri, 1963) and Central Italy (Dieci & Russo, 1965 and Russo, 1968 as *Loxoconcha* aff. *sagittula* (Reuss).

– *Cytherelloidea creutzburgi* Sissingh, 1972: known from the upper Miocene to the Lower Pleistocene of Italy and Greece (Sissingh, 1972; Mostafawi, 1989; Ruggieri & D'Arpa, 1993; Dall'Antonia, 2003).

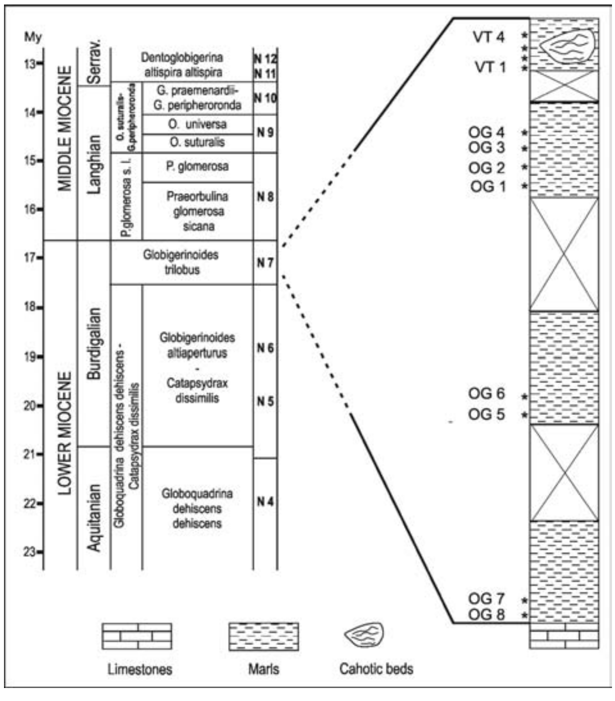

Fig. 5 - Sampled succession: lithology and bio-chronostratigraphy based on the foraminiferal zonal scheme of Foresi *et al.* (2002), modified.

Tab. 1 - Stratigraphical distribution of ostracod species. Bold numbers refer to adult valves, italic to instars, underlined to both instars and adult.

Ostracod species	Samples											
	OG 7	OG 8	OG 5	OG 6	OG 1	OG 2	OG 3	OG 4	VT 1	VT 2	VT 3	VT 4
Aurila cicatricosa (Reuss, 1850)	**4**											
Bairdia conformis Terquem, 1878	**4**		**8**	**4**	**11**	**7**	4	35	57	30	12	
Buntonia dertonensis Ruggieri, 1954	**1**		**4**	**2**			**1**	**30**				
Cytherella postdenticulata Oertli, 1961	**6**		**7**		**8**			**1**		27		**9**
Heliocythere vejhoneni s (Prochazka, 1893)	**1**			**1**	**2**		*3*			14		
Loxocorniculum quadricornis (Ruggieri, 1962)	**3**			**4**		**1**	3	**1**	**3**	**16**		
Aurila bullapunctata Ulicnzny, 1969			**1**		**1**	**3**						
Aurila spp.			*1*	22		1			**4**		3	
Cardobairdia sp.			**2**									
Cnestocythere truncata (Reuss, 1850)			**1**		**1**				**4**	29	**1**	
Costa tricostata (Reuss, 1850)			**1**	6	**10**	8	10		**6**			
Cytherella inaequalis Moyes, 1965			**1**		**7**	**1**		**2**	16	28		**10**
Cytherella vandenboldi Sissignh, 1972			**4**		**18**		*1*		**12**	**2**		
Henryhowella asperrima (Reuss, 1850)			**6**		**2**			6	**3**	10		
Parakrithe declivis Ciampo, 1980			**10**					**41**		**8**		
Xestoleberis aff. *comunis* Müller, 1894			**2**				**1**	**17**		**3**		
Carinovalva rotundata (Ruggieri, 1962)				**4**		**2**			**11**	**6**		
Cytherella gr. *vulgata* Ruggieri, 1962				7	**2**			**2**	**15**	34		
Grinioneis haidingeri (Reuss, 1850)				**2**			*2*		7	4		
Sagmatocythere gibboso-foveolata (Seguenza, 1880)				**1**		**1**			6	3	**2**	
Paracypris sp.				**2**				**4**		**22**		
Paracytheridea triquetra (Reuss, 1850)				**2**					*10*	**2**		
Parakrithe ariminiensis (Ruggieri, 1967)				**3**						**10**		
Pterigocythereis cornuta (Roemer, 1838)				**2**						**1**		
Ruggieria tetraptera (Seguenza, 1880)				**13**		7	3		**10**	35		
Xestoleberis aff. *dispar* Müller, 1894				**1**						**4**		
Bairdia gr. *mediterranea* Müller, *1894*					*1*						7	
Carinovalva aquila (Ruggieri, 1972)					**3**				**2**	**1**		
Eucythere curta Ruggieri, 1975					**1**							
Olimfalunia plicatula (Reuss, 1850)					*1*			*1*				
Olimfalunia sp. 2 *sensu* Russo, 1968					*1*			**1**				
Puricytheretta melitensis Russo and Bossio, 1975					**1**				**2**	**10**		
Ruggieria micheliniana (Bosquet, 1852)					**1**				12	3	8	
Loxoconcha hastata (Reuss, 1850)						*1*			**1**	**8**	3	
Cytheropteron bifidum Colalongo and Pasini, 1980						**2**						
Graptocythere sp.						*1*						
Callistocythere spp.							**1**	**1**	**2**	**8**	**2**	
Cytherella sp.							*2*	**3**				
Cytheropteron sp.							**1**					
Eucytherura mistrettai Sissingh, 1972							**2**		**1**			
Loxoconcha spp.							**1**		**1**	*4*	**2**	
Sagmatocythere tenuis (Ciampo, 1980)							**1**		**2**			
Monoceratina cf. *plaga* Ciampo, 1986								**1**				
Pokornyella deformis (Reuss, 1850)								**1**	**1**	*3*		
Pseudopsammocythere kollmanni Carbonell, 1966								**2**				
Aurila gr. *convexa* (Baird, 1850)									**22**	28	**2**	
Costa punctatissima Ruggieri, 1961									**1**	6		
Cytherella gr. *circumpunctata* Ciampo, 1976									**1**	8	6	
Cytherelloidea creutzburgi Sissingh, 1972									8	**4**	**2**	
Flexus tenuicarenatus (Capeder, 1902)									**7**			
Loxoconcha gr. *rhomboidea* (Fisher, 1855)									**2**			
Nonurocythereis seminula (Seguenza, 1880)									**3**			
Paracytheridea grignonensis Keji, 1957									**4**	**1**	**2**	
Phlyctenophora arcuata (Von Münster, 1830)									**6**		**5**	
Sagmatocythere sp.									**3**	**3**		
Semicytherura alifera (Müller, 1894)									**5**	**14**		
Semicytherura velata Ciampo, 1986									**1**			
Callistocythere montana Doruk, 1980										**8**		
Cytherelloidea cf. *hieroglyphica* (Bosquet, 1852)										**2**		
Pachicaudites ungeri (Reuss, 1850)										3	**2**	
Pterigocythereis fimbriata (Von Münster, 1830)										**3**		
Rectobuntonia subulata (Ruggieri, 1954)										**25**		
Semicytherura sp.										**1**		
Tubercolocythere sp.										**2**		
Aurila cf. *opaca* (Reuss, 1850)											**2**	
Cytherella russoi Sissingh, 1972												6
Cytheretta cf. *semipunctata* (Bornemann, 1855)											**5**	
Loxoconcha punctatella (Reuss, 1850)											*6*	
Monoceratina mediterranea Sissingh, 1972											**1**	
N° valves	19	0	48	76	71	35	36	17	251	433	73	25
N° species	6	0	13	16	17	12	15	149	35	41	19	3

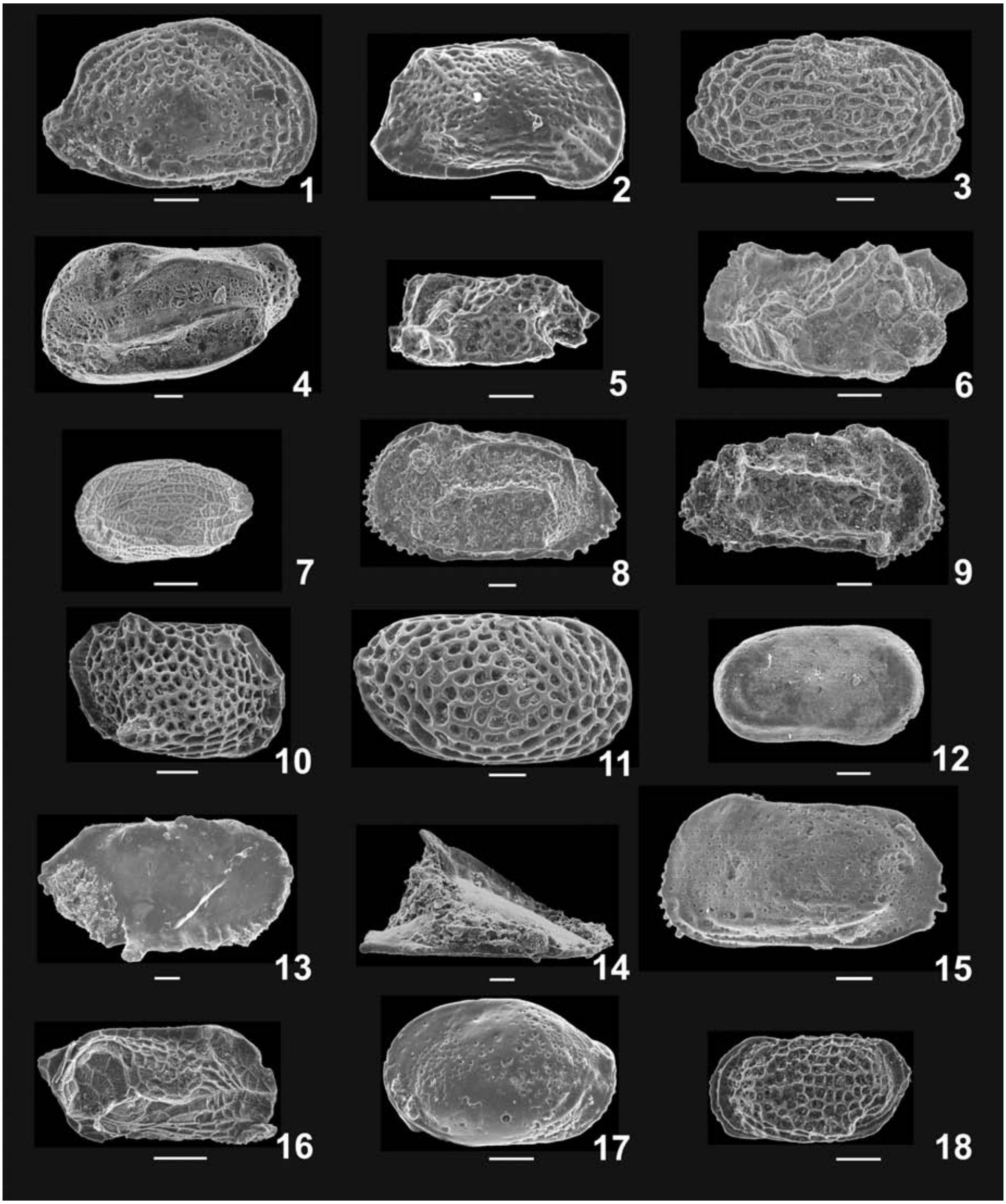

Plate 1
1 - *Aurila bullapunctata* (Uliczny). RV (sample OG 2). 2 - *Heliocythere vejhonensis* Prochazka. RV (sample VT 2). 3 - *Nonurocythereis seminula*. (Seguenza). RV (sample VT 1). 4 - *Flexus tenuicarenatus*. (Capeder). LV (sample VT 1). 5 - *Paracytheridea triquetra* (Reuss). LV (sample VT 2). 6 - *Paracytheridea grignonensis* Keji. LV (sample VT 1). 7 - *Semicytherura velata* Ciampo. LV (sample VT 1). 8 - *Costa tricostata* (Reuss) LV (sample OG 2). 9 - *Costa punctatissima* (Ruggieri). LV (sample VT1). 10 - *Loxocorniculum quadricornis* Ruggieri. RV (sample VT 2). 11 - *Sagmatocythere gibbosofoveolata* (Sequenza). RV (sample VT1). 12 - *Cytherelloidea creutzburgi* Sissing. RV (sample VT 2). 13 - *Pterygocythereis cornuta* (Roemer). LV (sample OG 6). 14 - *Pterygocythereis cornuta* (Roemer). DV (sample OG 6). 15 - *Ruggieria micheliniana* (Bosquet). LV (sample VT 1). 16 - *Semicytharura alifera* (Müller). LV (sample VT 1). 17 - *Buntonia dertonensis* Ruggieri. LV (sample OG 3). 18 - *Sagmatocythere tenuis* (Ciampo). LV (sample VT 1).
S.E.M. microphotographs of selected ostracods taxa (scale bars = 100 μm).

From a palaeoecological viewpoint, assemblages do not show significant compositional changes, but only modifications of the relative abundance of single species. Major components of the fauna are in order of relative abundance species of the genera *Bairdia* (almost exclusively *B. conformis*), *Cytherella* (*C. postdenticulata*, *C. vandenboldi*, *C.* gr. *vulgata*), *Ruggieria* (*R. micheliniana*, *R. tetraptera*), *Costa* (*C. tricostata*, *C. punctatissima*), which are quite tolerant taxa typical of an outer neritic zone but most able to live also in upper epibathyal environment. Representatives of *Parakrithe*, Loxoconchidae and Hemicytherinae (*Aurila*, mainly instars) are also relatively frequent present. Other noteworthy features are:

– the presence of *Henryhowella asperrima* and the local occurrence of *Puricytheretta melitensis*, *Carinovalva aquila* and *Monoceratina* spp. which prefer relatively deep waters;
– the scattered and reduced occurrence of typical littoral taxa such as *Cytheretta*, *Flexus*, *Phlyctenophora*, *Xestoleberis*.

On the whole the ostracod faunal composition dominated by taxa mainly related to an open shelf environment, in accordance with foraminifer P/B ratio, indicates a depositional setting referable to the intermediate part of the outer neritic zone.

CONCLUSION

The preliminary planktonic foraminifer and ostracod study carried out on Northern Sardinia marly deposits of the Porto Torres Basin allowed to recognize the presence of Burdigalian (N7 Zone of Blow, 1969) and to locate the sediment in the outer neritic shelf. In the Logudoro Basin similar deposits were referred to the Langhian (Mazzei & Oggiano, 1990). The present results open new prospective for improving the knowledge on the stratigraphy of the Miocene succession in Northern Sardinia, giving also the opportunity to start a detailed study of lower Miocene Mediterranean ostracods that are still poorly known. Moreover, as the marl, among the Miocene deposits of western Sardinia, is the lithofacies that denotes the maximum depth, further comparisons between the age obtained in the study area and that attainable by marls of other, adjacent half-grabens, will be useful to highlight diachronies in the deepening of the intra-continental basins of Sardinia (Plate 1)

ACKNOWLEDGEMENTS

Research supported by PIC INTERREG III A Italia-Francia «Isole» Sardegna-Corsica-Toscana.

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(ms. pres. il 30 settembre 2006; ult. bozze il 5 febbraio 2007)