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THE LOWER PLEISTOCENE SUCCESSION OF CONTRADA TORSANO (NARDÒ, LECCE PROVINCE)

SUMMARY

This paper deals with the stratigraphic and paleontological features of a 4.1 m thick succession outcropping at Contrada Torsano (Nardò, Lecce province). Shell concentration due to biological processes, particularly rich in the northern guests *Arctica islandica*, *Pseudamussium septemradiatum* and *Paphia rhomboides* are described. Based on *Terebratula scillae* and *Dentalium rectum* presences, the succession must be attributed to the lower Pleistocene. The high specimen density could be due to opportunistic life strategies and optimal ecological conditions. Environmental change can be recognized from the infralittoral zone, exposed to the marine abrasion, to circalittoral zone as the result of the increasing of both depth and sea water turbidity.

RIASSUNTO

Vengono esposti aspetti stratigrafici e paleontologici di una successione calcarenitico-sabbioso-argillosa spessa 4,1 m, affiorante in Contrada Torsano (Nardò, provincia di Lecce), caratterizzata da livelli fossiliferi a molluschi, scafopodi, brachiopodi e coralli tra cui prevalgono *Venus verrucosa*, *V. casina, Acanthocardia tuberculata, Aequipecten opercularis, Glossus humanus, Thracia convexa, Neopycnodonte cochlear, Pecten jacobaeus, Terebratula scillae, Dentalium rectum* e *Flabellum* sp.; sono altresì presenti gli "ospiti nordici" *Pseudamussium septemradiatum*, *Paphia rhomboides* e soprattuto *Arctica islandica*. Quest'ultima è rappresentata da individui di grande taglia analogamente a popolamenti nordatlantici attuali (Kennish and Lutz, 1995; Thorarinsdottir and Einarsson, 1996). I livelli fossiliferi (*shell concentrations sensu* Kidwell, 1991; Fürsich, 1995) hanno caratteri di deposito primario e possono rappresentare il prodotto di strategie di adattamento o di favorevoli condizioni ecologiche.

La maggior parte delle specie riconosciute nella successione di Torsano è attualmente presente nel Mediterraneo (Parenzan, 1970; 1974; 1976; Demir, 2003; Repetto *et al*., 2005). Alcune sono indicative di particolari condizioni ambientali come

Lucinoma boreale, tipica di fondali mobili (Malatesta, 1974) e *Thracia convexa*, esclusiva delle Biocenosi dei fanghi Terrigeni Costieri (Picard, 1965; Pérès, 1967).

In generale, dalla base al tetto della successione analizzata, è definibile un cambiamento delle condizioni paleoambientali dalla zona infralitorale, soggetta a fenomeni di abrasione meccanica delle onde, a quella circalitorale per progressivi aumenti delle profondità del fondale e della torbidità delle acque.

INTRODUCTION

Within the sedimentary successions, the definition of stratigraphic units containing thanatocenosis similar to the present marine biocenosis was formalized with the introduction of the Pliocene (Lyell, 1832). The main difference between this epoch, that conventionally closes the Tertiary, and the previous Miocene, consist of the negative characters of the fauna content, or rather the high amount of extincted species than the new appearances. About 60% of the forms living during Pliocene are still alive, and the percentage progressively increases towards the present time (Azzaroli and Cita, 1980). As a consequence, the useful features to recognized the so called "Post Pliocene" deposits, formerly mapped in the first geological map of Salento (De Giorgi, 1879), was based on the principle of the "fauna modernity".

Lyell (1839) proposed to attribute to the Pleistocene the deposits containing more than 70% of species still alive. Nevertheless, the boundary between Pliocene and Pleistocene (P/P) was put at the FAD (First Appearance Datum) of the so called "northern guests", that are boreal and artic fauna migrated into Mediterranean during cold phase, and especially of *Arctica islandica* (Gignoux, 1913). This concept, that was conventionally ratified several tens of years later (Aguirre and Pasini, 1985), allows us to establish a geochronological schemes (Tab. 1), although the chronostratigraphic position of P/P, and consequently the Tertiary-Quaternary boundary, are again argument of strong debates (Bonadonna and Alberdi, 1987; Partridge, 1997; Vai, 1997).

Tab. 1 - Pliocene and Pleistocene chronology and calibrated age (based on Cita and Castradori, 1995; Rio *et al.*, 1998; Gibbard *et al.*, 2004).

Absolute age BP	Conventional subdivision	Unofficial subdivision	Epoch	Stage	
0.12 My	Quaternary	Quaternary	Pleistocene	upper (Tarentian)	
0.78 My				middle (Ionian or Crotonian)	
				Lower (Calabrian)	Sicilian
					Emilian
1.83 My					Santernian
2.53 My	Tertiary		Pliocene	Upper (Gelasian)	
3.57 My		Tertiary		Middle (Piacenzan)	
5.33 My				Lower (Zanclean)	

Italy has a specific importance about the Pliocene and Pleistocene researches, being the formalized stratotypes, as well as a number of the proposed ones, located at ionian and padanian regions (Cita and Castradori, 1995; Rio *et al.*, 1998). The Salento peninsula, by virtue of its geographical position and the extension of outcropping Pliocene and Pleistocene deposits rich in mollusc's shells (D'Alessandro *et al.*, 2004; Bossio *et al.*, 1987a,b,c), appears particularly promising for paleo-environmental reconstructions useful to learn the present ecosystem and the biogeographical distribution of the species. The discovery (Delle Rose and Medagli, 2006) of strata containing abundant *Arctica islandica* at Contrada Torsano (about 5 km W of Nardò) in place of deposits referred to the upper Pliocene, and dubitatively to middle ones, from the "Foglio 214 Gallipoli" of the official Italian Geological Map at scale 1:100.000 (Servizio Geologico d'Italia, 1969), arises the opportunity to make the present study.

GEOLOGICAL BACKGROUND

Salento forms the topographically less elevated sector of the Carbonate Apulian Chain (Auct.) and it constraints with the Murge plateau along a E-W tectonical deformation strip (Arnoux *et al.*, 1985). It shows a NNW-SSE, and subordinately NW-SE, horst and graben arrangement, that is morphologically marked by the juxtaposition of the Serre hills and the depression planes (Nardin and Rossi, 1966; Martinis, 1967). The tectonic setting is the result of mainly disjunctive crust stress that have disarticulated the substratum starting from the Upper Cretaceous and successively during Miocene and Pliocene, in concomitance of Apennine and Dinaric deformation phases (Ciaranfi *et al.*, 1988), that influenced the physiographic shapes of the Neogene Salento, too (Delle Rose, 1993; 2001; 2006). The differentiation between Miocene and Pliocene deposits of the Salento was introduced by Mauget (1864), whereas the first exhaustive study was performed by De Giorgi (1876). The latter Author considered strata crop out N of Ostuni and within the Diso-Marittima zone (Fig. 1) such as the oldest Pliocene deposits. They pointed out the presence at Leuca of a fossiliferous calcarenites containing carbonate lithic blocks of "Recent Pliocene" according to the schemes of Seguenza (1873; 1874; 1875; 1876).

The attribution to Pliocene and Post Pliocene concerning the units younger than Miocene inside the geological map of Salento of De Giorgi (1879) was adopted by the first edition of the "Foglio 214 Gallipoli" of the official Italian Geological Map at scale 1:100.000 (Ufficio Geologico d'Italia, 1904), in spite of a partial chronostratigraphic revision of De Giorgi (1903) performed after a re-examination of the malacology presences. Authors and geological Schools that successively studied the Salento Pliocene and lower Pleistocene deposits proposed various reconstructions and hypothesis about number of distinguishable units, extension of their outcropping areas, ages and paleo-environmental significances that have

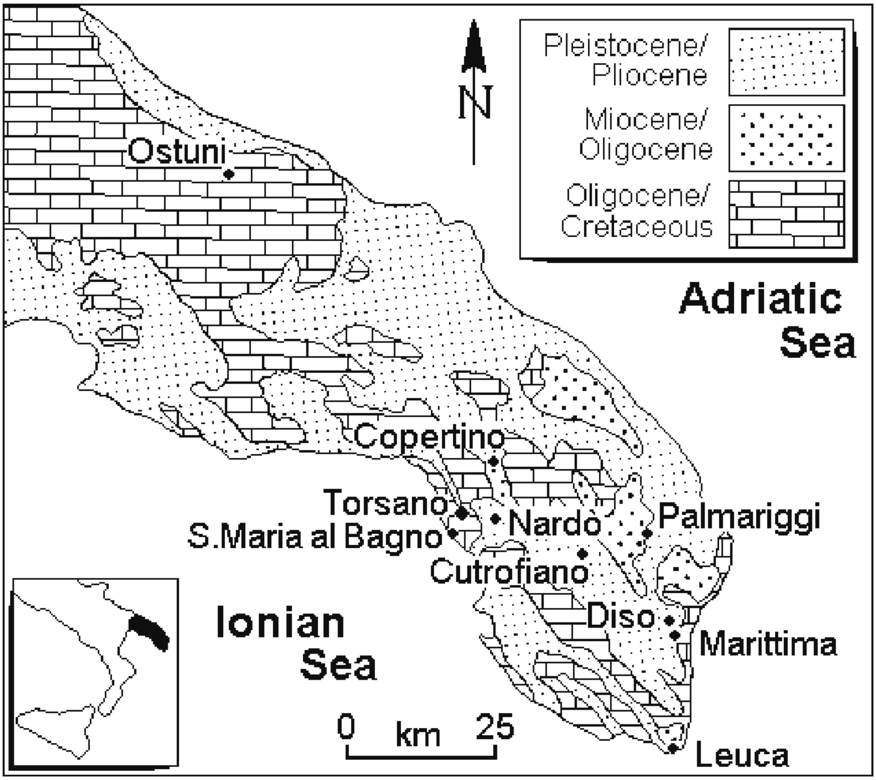

Fig. 1 - Geologial scheme of Salento and South Murge; localities are mentioned in the text.

arisen a number of stratigraphic questions (D'Alessandro and Palmentola, 1978; D'Alessandro *et al.*, 1994; Bosellini *et al.,* 1999; Tropeano *et al.*, 2004; Delle Rose, 2006, and reference therein).

The causes of the above questions appear mainly the scarcity and the bad state of conservation of micro e nanno-fossils having roles of true (i. e. conventionally ratified; see: Martini, 1971; Cita, 1975; Ruggieri and Sprovieri, 1977; Sprovieri *et al.*, 1980; Iaccarino and Salvatorini, 1982; Castradori *et al.*, 1998; Rio *et al.*, 1998; Commissione Italiana di Stratigrafia della S.G.I., 2003; Gradstein *et al.*, 2004; Patacca and Scandone, 2004) biostratigraphical markers recognizable inside the Salento deposits as pointed out by Martinis (1967) Largaiolli *et al.* (1969), Bossio *et al.* (1987b,c) and D'Alessandro *et al.* (2004). However some Authors modifying the current conventional schemes on the basis of new and partially unpublished researches (Bossio *et al.*, 1991), have proposed an informal bio-chronostratigraphic zonation (Bossio *et al.,* 1987a) that, in turn, substantially follows an older geo-chronological partition (cf. Colalongo and Sartoni, 1979). Such Authors untimely used a non-conventional three-folded chronological

Tab. 2 - Correlation between the chronological informal subdivision and the conventional partition of the Pliocene - early Pleistocene. FO = First Occurrence; LO = Last Occurrence.

Colalongo and Sartoni (1979), Bossio *et al.* (1987a,b; 1991)		MY	Gradstein *et al.* (2004), Patacca and Scandone (2004, and references therein)	
Bio zones	Informal subdivision	0.78	Stages	Main biological events
Gt. truncatulinoides excelsa	Lower Pleistocene		Lower Pleistocene	FO *Gt. truncatulinoides excelsa* FO *H. baltica* FO *A. islandica*
Gt. cariacoensis		1.63		
Gt. inflata	Upper Pliocene	1.83		
		2.00	Upper Pliocene	LO *D. pentaradiatus*
Gt. gr. crassaformis	Middle Pliocene	2.53		
		3.10	Middle Pliocene	FO *Gt. crassaformis*
Gt. puncticulata / *Gt. margaritae*	Lower Pliocene	3.57		
		5.33	Lower Pliocene	FO *Ce. acutus*

Pliocene scheme (Tab. 2) and "failed to acknowledge taxa and a number of events between the foraminifera" of the Pliocene/Pleistocene Vrica section (Bossio *et al.*, 1987b), which is the Global Boundary Stratotype Section and Point (GSSP) officially recognized by the International Commission of Stratigraphy (Aguirre and Pasini, 1985; Bassett, 1985; Gradstein *et al.*, 2004).

As a consequence, the problem of stratigraphic attribution inside the Salento successions are actually a questionable task; to provide an example, it can be consider the deposits outcropping east of Palmariggi (Fig. 1) in the E Salento, which has been referred to the middle Pliocene by Bossio *et al.* (1991), whereas according to Maiorano (in D'Alessandro *et al.*, 2004) it "did not yield any key species to support this attribution".

Also the stratigraphy of the Pleistocene deposits cropping out few kilometres SW of Contrada Torsano had been differently schematized by various geological Schools. For instance, the outcrops of Santa Maria al Bagno (Fig. 1) have been referred to the *calcareniti del Salento* and the Gallipoli formation of Sicilian age by Bossio *et al.* (1992), whereas the same sequence have been related to the litostratigraphic units named *Calcareniti di Gravina*, *sabbie a brachiopodi* and *argille di Mondo Nuovo*, covering an early-middle Pleistocene interval, by D'Alessandro *et al.* (1994).

To end this brief but necessary overview at least other two aspects concerning the aforementioned stratigraphic problems must be mentioned: the reworking of the sediments which have determined the mixing of *taxa* related to different noncoeval fossils assemblages (see, as an example, Bossio *et al.*, 1991); the facies itself of the Salento deposits which were usually ill-suited to the settlement of chrono – stratigraphically relevant foraminifera (such as *Hyalinea baltica*) and nanno-fossils (as an example medium and large *Gephyrocapsa* spp.) how revealed by Barbera *et al.* (1993). Nevertheless, a substantial biostratigraphical revision of the Pliocene and Pleistocene Salento deposits must be done also tacking into account their sedimentological features (Tropeano *et al.*, 2004, and reference therein).

Notwithstanding the unsolved questions of the present state of the knowledge, an essential scheme of upper Pliocene – lower Pleistocene of the Nardò area can be outlined (Tab. 3). At the bottom calcarenites can be referred some stones traditionally called *tufi* and *carpari* (Largaiolli *et al.*, 1969). A typical common feature of this deposits is the high amount of "northern guests" (D'Alessandro and Palmentola, 1978; Delle Rose and Medagli, 2006).

At Contrada Torsano, the outcropping calcarenites have been referred to the calcareniti del Salento, and differently mapped by adjacent plio-pleistocene units, inside the "Foglio 214 Gallipoli" (Servizio Geologico d'Italia, 1969), whereas they are ascribed to the *Calcareniti di Gravina* in the "Geological Map of Murge and Salento" of Ciaranfi *et al.* (1988).

Tab. 3 - Lithostratigraphic nomenclature of the upper Pliocene – lower Pleistocene Nardò area.

Geological column	Servizio Geologico d'Italia (1969), Bossio *et al.* (1992)	Cherubini and Margiotta (1984), D'Alessandro *et al.* (1994)
clayey marls	formazione di Gallipoli	Argille subappennine (Mondo Nuovo)
silty-sands	-	sabbie a brachiopodi
calcarenites	calcareniti del Salento	Calcareniti di Gravina

STUDY METHOD

This paper deals with the stratigraphic and paleontological features of a 4.1 m thick succession, that was reconstructed by means of the correlation of some sections cropping out along artificial cuts of the substratum at Masseria Torsano.

Such cuts, resulted of mechanical excavations, arose the possibility to perform detailed lithostratigraphic and sedimentological observation as well as sampling of malacofauna available for tassonomic and taphonomic analyses. The studied outcrops are along E-O and N-S oriented cuts, whose height ranges from 1 and 4 m and with a total length of about 120 m. Stratigraphic observations were made also into and ancient well (locally named *trozza*), hand-excavated into the calcarenites, by means of speleological progression. The reconstructed stratigraphic setting was verified in the surrounding area by means of a detailed geological survey.

The malacological tassonomic results have firstly used to place the succession into the chronological scheme (Tab.1), being some recognized fossils decisive key-species and also taking into account that the Pliocene and Pleistocene macro-fauna assemblages of the Salento are attested chronostratigraphic tools often better than the micro and nanno-fossils (cf. Bossio *et al.*, 1987b; D'Alessandro *et al.*, 2004). Later, species listed and taphonomic observations were used to infer some paleo-ecological features of the shelf environment on the basis of at length tested praxis (Pérès and Picard, 1964; Picard, 1965; Pérès, 1967; D'Alessandro and Iannone, 1982; Kidwell, 1991; Fürsich, 1995; D'Alessandro *et al.*, 2004). Such scheme of study is tightly consistent with the regional geological evolution (Arnoux *et al.*, 1985; Bossio *et al.*, 1987a,b,c; Ciaranfi *et al.*, 1988; D'Alessandro *et al.*, 2004).

To better propose some ecological features of the sea bottom, by virtue of the recognized "fauna modernity" characters of the study succession, a number of considerations were made on the basis of present molluscan communities. Eventually, some starting-points available for further studies, arisen by recognition of deposits, morphologies and concretions during the geological survey and by data elaborations, are also proposed.

STRATIGRAPHIC FEATURES

Contrada Torsano is part of a ramp that gently slopes toward Ionian, some tens of km^2 wide and breaks, about 1 km far from the present coastline, by a few m high cliff that culminate at Serra Cicora escarpment. As reconstructed by detailed geological survey (Fig. 2), within a narrow morphological - structural depression, calcarenitic-sandy-clayey deposits overlie the substratum, consisting of Cretaceous limestones (Servizio Geologico d'Italia, 1969), by a stratigraphic discordance. The cover deposits are bored by sub-vertical karst pipes, shaped by flow-karst processes (cf. Usepa, 2002), some m depth and few dm large. The importance of the sub-aerial landscape processes is also proved by the wide and thick alluvial soils which usually filled gullies which were, in turn, eroded along the stratigraphic contact between limestone and the uppermost calcarenitic-sandy-clayey deposits.

The best exposed succession was at Masseria Torsano in correspondence of the aforementioned artificial cuts. Here, the stratification is marked by fossil arrangement and by lithologic change and, as a whole, the thickness of the strata tends to reduce from W toward E where, inside the aforementioned well, only few dm of calcarenites are observed. At the outcropping scale, the stratification appears plane-parallel and gently slopes (immersion on few angular degrees) toward S-W. Strata show a fining up trend of the granulometric size of the clastic components, changing from a basal medium-coarse sand to a medium-fine sand and clayey silt of the top.

The contact between the Cretaceous limestones and the studied deposits was

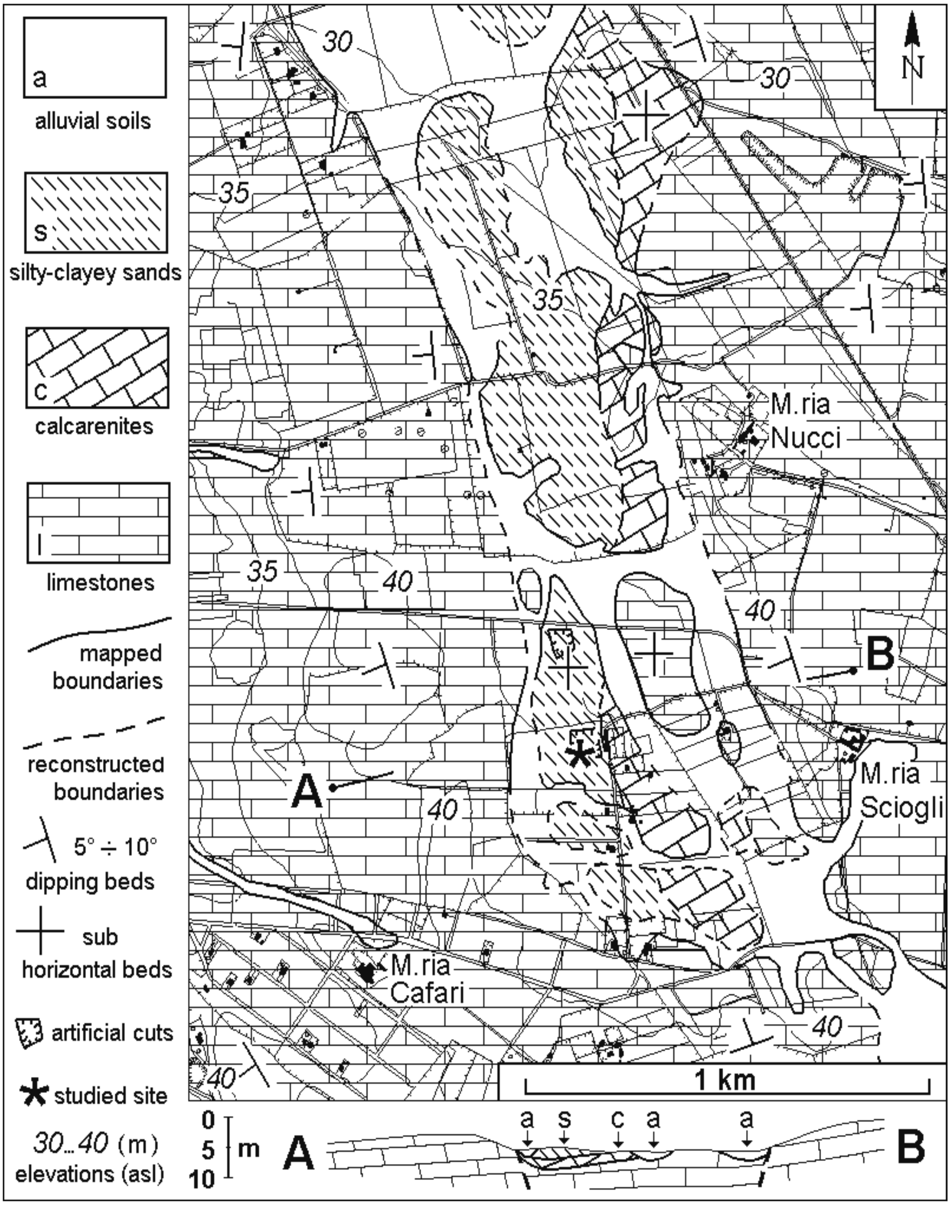

Fig. 2 - Geological map of Contrada Torsano. Topography extract from sheet 525040 of Technical Map of Lecce Province.

observed E of Masseria Torsano, along a sub-plane excavated surface several tens of m^2 wide. It seems nearly plane and inclined toward W only of few degrees. Top of limestones is extensively perforated by a number of cylindrical and sub vertical 3-5 cm depth bores with diameter of 2-2,5 cm, having sub-spherical bottom. Along this surface, it was observed a concavity, some tens of cm large and about 15 cm depth, filled by a ochre-brown sands.

The calcarenitic deposit begins with a macrofossiliferous bed, whose sedimentological and paleontological features cannot be described in detail owing to the mechanical excavation disturbs. In any case, the fragmented fauna containing within this bed appear to be analogous to those observed into the overlying strata, with a high probably presence of *Arctica islandica*. The initial 30 cm of calcarenites are hardly cemented, yellow-grey in colour, with abundant malacological remains, such as mineralized shells, internal casts and external molds.

Above the hardly cemented basal level, calcarenites present the usual yellowish colour as well as the normal hardness of the Salento calcareous "tufas", whereas several shells are partially decalcified.

PALEONTOLOGICAL OBSERVATIONS

Levels particularly rich in macrofossils are at about 0.5 and 1 m from the contact with the underlying limestones, the second of which showing a high frequency of *Arctica islandica* shells, usually with articulated valves. Along the vertical cuts of the digging, the fragmentation of the shells and the disturbs of the sedimentological structures caused by mechanical excavation, have made detailed observation impossible.

The fossil arrangement, and especially their density, are the main sedimentary features of the Contrada Torsano deposits. The stratigraphic column of Figure 3 was reconstructed by correlations of a number of cuts crop out W of Masseria Torsano, where more depth was the artificial diggings and thicker deposits was found, although the contact with the Cretaceous limestones was not observable.

The basal portion of the measured succession shows chaotic disposition of fossils containing in yellowish calcarenite (Fig. 3); at 0.9-1m a level very rich in disarticulated and aligned *Arctica islandica* shells is interposed inside massive deposits. A second fossiliferous level, about 15 cm thick, characterized by frequent articulated shells of *A. islandica*, other benthic bivalves (especially belonging to Cardiidae, Veneridae and Pectinidae families) and a relatively high presences of gastropods, is interposed at 1.4 m above the base of the measured column.

After 0.6 m of massive calcarenites, three 5-10 cm thick discontinuous fossiliferous levels, containing articulated shells of *Arctica*, as well as species of Cardiidae, Veneridae and Pectinidae, are intercalated in the calcarenitic deposits. The level 2.6 m above the base of the succession (Fig. 3) is characterized by a number of chaotically disposed *Venus* shells. Within the upper part of the succession, the

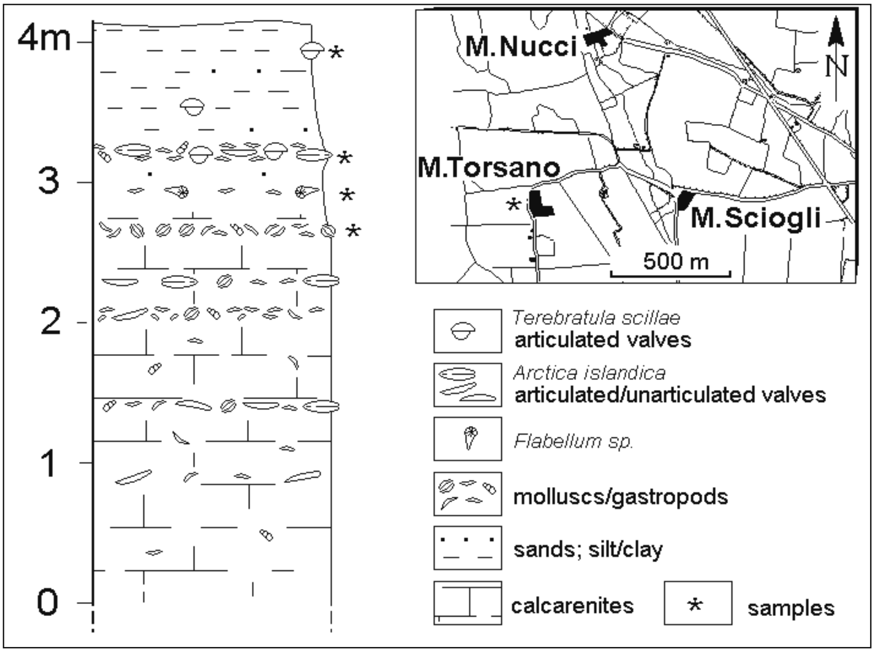

Fig. 3 - Stratigraphic Column with sampling indications.

matrix is few cemented and, as a consequence, it get the features of a sand, keeping the yellowish colour.

After further 25 cm, a thin (3-4 cm) *Flabellum* sp. rich horizon is intercalated in the column (Fig. 3). At about 3.1 m above the base succession, a 20 cm thick level can be observed. Besides abundant articulated *Arctica islandica* specimens, very frequent *T. scillae, P. septemradiatum*, *V. verrucosa* and *Flabellum* sp. are contained within a sandy matrix. The top of the succession is made up by about 1 m of silty-clayey sand, greenish in colour, that include specimens of *Terebratula scillae* and a number of centimetric sub-spheroidal carbonatic concretions.

Erosional contact evidences have not observed along the studied succession; the stratigraphic limits seems to be gradual, whereas they are sharp in proximity of the main lithological changes from calcarenites to sand as well as from sand to silty-clayey sand.

The geometrical disposition of the shells (biofabric) of the upper fossiliferous level has detailed observed, by means of the presence of large artificial expositions few disturbed by the mechanical excavation. The shells doesn't show dimensional gradation perpendicularly at the stratification (ungraded) and are made up by specimens showing from large (about 10 cm of maximum axis concerning *Arctica islandica* and *Glossus humanus*) to little size (few mm of a number of molluscs and gastropods). As a consequence, they exhibit a wide dimensional sorting. The major density of the shells is visible along the middle part of the level. Imbricate structure (i. e. imbrications of shell tilted on the same direction) are not detected, whereas the closure plane of the molluscs are frequently disposed parallel to the stratification. Disarticulated valves are mainly convex-up disposed than concave-up. Shells macroscopically appears unbroken (except for some post-depositional fractures due to lithostatic pressure) and are not bored, encrusted or corroded (Fig. 4).

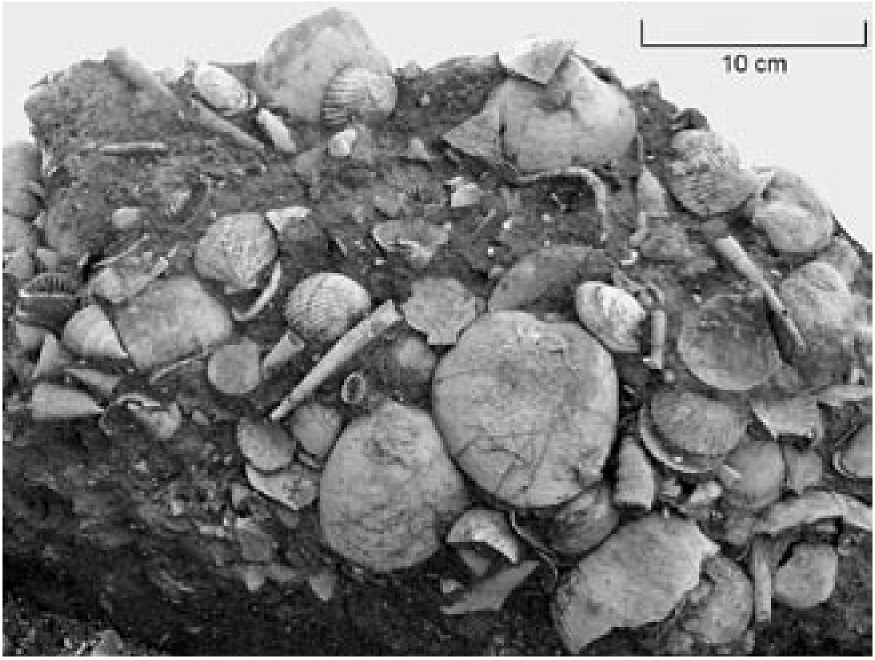

Fig. 4 - Top of the higher shell concentration with in evidence numerous specimens of *Arctica*, *Venus*, *Acanthocardia*, *Dentalium* and *Flabellum*.

The upper sandy and silty-clayey sandy portions of the studied succession, well exposed along the W of Masseria Torsano artificial cuts, have samples (Fig. 3). Sampling was performed gathering a number of individuals per species proportional to the relative outcropping frequency, preferentially selecting shells without fracture due to mechanical excavation (Tab. 4).

The sampled interval is characterized by high amount of frequently articulated specimens of *Paphia rhomboides, Venus verrucosa, V. casina, Acanthocardia tuberculata, Aequipecten opercularis*. Common are also *Glossus humanus, Thracia convexa, Neopycnodonte cochlear, Pecten jacobaeus*, as well as complete shells of the brachiopod *Terebratula scillae*, the scaphopod *Dentalium rectum* and solitary corals such as *Flabellum* sp.. Common is also *Panopea glycimeris*, some individuals of which, with articulated valves, are broken owing to the excavation.

About the northern guests, very frequent is *Arctica islandica*, mainly as large

Tab. 4 - List of the forms sampled and recognized in Contrada Torsano. * = 1-2 sampled specimens; ** = 3-5 s.s.; *** = 6-10 s.s.; **** > 10 s.s..

Acanthocardia tuberculata (Linné, 1758)	****
Aequipecten opercularis (Linné, 1758)	***
Antalis (Dentalium) vulgare (Da Costa, 1778)	****
Arctica islandica (Linné, 1767)	****
Astarte sulcata (Da Costa, 1778)	*
Azorinus chamasolen (Da Costa, 1778)	*
Bolma (Astraea) rugosa (Linné, 1767)	*
Calyptraea chinensis (Linné, 1758)	*
Charonia cfr. *lampas* (Linné, 1758)	*
Clelandella (Jujubinus) miliaris (Brocchi, 1814)	*
Crassadoma (Chlamys) multistriata (Poli, 1795)	**
Cuspidaria rostrata (Sprengel, 1783)	*
Cymathium (Charonia) corrugatum (Lamarck, 1816)	fragments
Dentalium rectum (Gmelin, 1790)	****
Diodora graeca (Linné, 1758)	*
Erato voluta (Montagu, 1803)	*
Euspira (Lunatia) fusca (Blainville, 1825)	***
Flabellum sp.	****
Glans elegans (Réquien, 1848)	*
Glossus humanus (Linné, 1758)	**
Heliacus subvariegatus (D'Orbigny, 1852)	*
Laevicardium crassum (Gmelin, 1791)	*
Lucinoma boreale (Linné, 1758)	***
Nassarius (Hinia) lima (Dillwin, 1817)	**
Natica stercusmuscarum (Gmelin, 1791)	**
Neopycnodonte cochlear (Poli, 1795)	****
Panopea glycimeris (Von Born, 1778)	*
Paphia (Venerupis) rhomboides (Pennant, 1777)	****
Pecten jacobeus (Linné, 1758)	*
Pinna sp.	fragments
Pseudamussium (peplum) clavatum (Poli, 1795)	**
Pseudamussium septemradiatum (Muller, 1776)	****
Serpula sp.	*
Terebratula scillae (Seguenza 1814)	****
Thracia convexa (Wood, 1815)	***
Turbonilla cfr. *lactea*	*
Turritella incrassata (Sowerby, 1814)	*
Venus casina (Linné 1758)	****
Venus verrucosa (Linné, 1758)	****
Xenophora crispa (Koenig, 1825)	*

size specimens (medium height of valve = 7.5 mm; medium length = 7.9 mm, values calculated on 36 sampled individuals, Fig. 5) with articulated valves. Abundant are also *Paphia rhomboides* and *Pseudamussium septemradiatum*, the former sometimes with articulated valves together which less common shells of *P. clavatum*.

Gastropods are less recurrent in the deposits than molluscs. Relatively frequent is *Euspira fusca*; among the other gastropods species, can be mentioned *Bolma rugosa, Cymathium corrugatum* and *Charonia* cfr. *lampas*.

As regard the taphonomy of the sampled shells, the more times aforementioned abundance of articulated shells is one of the main aspects. Noticeable is also the presence of large fragments of *Pinna* sp., whose fragile shell frequently occurred within the deposits. Nevertheless, also the lack of traces of synsedimentary mechanic abrasion, together with the macroscopic absence of bioerosions and a general good state of conservation of the shells, represent important features useful to learn the origin of the fossiliferous levels.

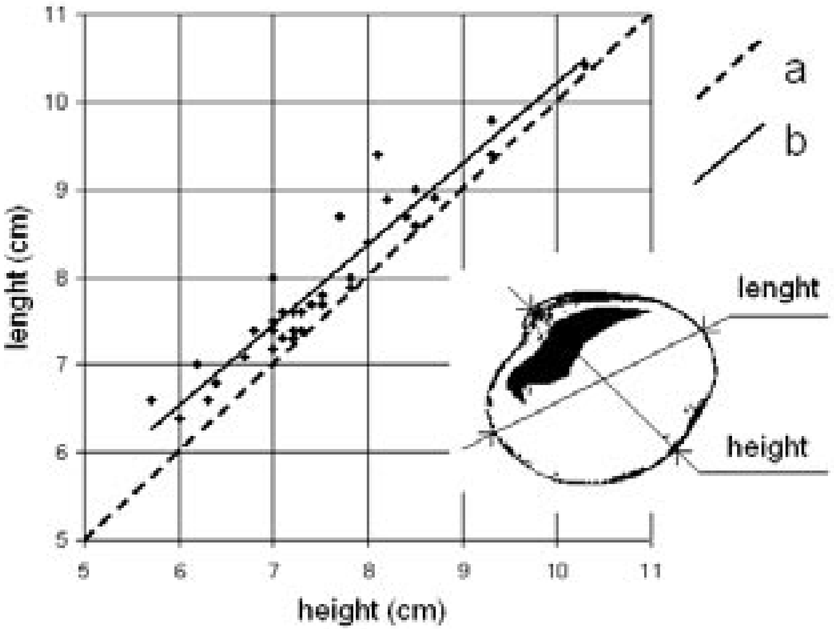

Fig. 5 - Height/Length dispersion graph of 36 sampled *Arctica islandica*. a, bisector; b, tendency line.

DISCUSSIONS

The performed observations allow us to set the depositional events record by the Torsano succession in the Salento Pleistocene evolution (Arnoux *et al.*, 1985; Ciaranfi *et al.*, 1988; D'Alessandro *et al.*, 2004) as well as to infer some sedimentological and ecological aspects concerning the marine bottom environment.

First of all, based on the international convention, the presence of *Arctica islandica* imposes a Pleistocene age and, more in detail, those of *Terebratula scillae* and *Dentalium rectum* (TADDEI RUGGIERO, 1994) bounds the chronological attribution at the Calabrian stage (Tab. 1).

At regional scale, the erosional surface comprised between Cretaceous and Pleistocene deposits of Torsano, is part of a complex ravinement surface, which was carved inside "Bradanic and Apulian sectors" starting from the upper Pliocene, before of the *Calcareniti di Gravina* deposition (TROPEANO and SABATO, 2000). This time trasgressive (or diachronous) landscape was modelled from nearshore marine and shoreline erosion associated with a sea-level rise, paralleling the shift of the shoreface "razor" across previously deposited littoral sediments such as the ochre-brown sands observed at Torsano. These, in turn, could be related to phosphatized calcirudite present in the S-E Salento (BOSSIO *et al.*, 1987b; DELLE ROSE, 2006; DELLE ROSE *et al.*, 2006). In this way, the centimetric cylindrical bores present on the upper Cretaceous surface, can be interpreted as boring ichnofossils due to lithophagus organisms (cf. D'ALESSANDRO and IANNONE, 1982; BROMLEY and D'ALESSANDRO, 1987).

The processes that turned the initial calcareous detritus into the present calcarenites, appear related to post-depositional diagenesis phenomena due to precipitation of Calcium carbonate coming from filtrating rain water solutions. As regard the above described different degree of cementation between the basal hard 30 cm horizon and the rest of the normal diagenized calcarenites, it can be due to the permeability differences of the Cretaceous limestones respect of the overlying calcareous detritus that could favoured a long duration of phreatic conditions as well as determined the mineralization of the shells.

The upper part of the succession of Fig. 3, along whith the out crop conditions let us to perform stratigraphic observations and the fossils sampling, shows lithostratigraphic analogies with the *sabbie a brachiopodi*, unformally defined few km toward NE, in Copertino zone (D'ALESSANDRO and PALMENTOLA, 1978) and recognized also below the Nardò urban area (CHERUBINI and MARGIOTTA, 1984). At the studied zone, a paraconformity between calcarenites and sands is put amid the fossil level rich respectively of *Venus* and *Flabellum* (Figg. 3, 6 and 7). In Copertino zone, D'ALESSANDRO and PALMENTOLA (1978), reported a thin discontinuous earthy-pebbly level, which can be formed by re-sedimentation, in shallow water environment, of weathering materials formed over an adjacent coeval strip of land. In any case, due to the lack of a biostratigraphic data, the correlation between Copertino, Nardò and Torsano successions is not sure at present.

The observed spheroidal concretions of the Torsano upper part succession can be of diagenitic origin (cf. SELLÉS-MARTÍNEZ, 1996); it is noticeable that their petrographic and mineralogical analyses could carry out post-depositional paleo-environmental information.

The fossils rich levels intercalated into the Torsano succession belong to the "shell concentrations" (*sensu* KIDWELL, 1991), showing high density of "biominer-

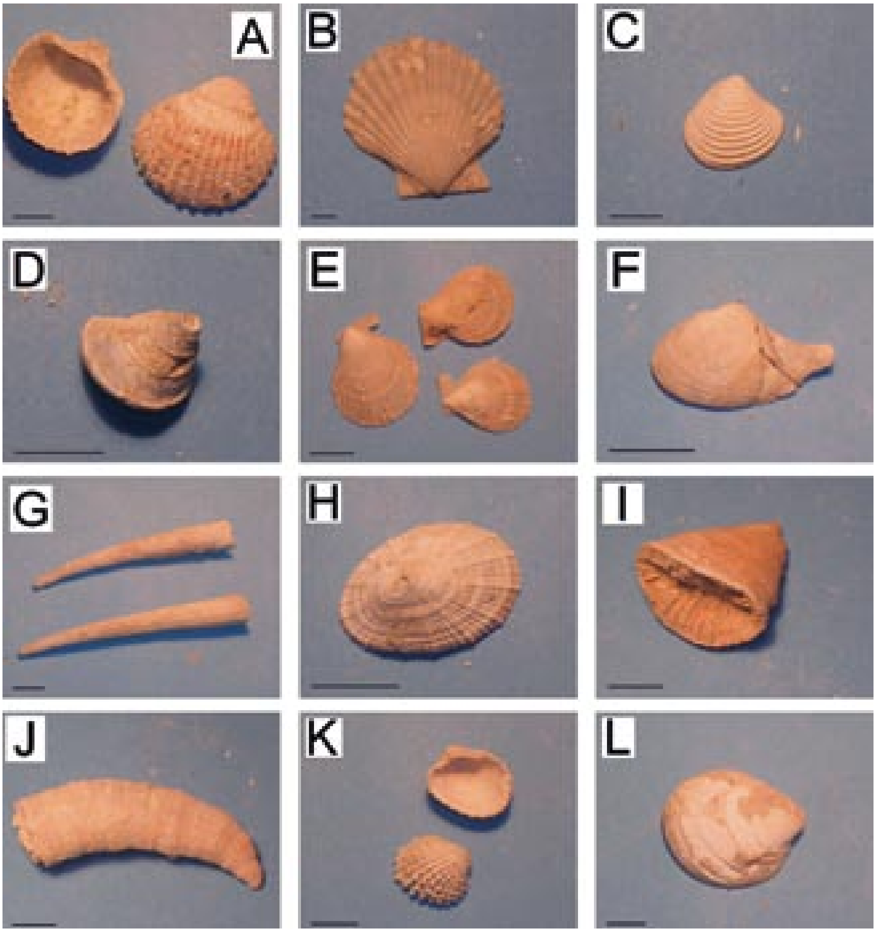

Fig. 6 - A, *Acanthocardia tuberculata*; B, *Aequipecten opercularis*; C, *Astarte sulcata*; D, *Clelandella miliaris*; E, *Crassadoma multistriata*; F, *Cuspidaria rostrata*; G, *Dentalium rectum*; H, *Diodora graeca*; I, J, *Flabellum*; K, *Glans elegans*; L, *Laevicardium crassum*. Bars (= 1 cm) for scale.

alized remains more than 2 mm in size from invertebrate animal". Both the genetic analyses and descriptive classification of the shell concentrations are based on the taphonomic compositions, 3-dimensional arrangement of the shells (biofabric), geometry and stratigraphic-sedimentological features of the deposits. They can reveal ecological, hydrodinamic and topographic information of the depositional environment (FÜRSICH, 1995).

Biological, physical and geological processes play essential roles in the formation of shell concentrations. Among the former, high population densities due to opportunistic life strategies or optimal ecological conditions and mass mortality of organisms caused by biogenic and abiotic phenomena, such us response to changing environmental conditions, represent the main origination events. As regard the physical processes, that frequently occurred in concentration events, the main of which are waves and currents, whose hydrodinamism produces transport and deposition according to weight and shape of shells.

Finally, about the geological processes, reduced rate of net sedimentation may lead to high density of inorganic remains even when the production of biogenic hardparts is low, whereas post deposition compaction of sediments and loading dissolution play only subordinate roles.

On the basis of the sedimentological and taphonomic features above showed (exspecially: the high amount of articulated valves, the absence of shells fragmentation as well as of synsedimentary abrasion, the frequent finding of fragile shell, such us *Pinna* sp.), the fossil-rich levels of Torsano must be considered mainly due to biological events, few reworked by hydrodinamic processes. The lacking of macroscopic evidence of bioerosion on the sampled shells, allows to leave out the rate of net sedimentation among the phenomena at the origin of the concentrations. Nevertheless, also researches carried out on a *Terebratula scillae* population sampled from deposits outcropping few tens of Km E of Torsano (Taddei Ruggiero and Annunziata, 2002), have detected a low percentage of individuals affected by bioerosion, a big amount of which however bored by predator organisms. If a reduced sedimentation rate could had a genetic importance about the formations of high density of shells, extensively trace of biogenic activities must occurred inside the concentrations (cf. Kidwell, 1991; Fürsich, 1995).

The features of the *Arctica islandica* population of Torsano succession let some paleo-ecological consideration; the species is missing from Mediterranean at the end of the last upper Pleistocene Glaciation, whereas it lives on stable bottom of sand and muddy within the biogeographical Boreal and Artic Provinces (Malatesta and Zarlenga, 1986; Cargnelli *et al.,* 1999). The prevalence of large size specimens above described displays singular analogies with the unimodal size distribution of present population living in Iceland (Thorarinsdottir and Einarsson, 1996) and in North America sea depths (Kennish and Lutz, 1995). The estimated optimal temperature and depth which presently favours the proliferation of *Arctica islandica* ranges respectively from 6°C to 16°C and from -25 m to -60 m (Cargnelli *et al.*, 1999). Out of this ranges, the species is present until the limit values of 21°C and -480 m, without forming high density populations.

About another northern guest of Torsano deposits, the *Pseudamussium septemradiatum*, it is necessary to consider that the species was often mistaken as *P. clavatum* (Raffi, 1986); therefore, the quotations which referred to this species within the Mediterranean Pleistocene and present time, are uncertain (Malatesta and Zarlenga, 1986). Parenzan (1974; 1976) recalls that *P. septemradiatum* was found in "some Mediterranean locality", whereas Raffi (1986) admits that the only certain record of living Mediterranean population is the one in Alboran Sea (western Mediterranean), reported by Pérès e Picard (1964). Presently, it is widespread along the eastern Atlantic, from the Norwegian coasts to Morocco, where it lives on muddy bottom at a depth ranging from a few to 200 m.

The third encountered northern guest, *Paphia rhomboides* (Fig. 7), was considered living in Mediterranean from the Santernian (Ruggieri and Sprovieri, 1977), but its presence was reported also within older sediments of the so called "Astian facies" (Caretto, 1985; Malatesta and Zarlenga, 1986). It is characteristic of sandy-muddy bottom of the infra- and circalittoral biological zones and presently widespread in Mediterranean sea (Pérès and Picard, 1964).

Some considerations must do about the conspicuous presence at Torsano of *Acanthocardia*, genus formed, according to Authors, by a variable number of species. In particular, *Acanthocardia tuberculata* is considered the Mediterranean form of *A. echinata* (Linné, 1767), which is presently living in Atlantic, even if

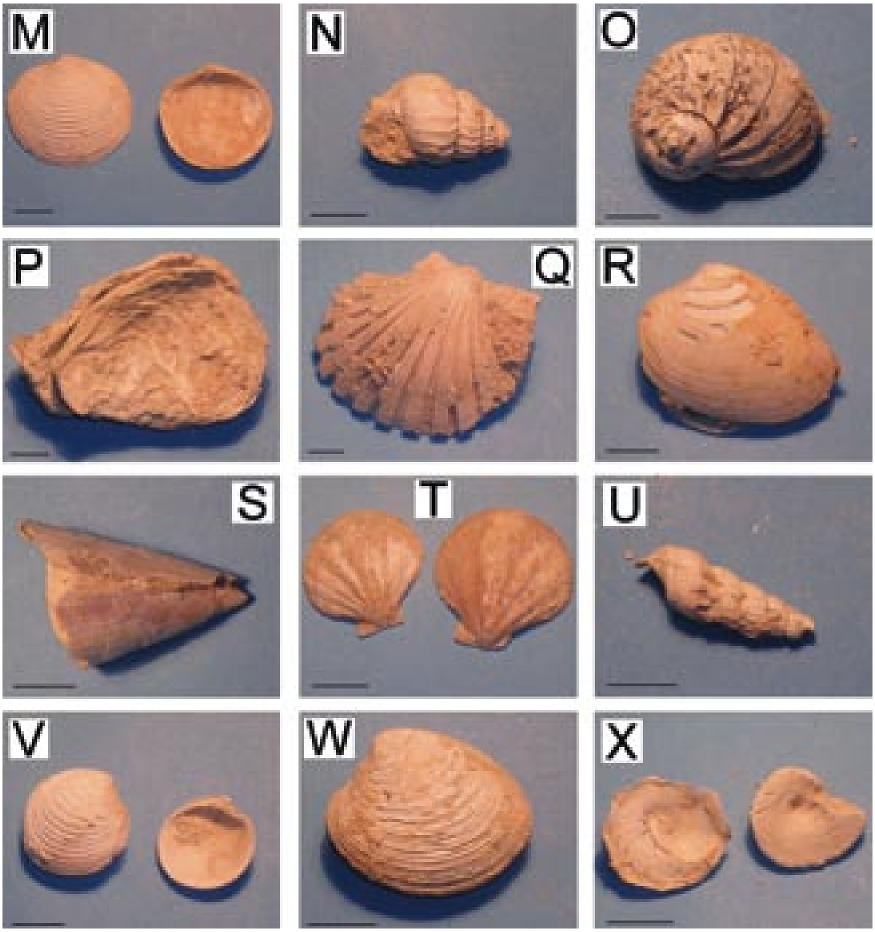

Fig. 7 - M, *Lucinoma boreale*; N, *Nassarius lima*; O, *Natica stercusmuscarum*; P, *Neopycnodonte cochlear*; Q, *Pecten jacobeus*; R, *Paphia rhomboides*; S, *Pinna*; T, *Pseudamussium clavatum*; U, *Turbonilla* cfr. *Lactea*; V, *Venus casina*; W, *Venus verrucosa*; X, *Xenophora crispa*. Bars (= 1 cm) for scale.

their phylogenetic relation appears to be uncertain. As a consequence, they are considered coincident or separate subspecies (Parenzan, 1974; 1976; Malatesta and Zarlenga, 1986). In any case, *A. echinata* “group” is reported in some lower Pleistocene deposits of the Salento peninsula (Macrì, 1983; D’Alessandro and Palmentola, 1978; D’Alessandro *et al.*, 2004). Delle Rose and Medagli (2006) referred to *A. echinata mucronata* some specimens sampled at Contrada Signorella, within the Cutrofiano territory (Fig. 1), that is usually considered a separated subspecies, too.

The genus *Turritella incrassata* (Sowerby, 1814) is described as of North Atlantic origin, migrate into the Mediterranean during the Pliocene or the Pleistocene (Ruggieri, 1949; Borghi and Vecchi, 2005). It is frequently reported within lower Pleistocene deposits, especially of the southern Italy (Ruggieri, 1949; Di Geronimo, 1969; Macrì, 1983), and is considered allochronous subspecies of the present form *T. turbona* (Borghi e Vecchi, 2005), whereas some Authors suggest *T. incrassata* = *T. biplicata* (Pelosio, 1964).

A few of the species recognized at Torsano, as *Dentalium rectum* and *Terebratula scillae*, are extinct at the end of the early Pleistocene. About the brachiopod, the ideal habitat has been supposed on muddy bottom, within the circalittoral zone at 100-150 m of depth (Taddei Ruggiero, 1994).

The remain distinguished fossils of Torsano succession, are presently living in Mediterranean again (Parenzan, 1970, 1974, 1976; Repetto *et al.*, 2005), the greatest part of which also in its eastern portion (Demir, 2003). Some molluscs are ecological key-specie indicative of well defined environmental conditions, such us *Lucinoma boreale*, typical of instable muddy bottom (Malatesta, 1974) and *Thracia convexa*, exclusive of coastal terrigenous muds biocenosis (VTC of Pérès and Picard, 1964; Picard, 1965; Pérès, 1967). Nevertheless, a number of species forming the described fossil community, such as *Antalis vulgare*, *Dentalium rectum, Glossus humanus, Venus casina*, *V. verrucosa, Xenophora crispa*, indicate muddy-bottom subtidal environmental conditions. Can be stressed also that *Acanthocardia tuberculata, Aequipecten opercularis, Glossus humanus* and *Pecten jacobeus* are species presently characterizing the external zone of the Apulian shelf (Marano *et al.*, 1989).

CONCLUSIONS

According to the current stratigraphic schemes (Aguirre and Pasini, 1985; Vai, 1997; Taddei Ruggiero, 1994), the presence of *Arctica islandica*, *Dentalium rectum* and *Terebratula scillae* allows to refer the studied succession to the lower Pleistocene, differently by the upper (and dubitatively also middle) Pliocene attribution of the “Foglio 214 Gallipoli” (Servizio Geologico d’Italia, 1969).

Fossils of the succession are mainly arranged within six shell concentrations (*sensu* Kidwell, 1991). Based on sedimentological, biofabric and taphonomic features, the origin of these concentrations must be due to biological processes, whereas less importance had physical processes (waves, current) as well as the rate of net sedimentation. The high specimen density of the concentrations could be produced by opportunistic life strategies and optimal ecological conditions, perhaps linked to cooling of the water (Fürsich, 1995). Ecological interpretations (Pérès and Picard, 1964; Picard, 1965; Pérès, 1967) of the described benthic thanatocenosis, infer the recognition, from the base to the top of Torsano succession, of a environmental change from infralittoral zone, exposed to marine abrasion by means of waves and currents, to circalittoral zone, caused both the increasing of bottom depth and of the sea water turbidity, which are tightly consistent with the early Pleistocene evolution of the Salento peninsula (Arnoux *et al.*, 1985; Bossio *et al.*, 1987a,b,c; Ciaranfi *et al.*, 1988; D'Alessandro *et al.*, 2004).

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REFERENCES

Aguirre E., Pasini G., 1985 – The Pliocene-Pleistocene Boundary. Episodes, 8: 116-120.

Arnoux C., Mascle J., Campredon R., Mascle G., Rossi S., 1985 – Cadre géodynamique et évolution récent de la dorsale apuliénne et dés ses bourdes. Giorn. di Geol., 47: 101-127.

Azzaroli A., Cita B.M., 1980 – Geologia stratigrafica vol. 3. Cisalpino Goliardica, Milano: 405 pp.

Barbera C., Bossio A., Matteucci R., Mazzei R., Monteforti B., Ragaini L., Salvatorini G., Varola A., 1993 – Il giacimento a scutelle di cava "I Rizzi" presso Galatone. In: Giuda alle escursioni XII Conv. Soc. Paleont. It., Terra d'Otranto 28 sett./2 ott.: 91-96.

Bassett M. G., 1985 - Towards a "Common Language" in Stratigraphy. Episodes, 8/2 : 87.

Bonadonna F.P., Alberdi M.T., 1987 – The N/Q boundary at 1.64 MA? Mediterranea, 6: 115-130.

Borghi M., Vecchi G., 2005 – La malacofauna plio-pleistocenica del Torrente Stirone (PR). Parva Naturalia, 7: 3-46.

Bosellini A., Bosellini F.R., Colalongo M.L., Parente M., Russo A., Vescogni A., 1999 – Stratigraphic architecture of the Salento coast from Capo d'Otranto to S. Maria di Leuca (Apulia, southern Italy). Rivista italiana di Paleontologia e Stratigrafia, 105: 397-416.

Bossio A., Guelfi F., Mazzei R., Monteforti B., Salvatorini G., 1987b - Precisazione sull'età della Formazione di Uggiano la Chiesa nella zona di Otranto (Lecce). Quaderni di ricerche del Centro Studi Geotecnici e di Ingegneria, 11: 175-194.

Bossio A., Guelfi F., Mazzei R., Monteforti B., Salvatorini G., Varola A., 1987c - Precisazione sull'età dei sedimenti pleistocenici di due cave del leccese (San Pietro in Lama e Cutrofiano). Quaderni di ricerche del Centro Studi Geotecnici e di Ingegneria, 11: 147-173.

Bossio A., Guelfi F., Mazzei R., Monteforti B., Salvatorini G., 1991 - Note geologiche e stratigrafiche sull'area di Palmariggi (Lecce, Puglia). Riv. It. Paleont. Strat., 97: 175-234.

Bossio A., Mazzei R., Monteforti B., Salvatorini G., 1987a - Evoluzione paleogeografica dell'area di Leuca nel contesto della dinamica Mediterranea. Quaderni di ricerche del Centro Studi Geotecnici e di Ingegneria, 11: 31-54.

Bossio A., Mazzei R., Monteforti B., Salvatorini G., 1992 – Notizie preliminari sul Miocene di S.Maria al Bagno – S.Caterina presso Nardò (Lecce). Paleopelagos, 2: 99-107.

Bromley R.G., D'Alessandro A., 1987 – Bioerosion of the Plio-Pleistocene transgression of Southern Italy. Riv. It. Paleont. Strat., 93: 379-442.

Caretto P.G., 1985 – Segnalazione del lamellibranco Venerupis rhomboides (Pennant, 1777) nel Pliocene Piemontese. Atti Soc. It. Sci. Nat., 126: 101-119.

Cargnelli L.M., Griesbach S.J., Packer D.B., Weissberger E., 1999 – Ocean Quahog, Arctica islandica, life history and habitat characteristics. NOAA Technical Memorandum, Massachusetts: 12 pp.

Castradori D., Rio D., Hilgen F.J., Lournes L.J., 1998 - The Global Standard Stratotype section and Point (GSSP) of the Piacenzian Stage (Middle Pliocene), Episodes 21: 88-93.

Ciaranfi N., Pieri P., Ricchetti G., 1988 – Note alla Carta Geologica delle Murge e del Salento (Puglia centromeridionale). Mem. Soc. Geol. It., 41: 449-460.

Cita B.M., 1975 - Planktonic foraminiferal biozonation of the mediterranean Pliocene deep sea record. A Revision, Riv. It. Paleont. Stratigr., 81: 503-558.

Cita B.M., Castradori D., 1995 – Rapporto sul workshop "Marine sections from the Gulf of Taranto (southern Italy) usable as potential stratotypes for the GSSP af the lower, middle and upper Pleistocene". Boll. Soc. Geol. It., 114: 319-336.

Cherubini C., Margiotta B., 1984 – Caratteristiche geolitologiche e geotecniche dei depositi quaternari di nardò (Lecce). Quaderni di ricerche del Centro Studi Geotecnici e di Ingegneria, 9: 3-19.

Colalongo M.L., Sartoni S., 1979 - Schema biostratigrafico per il Pliocene ed il basso Pleistocene in Italia, Pubbl. 251, P. F. Geodinamica, C.N.R.: 645-654.

Commissione Italiana di Stratigrafia della S.G.I., 2003 – Giuda italiana alla classificazione e alla terminologia stratigrafica, APAT, quaderni serie III, 9: 156 pp.

D'Alessandro A., Iannone A., 1982 – Pleistocene carbonate deposits in the area of Monopoli (Bari province): sedimentology and palaeoecology. Geologica Romana, 21: 603-653.

D'Alessandro T., Massari F., Davaud E., Ghibaudo G., 2004 – Pliocene-Pleistocene sequences bounded by subaerial uncondormities within foramol ramp calcarenites and mixed deposits (Salento, SE Italy). Sedimentary Geology, 166: 89-144.

D'Alessandro A., Mastronuzzi G., Palmentola G., Sansò P., 1994 – Pleistocene deposits

of Salento leccese (Southern Italy): Problematic relationships. Boll. Soc. Paleont. It., 33: 257-263.
D'Alessandro A., Palmentola G., 1978 – Sabbie a Brachiopodi, una nuova unità del Salento leccese (aspetti litostratigrafici e paleoambientali). Riv. It. Paleont., 84: 1083-1120.
De Giorgi C., 1876 – Note geologiche sulla provincia di Lecce. Boll. R. Com. Glac. d'It., Roma: 280 pp.
De Giorgi C., 1879 – Carta Geologica della Provincia di Lecce (scala 1:400.000). Comit. Geol. Ital., Roma.
De Giorgi C., 1903 – La serie geologica dei terreni nella Penisola Salentina. Mem. Pont. Acc. Rom. N. Lincei, 20: 155-218.
Demir M., 2003 – Shells of Mollusca Collected from the Seas of Turkey. Turk J. Zool., 27: 101-140.
Delle Rose M., 1993 – Caratteri della sedimentazione miocenica del Salento. Riassunti 3a riunione Gr. Inf. Sedim. CNR, Salice Terme.
Delle Rose M., 2001 - Salento Miocene: a preliminary paleoenvironmental reconstruction. Thalassia Salentina, 25: 41-66.
Delle Rose M., 2006 – Mediterranean Pliocene events in the Salento geological record. Thalassia Salentina, 29: 77-99.
Delle Rose M., Medagli P., 2006 – Osservazioni su strati con malacofaune "nordiche" del Pleistocene salentino. Riassunti 83° Congresso SGI, Chieti, 113-115.
Delle Rose M., Resta F., Pappafico G., 2006 – Problematiche stratigrafiche e cartografiche del Pliocene a est di Lecce. Riassunti 83° Congresso SGI, Chieti, 117-120.
Di Geronimo I., 1969 – I depositi quaternari tra Brindisi e Torre Canne. Atti Acc. Gioenia Sc. Nat., 20: 195-224.
Fürsich F.T., 1995 – Shell concentrations. Eclogae Geol. Helv., 88: 643-655.
Gignoux M., 1913 – Les formations marines pliocènes et quaternaries de l'Italie du Sud et de la Sicilie. Ann. Univ. Lyon N.S., 36: 633 pp.
Gradstein F.M., Ogg J.M., Smith A.G., 2004 – A Geological Time Scale 2004. Cambridge University Press: 589 pp.
Kennish M.J., Lutz R.A., 1995 – Assessment of the ocean quahog, Arctica islandica (Linneus, 1767), in the New Jersey fishery. Journal of Shellfish Research, 14: 45-52.
Kidwell S.M., 1991 – The stratigraphy of shell concentrations. In: Allison P.A., Briggs D.E.G., Taphonomy. Releasing the data locked in the fossil record. Plenum Press: 211-290.
Largaiolli T., Martinis B., Mozzi G., Nardin M., Rossi D., Ungaro S., 1969 – Note Illustrative della CGI, Foglio 214 Gallipoli. Servizio Geologico d'Italia, Roma: 64 pp.
Lyell C., 1832 – Principles of Geology, being an attempt to explain the former changes of the earth's surface, by references to causes now in operation, vol. 2. John Murray, London: 232-233.
Lyell C., 1839 – Noveaux éléments de géologie. Pitois-Levranet, Paris : 648 pp.
Iaccarino S., Salvatorini G., 1982 - A framework pf planktonic biostratigraphy for Early Miocene to Late Pliocene Mediterranean sea. Paleont. Strat. Evol., 2 : 115-125.
Macrì G., 1983 – Contributo alla conoscenza delle argille di Cutrofiano (LE). Quaderni del Museo Civico di Paleontologia e Paletnologia di Maglie, 1: 101-141.
Mauget A., 1864 – Note geologiche sulla provincia di Terra d'Otranto diretta alla ricerca di pozzi artesiani. Traduzione di Mandarini A., opera in 8°, Lecce: 32 pp.

Malatesta A., 1974 – Malacofauna pliocenica umbra. Mem. Serv. Carta Geol. It., 13: 498 pp.

Malatesta A., Zarlenga F., 1986 – Northern guests in the Pleistocene Mediterranean Sea. Geologica Romana, 25: 91-154.

Marano G., Ungaro N., Vaccarella R., 1989 – Nota preliminare sulle comunità di macroinvertebrati dei fondi strascicabili dell'Adriatico pugliese. Thalassia Salentina, 19: 3-19.

Martini E., 1971 - Standard Tertiary and Quaternary calcareous nannoplancton zonation. Proc. II Plankt. Confer.: 739-785.

Martinis B., 1967 – Note geologiche sui dintorni di Casarano e di Castro (Lecce). Riv. Ital. di Paleont. e Strat., 73: 1297-1380.

Nardin M., Rossi D., 1966 – Condizioni strutturali della zona compresa nel foglio Otranto. Mem. Mus. Civ. St. Nat., 14: 415-430.

Parenzan P., 1970 – Carta d'identità delle conchiglie del Mediterraneo. I Gasteropodi. Bios Taras Ed., Taranto: 283 pp.

Parenzan P., 1974 – Carta d'identità delle conchiglie del Mediterraneo. I Bivalvi I. Bios Taras Ed., Taranto: 280 pp.

Parenzan P., 1976 – Carta d'identità delle conchiglie del Mediterraneo. I Bivalvi II. Bios Taras Ed., Taranto: 546 pp.

Partridge, 1997 – Reassessment of the position of the Plio-Pleistocene boundary: is there a case for lowering it to the Gauss-Matuyama paleomagnetic reversal? Quaternary International, 40: 5-10.

Patacca E., Scandone P., 2004 - The Plio-Pleistocene thrust belt-foredeep system in the Southern Apennines and Sicily (Italy), special volume of the Italian Geological Society for the IGC 32, 93-129.

Pelosio G., 1964 – Nuovi dati sul Calabriano a Cyprina islandica nel Parmense occidentale: V° contributo alla conoscenza del Calabriano nel Preappennino Parmense. L'Ateneo Parmense, 35: 57-74.

Pérès J.M., 1967 – The Mediterranean benthos. Oceanogr. Mar. Biol. Am. Rev., 5: 449-533.

Pérès J.M., Picard J., 1964 – Nouveau manuel de Bionomie benthique de la Mer Mediterraneé. Rec. Trav. Stat. Mar. End., 31: 137 pp.

Picard J., 1965 – Recherches quelitatives sur les biocénoses des substrats meubles draguables de la région marseillaise. Bull. Rec. Trav. St. Mar. Endoume, 36: 1-160.

Raffi S., 1986 – The significance of marine boreal Mollusks in the early Pleistocene faunas of the Mediterranean Sea. Palaeogeogr., Palaeoclim., Palaleoecol., 52: 267-289.

Repetto G., Orlando F., Arduino G., 2005 – Conchiglie del Mediterraneo. Ass. Amici Museo F. Eusebio, Alba: 392 pp.

Rio D., Sprovieri R., Castradori D., Di Stefano E., 1998 – The Gelasian stage (Upper Pliocene): A new unit of the global standard chronostratigraphic scale. Episodes, 21: 82-87.

Ruggieri G., 1949 – Il terrazzo marino presiciliano della penisola di Crotone. Giorn. Geol., 20: 63-110.

Ruggieri G., Sprovieri R., 1977 – A revision of Italian Pleistocene stratigraphy. Geologica Romana, 16: 131-139.

Seguenza G., 1873, 1874, 1875, 1876 – Studi stratigrafici sulla formazione pliocenica dell'Italia meridionale. Boll. R. Com. Geol. It., vol. 4, 5, 6, 7. Fide De Giorgi C., 1903.

SELLÉS-MARTÍNEZ J., 1996 – Concretion morphology, classification and genesis. Earth-Science Review, 41: 177-210.

SERVIZIO GEOLOGICO D'ITALIA, 1969 – Carta geologica d'Italia a scala 1:100.000, II edizione, Foglio 214 "Gallipoli". Ist. Grafico Litostampa, Gorle.

SPROVIERI R., RUGGIERI G., UNTI M., 1980 - Globorotalia truncatulinoides excelsa N. Subsp., foraminifero planctonico guida per il Pleistocene inferiore. Boll. Soc. Geol. It., 99: 3-11.

TADDEI RUGGERO E., 1994 – Neogene Salento brachiopod palaeocommunities. Boll. Soc. Paleont. It., 33: 197-213.

TADDEI RUGGERO E., ANNUNZIATA G., 2002 – Bioerosion on a Terebratula scillae population from the Lower Pleistocene of Lecce area (Southern Italy). Acta Geologica Ispanica, 37: 43-51.

THORARINSDOTTIR G.C., EINARSSON S.T., 1996 – Distribution, abundance, population structure and meat yeld of the ocean quahog, Arctica islandica, in Icelandic waters. Jour. Mar. Biol. Ass. UK, 76: 1107-1114.

TROPEANO M., SABATO L., 2000 – Response of Plio-Pleistocene mixed biclastic-lithoclastic temperate-water carbonate systems to forced regression: the Calcarenite di Gravina Formation, Puglia, SE Italy. In: Hunt D., Gawthorpe R.L., Sedimentary Responses to Forced Regression. Geological Soc. London, sp. Publ., 172: 217-243.

TROPEANO M., SPALLUTO L., MORETTI M., PIERI P., SABATO L., 2004 – Depositi carbonatici infrapleistocenici di tipo foramol in sistemi di scarpata (Salento – Italia meridionale). Il Quaternario, 17(2): 537-546.

UFFICIO GEOLOGICO D'ITALIA, 1904 – Carta geologica d'Italia a scala 1:100.000, Foglio 214 "Gallipoli". Firenze.

USEPA, 2002 – A Lexicon of Cave and Karst Terminology with Special Reference to Environmental Karst Hydrology. Washington D.C.: 221 pp.

VAI G.B., 1997 – Twisting or stable Quaternary boundary? A perspective on the glacial late Pliocene concept. Quaternary International, 40: 11-22.