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Arbacina romana (Merian, 1858) from the lower Pleistocene of Favignana Island (Sicily)

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Riassunto

Viene esaminata la popolazione di *Arbacina romana* (Merian, 1858), un echinide appartenente alla famiglia Temnopleuridae, presente nel Pleistocene inferiore dell'Isola di Favignana (Trapani). In tabella 1 sono indicati gli affioramenti dell'isola dove sono stati raccolti i 121 esemplari oggetto dello studio. La quantità e lo stato di conservazione mediamente buono del materiale fossile disponibile permettono un confronto con campionature attribuite alla stessa specie raccolte nel Pliocene e nel Pleistocene di altre 6 località italiane, confermandone la corrispondenza tassonomica. Viene descritta la distribuzione della colorazione originaria che non era ancora nota; si riportano inoltre alcune osservazioni riguardanti la natura delle depressioni e delle indentazioni alla base dei tubercoli, due caratteri morfologici che sono considerati diagnostici a livello generico. I dati desunti da una sintetica analisi statistica biometrica (tabella 2) quantificano le principali variazioni morfologiche presenti all'interno del campione esaminato, composto da 87 esemplari. Viene proposta un'interpretazione dell'ambiente originario di vita di questa specie; i risultati desunti corrispondono ai dati paleoecologici riportati in studi esistenti riguardanti alcune delle località di ritrovamento di questa specie nel Mediterraneo: *Arbacina* era un piccolo echinide che viveva come epibionte vagile su fondali di bassa profondità, caratterizzati dalla presenza di tappeti di briozoi e di alghe, che potevano essere esposti a una notevole attività idrodinamica. Un confronto con campionature costituite da numerosi esemplari attribuiti a *Genocidaris maculata* A. Agassiz, 1869 raccolte nel Pliocene e nel Pleistocene del torrente Arda presso Castell'Arquato (Piacenza) e del torrente Stirone presso Salsomaggiore (Parma), permette di impostare un'indagine preliminare sulla validità dei criteri stabiliti per separare i generi *Arbacina* Pomel, 1869 e

Genocidaris A. AGASSIZ, 1869. Dal momento che i caratteri morfologici distintivi coesistono, seppur con diversa frequenza, nelle popolazioni attribuite in letteratura ai due generi, sorgono dubbi sull'opportunità di mantenere separati questi due generi. Studi più approfonditi (in corso) potranno chiarire definitivamente la questione. Nel frattempo si ritiene corretto mantenere separati questi due taxa ed effettuare l'attribuzione a livello generico sulla base della frequenza con la quale i caratteri ritenuti diagnostici si presentano all'interno di un campione rappresentativo della popolazione studiata.

Abstract

This article deals with the study of a population of *Arbacina romana* (MERIAN, 1858) from the lower Pleistocene of Favignana Island (Egadi Archipelago, Western Sicily). The quantity and the preservation of the fossil material allow a morphological comparison with samples attributed to the same species from six Pliocene and Pleistocene Italian localities. An interpretation of the ecological requirements of this echinoid is proposed. A morphological comparison with specimens of *Genocidaris maculata* A. AGASSIZ, 1869 from the Plio-Pleistocene of Emilia (Northern Italy) allows a preliminary investigation into the reliability of the distinctive morphological characters separating genera *Arbacina* POMEL, 1869 and *Genocidaris* A. AGASSIZ, 1869.

Parole chiave: Echinoidea, Plio-Pleistocene, Mediterraneo, *Arbacina romana*, relazione *Arbacina - Genocidaris*.

key words: Echinoidea, Plio-Pleistocene, Mediterranean, *Arbacina romana*, relationship *Arbacina-Genocidaris*.

* * *

Introduction

The isle of Favignana belongs to the Egadi Archipelago, situated in front of the western coast of Sicily. Our research in this locality was conducted between 1997 and 2000; 607 echinoid specimens were collected or studied in the field, eleven genera and fourteen species were identified. The list of the recognised taxa is reported in table 1.

This rich echinoid fauna has received scant attention till now since a sole previous record by Checchia Rispoli (1938) is present in literature; the Sicilian echinologist, when studying a private collection, recognised only three taxa from Favignana: *Sphaerechinus granularis, Echinolampas hoffmanni* and *Spatangus purpureus*. He had not the opportunity to collect the fossil material in the field, as a consequence he erroneously attributed this association to the Tyrrhenian outcrops, previously described by Gemellaro (1919). In reality in the upper Pleistocene sediments only rare and poorly preserved tests of *Genocidaris maculata* and *Echinocyamus pusillus* are present: we collected a few specimens belonging to these species at Punta Marsala and along the coast between Grotta Perciata and Punta Fanfalo (see the location map: fig.1). *Sphaerechinus,*

Echinolampas and *Spatangus* instead are common in the lower Pleistocene biocalcarenites, associated to most of the other echinoids.
This paper concerns in particular the population of *Arbacina romana*: the specimens collected at Favignana and those housed in the University of Palermo from the Quaternary of Monte Pellegrino, studied by Checchia Rispoli (1907, 1916), represent the largest samples of this species available from Italian localities. The observation of this fossil material improves the knowledge regarding the morphological features of genus *Arbacina* and allows a more reliable discussion on its diagnostic characters.

Fig. 1 *Map of Favignana Island reporting the localities cited in the text.*
Fig. 1 Mappa dell'isola di Favignana con l'indicazione delle località riportate nel testo.

n.1 Ancient quarries along the coast between the Port of Favignana and Cala San Nicola
n.2 Cala Rossa
n.3 Bue Marino
n.4 Punta Marsala
n.5 Cliffs between Grotta Perciata and Punta Fanfalo

n.1 Antiche cave lungo la costa tra il porto di Favignana e Cala San Nicola
n.2 Cala Rossa
n.3 Bue Marino
n.4 Punta Marsala
n. 5 Scogliere tra Grotta Perciata e Punta Fanfalo

Tab. 1 *List of the echinoid taxa recognised at Favignana.*
Tab. 1 Elenco degli echinoidi riconosciuti a Favignana.

Abbreviations used:
C = common (more than 50 specimens)
F = frequent (10 - 50 specimens)
R = rare (1 - 9 specimens)

Abbreviazioni utilizzate:
C = comune (più di 50 esemplari)
F = frequente (10 - 50 esemplari)
R = raro (1-9 esemplari)

lower Pleistocene (Sicilian) Pleistocene inferiore (Siciliano)		frequency frequenza
Cidaris cidaris	(Linneus, 1758)	R
Arbacina romana	(Merian, 1858)	C
Sphaerechinus granularis	(Lamarck, 1816)	C
Psammechinus astensis	Sismonda, 1842	F
Echinus acutus	Lamarck, 1816	F
Echinus siculus	Checchia Rispoli, 1916	F
Paracentrotus lividus	(Lamarck, 1816)	C
Echinocyamus pusillus	(Muller, 1778)	F
Echinolampas hoffmanni	Desor, 1858	C
Brissus unicolor	(Leske, 1778)	R
Spatangus purpureus	(Muller, 1778)	C
Spatangus subinermis	Pomel, 1887	R
Echinocardium cordatum	(Pennant, 1777)	R
Echinocardium melii	(Checchia Rispoli, 1923)	F
upper Pleistocene (Tyrrhenian) Pleistocene superiore (Tirreniano)		frequency frequenza
Echinocyamus pusillus	(Muller, 1778)	R
Genocidaris maculata	A. Agassiz, 1869	R

Geological setting

The sediments outcropping in the eastern part of the isle mostly date to the lower Pleistocene (Malatesta, 1957; Agnesi *et al.*, 1993); they are directly lying on the Mesozoic-Tertiary grounds. Only in a few localities the Quaternary deposits lie in discordance on early-Pliocene grey-whitish marls: at Cala Rossa (Red Bay) and along the western bank of the Port of Favignana.

The lower Pleistocene sediments are constituted by a thick package of whitish biocalcarenites, stratified in big benches. They are relatively tender and easily workable by manual tools; this explains the intense extracting activity, lasting since ancient times (Racheli, 1979). The square blocks of "Pietra di Favignana" were carved in numerous quarries, still well visible on the eastern part of the island. This material was largely utilised for construction purposes: many buildings in the centre town of Trapani are made of these stones. A few quarries are still active, nevertheless the present extractive method, based on mechanical sawing, prevents to collect complete fossils.

Wide remains of Tyrrhenian deposits are still laying on the calcareous sandstones of the western part of the island, from 5 to 30 m above the sea level. According to Malatesta (1957) these deposits were present also on the eastern part but they were removed by the intensive extracting activity.

At Cala Rossa the upper Pleistocene is represented by a heterogeneous well-cemented conglomerate covered by a landslide deposit containing large chaotically mixed blocks; these calcarenite blocks, and the enclosed fossil echinoids, belong to the main lower-Pleistocene bank; a continental deposit lies over these sediments (Agnesi *et al.*,1993).

The morphology of the isle is characterised by two wide flat areas interpreted as sea-abraded surfaces, due to marine transgressions occurred in the upper Pleistocene (Agnesi *et al.*, 1993); they are separated by a more elevated central portion made by Mesozoic and Tertiary sediments, corresponding to Monte Santa Caterina (302 m).

Materials and methods

The echinofauna is not uniformly distributed over the section of the calcarenite bank: e.g. specimens belonging to *Echinolampas hoffmanni* are rather common but they are concentrated in two layers outcropping along the northern coast of the isle. Also the other echinoids are usually concentrated in shell beds.

The most interesting fossiliferous outcrops are situated along the coast, at the point where the sediments are weathered out by the sea-waves: the cliffs between the port of Favignana and Punta San Nicola, Cala Rossa, near the lighthouse of Punta Marsala and between Grotta Perciata and Punta Fanfalo.

The echinoids of the small forms are often preserved as whole coronas; the larger tests of *Echinus acutus, Sphaerechinus granularis* and *Spatangus purpureus* instead are usually fragmented or crushed by compression.

Almost 20% of the echinoid specimens recognised at Favignana belong to *Arbacina*: the available material consists of 121 whole coronas and several fragments. A sample consisting in 87 specimens was utilised for a statistical biometric analysis in order to quantify the main morphological variations of the population. The specimens were obtained by simple hand picking; two bulk samples, taken at Punta Marsala and Grotta Perciata from a friable part of the calcarenite, were washed with hydrogen peroxide and then wet sieved: two small specimens were obtained by picking from the residue using a binocular microscope. The morphology of the test is characterized by 4 measurements and by 3 ratios: the obtained statistical data are reported in table 2. All the measures are in millimetres; they were obtained using a stereomicroscope Konus 6000 bearing a graduate lens and by a digital calliper.

The abbreviations used are:

D =	diameter of the test at the ambitus
H =	height of the test
A =	diameter of the apical apparatus
P =	diameter of the peristome
Na =	number of the plates present in a vertical ambulacral series
Nia =	number of the plates present in a vertical interambulacral series
M =	mean value
N =	number of specimens
SD =	standard deviation
SE =	standard error
r =	correlation index

The SEM photos were taken at the Electronic Microscopic Service of Salamanca University, the SEM photo reported in pl. 2, fig. 4 was provided by the Institute of Paleontology, University of Vienna. The macro-photos were taken utilising a 70 mm macro objective and extendible bellows.

The specimens of *Arbacina romana* from Favignana and of *Genocidaris maculata* from the Arda and the Stirone Rivers (Emilia, Northern Italy) utilised for this study are deposited in the Museo Geologico G. Cortesi of Castell'Arquato (Piacenza) and in the Museo Civico of Salsomaggiore.

The catalogue numbers are constituted by the abbreviation Ar (*Arbacina*) and Gm (*Genocidaris*), followed by the serial number.

Tab. 2 *Sample of Arbacina romana from Favignana: main statistical data.*
Tab. 2 Dati statistici principali della campionatura raccolta a Favignana.

	N	min	Max	M	SD	SE	r
D	87	4.3	17.8	9.24	2.41	0.26	-
H	87	2.5	10.9	5.90	1.67	0.18	0.97
A	75	1.6	4.3	2.73	0.57	0.07	0.93
P	83	2.1	6.1	4.01	0.82	0.09	0.93
100 H/D	87	51	77	63.4	4.56	0.49	-
100 A/D	75	24	37	29.4	2.72	0.31	-
100 P/D	83	34	53	44.1	3.60	0.40	-

Systematic part

Class Echinoidea LESKE, 1778
Subclass Euechinoidea BRONN, 1860
Infraclass Acroechinoidea SMITH, 1981
Cohort Echinacea CLAUS, 1876
Superorder Camarodonta JACKSON, 1912
Order Temnopleroida MORTENSEN, 1941
Family Temnopleuridae A. AGASSIZ, 1872
Genus *Arbacina* POMEL, 1869

Arbacina romana (MERIAN, 1858)

?	1853	*Arbacia depressa* A. AGASSIZ	Aradas: p.175
	1858	*Psammechinus romanus* n. sp.	Merian in Desor: p.122
	1880	*Psammechinus monilis* DESMOULINS	Manzoni: p.6
	1907	*Arbacina depressa* ARADAS	Checchia Rispoli: p. 208; pl. 17, fig. 15-33
	1916	*Arbacina romana* (MERIAN)	Checchia Rispoli: p. 233
	1923	*Arbacina romana* (MERIAN)	Checchia Rispoli: p. 11-12; pl. 2, fig.12-16
	1936	*Arbacina romana* (MERIAN)	Checchia Rispoli: p. 307-308; pl. 16, fig. 6
	1938	*Arbacina romana* (MERIAN)	Checchia Rispoli: p. 208

The specimens from Favignana show the typical morphological features of this species, as it was interpreted by Checchia Rispoli (1907).
The test is small, hemispherical, more or less depressed (pl. 1, fig. 2); the outline is circular (pl. 1, fig. 1), seldom sub-pentagonal, the oral surface is flattened The apical system is dicyclic with ocular plates exert (pl. 1, fig. 7). Both in ambulacral and interambulacral plates the primary tubercles are imperforate and non crenulate, with a distinct boss

and a globular mamelon with undercut neck; they are close to the lower edge of the plates, the ambulacral ones are adjoining to the poriferous zones. The bases of the tubercles are smooth (pl. 1, fig. 6). The primary tubercles are often linked into vertical columns by two more or less pronounced ridges (catenae) (pl. 1, fig. 4; pl. 4, fig. 5). The surface of the plates is covered by a dense secondary tuberculation; the mamelonate secondary tubercles are more frequent than the granules. The primary tubercles may be surrounded by an areole made by secondary ones. The poriferous zones are almost straight; each ambulacral plate bears three partitioned P2 isopores (compare Smith, 1978). There may be small depressions on the surface of the plates, above all along the horizontal sutures; they are more frequent in large specimens, on the plates situated near the ambitus. The gill slits are little developed. The auricles instead are well developed and always joined above in adult individuals.

The observation of the specimens from Favignana brings some news concerning the morphological features of this species:

The ridges linking the primary tubercles (catenae) usually cross over the horizontal sutural line and connect to the base of the couple of secondary tubercles situated nearby to the upper edge of the adjacent plate; between these secondary tubercles there is often a small granule (pl. 1, fig. 5).

Sections taken in correspondence of the depressions show that the variation in the thickness of the plate is usually modest or even absent (pl. 3, fig. 8); therefore these "depressions" often consist only in small areas deprived of the dense tuberculation which crowds the surface of the plates.

The depressions are rather frequent also around the primary tubercles, seldom even slightly notching their base (pl. 1, fig. 4).

Two specimens still bear patterns of the original coloration: large clear sub-circular spots are scattered just above the ambitus (pl. 4, fig. 4); they are positioned higher up in the ambulacral series than in the interambulacral ones.

The ontogenetic morphological variations, deduced by the statistical biometric analysis, correspond to those observed by Philippe (1998) concerning a Miocene sample of *Arbacina catenata* from France: the young individuals are on the average more depressed than the adults, their peristome is wider in proportion; in the largest specimens the profile of the test is more elevated and the peristome becomes proportionally smaller.

Records of *Arbacina romana* from other Italian localities

The first description of specimens belonging to *Arbacina* from the Pleistocene of Sicily most probably dates back to 1853 by Aradas, who studied a few tests from Militello near Catania; nevertheless he erroneously attributed them to *Arbacia depressa* A. AGASSIZ. Subsequently Checchia Rispoli (1907) reassigned these specimens and other similar ones from the Sicilian of Palermo to a new species: *Arbacina depressa* ARADAS. This state-

ment was not accepted by Lambert (1910) due to the insufficient original description and illustrations given by Aradas. Lambert instead proposed the identity of these fossils with the holotype of *A. romana* MERIAN from Monte Mario (Rome), he indicated the description and the figures given by Checchia Rispoli (1907) as the best interpretation of this taxon.

We examined samples from other Italian localities for comparison (fig. 2).

A romana is rare in the type-locality: only one specimen was studied by Merian from Monte Mario and we were not able to find any specimen there.

Checchia Rispoli recognised *A. romana* in the lower Pliocene of Altavilla in Sicily (1916), in the lower Pleistocene of Palermo (1907, 1916) and Lentini near Siracusa (1936). The collections of the Geologic Museum of the Palermo University were consulted: 220 tests studied by Checchia Rispoli are housed there, they were collected in the surroundings of the town (base of Monte Pellegrino) in sediments attributed to the Sicilian; specimens from Altavilla and from Lentini are stored there, too.

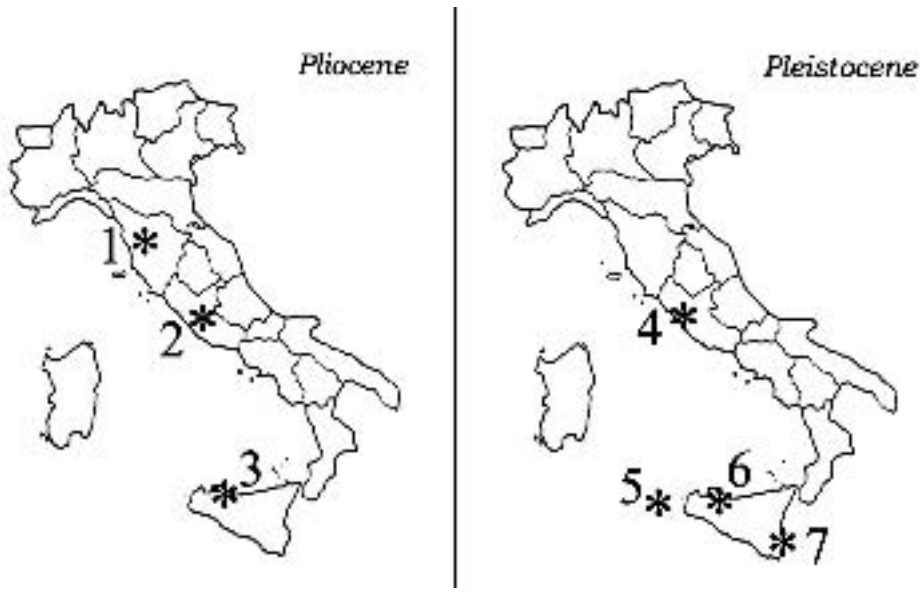
According to Checchia Rispoli (1923) this species was once common at Anzio in upper Pliocene calcarenites; nevertheless we were able to collect only six specimens there, since only small outcrops are still accessible in this classic locality, due to the recent heavy building there.

Manzoni (1880) recorded *Psammechinus monilis* DESMOULINS in the upper Pliocene of Usigliano, San Frediano and Parlascio near Pisa (Tuscany); in reality at least five specimens in Manzoni's collection housed in the Capellini Museum (University of Bologna) labelled with this classification, belong to *Arbacina romana*.

Menesini (1968) attributed nine specimens from the Pleistocene of Punta Ristola near Lecce to *Arbacina cfr. romana*; nevertheless the poor preservation of this fossil material prevents a reliable classification, even at the generic level.

The morphological features shown by the specimens from these localities correspond well to those observed in the sample from Favignana: the shape and the size of the test are similar; the holotype from Monte Mario shows an elevated test which does not correspond to the shape usually present in the samples from Favignana and from the other localities; nevertheless Checchia Rispoli (1907) confirmed the presence in the sample from Palermo of rare individuals similar to the holotype, underlining that the depressed outline represented the more frequent shape. The arrangement of the dense secondary tuberculation, which appears to be the most variable feature of this genus, corresponds too: secondary tubercles form rather regular series on the adoral side, the granules are less numerous than the mamelonate secondary tubercles; specimens from Anzio and from Sicily sometimes show rather regular series also on the aboral side of the test, made by the two or three secondary tubercles positioned above the primary ones. Indentations are always rare. Shape and arrangement of the depressions are similar; in the samples from Sicily the depressions around the primary tubercles are on the average less frequent.

Shape and occurrence frequency of the catenae correspond too. The observed slight differences do not allow any taxonomic distinction; it seems likely that the Plio-Pleistocene records of *Arbacina* from the examined Italian localities are referable to a single species. *A. romana* is recorded by Roman & Soudet (1990) in early and middle Pliocene of Spain and by Marcopoulos Diacantoni (1974) in the Pliocene of the Aegean Sea (Carpathos and Aegina Islands). In the Treatise of Invertebrate Paleontology (Fell in Moore, 1966) genus *Arbacina* POMEL, 1869 is recorded from the lower Miocene to the upper Pliocene of Europe and Western Africa; its chronological range must be extended to the Quaternary of the Mediterranean since it has been ascertained that the specimens from Palermo and Lentini studied by Checchia Rispoli (1907, 1916, 1936), and those from Favignana, date from lower Pleistocene.



Tab. 2 Location map of the records of *Arbacina romana* from Italy.
Tab. 2 Mappa con indicazione delle località di ritrovamento di Arbacina romana in Italia.

n.1 Parlascio, S. Frediano (Pisa)	upper Pliocene	Pliocene superiore
n. 2 Anzio (Roma)	upper Pliocene	Pliocene superiore
n. 3 Altavilla (Palermo)	lower Pliocene	Pliocene inferiore
n. 4 Monte Mario (Roma)	lower Pleistocene	Pleistocene inferiore
n. 5 Favignana Is. (Trapani)	lower Pleistocene	Pleistocene inferiore
n. 6 Monte Pellegrino (Palermo)	lower Pleistocene	Pleistocene inferiore
n. 7 Lentini (Siracusa)	lower Pleistocene	Pleistocene inferiore

Paleoecological observations

At Favignana the specimens of *Arbacina romana* are mainly concentrated in shell-beds. Despite the presence of transported forms showing different bathymetric and ecological requirements, it seems possible to hypothesise the original environment of *Arbacina* in this locality.

The shell beds are always made by coarse bioclastic detritus constituted by fragments of bryozoans, corallinaceous algae, echinoderms and bivalves; fine sediments are very scarce. The foraminiferal fauna is dominated by epifaunal Infralittoral forms, free living on sand and vegetation: mainly *Elphidium*, usually represented by heavily shelled and abraded specimens, subordinately *Asterigerinata* and *Cibicides*; the planktonic forms instead are rare. Concerning echinoids: well preserved specimens of *Paracentrotus lividus* and *Sphaerechinus granularis* are commonly associated to *Arbacina*; in present Mediterranean these species are more frequent between 1-15 m waters depth (Riedl, 1991); *Cidaris cidaris* instead is known to live only below 50 m (Tortonese, 1965): it is seldom associated to *Arbacina* near the Port of Favignana. Loose valves of *Gryphus minor* PHILIPPI, 1836 and *Terebratula scillae* SEGUENZA, 1871 are present in the shell beds; according to Taddei Ruggiero (1994) these brachiopods lived on rather deep muddy-detritic bottoms in the lower Circalittoral (70-120 m waters depth); at Grotta Perciata and Cala Azzurra concentrations of well preserved specimens of these species probably form *in situ* colonies inside fine-grained sediments: no traces of *Arbacina* and of other shallow-water species are associated to them. A few brachyurans collected at Grotta Perciata and near the lighthouse of Punta Marsala were attributed by Garassino & De Angeli (2004) to *Parthenope angulifrons* LATREILLE, 1825 and to *Atelecyclus rotundatus* (OLIVI, 1872): these species are known to live in present Mediterranean respectively between 10-40 m and 20-90 m waters depth. Concentrations of numerous specimens of *Ditrupa cornea* are frequent; according to Cheng (1974) *Ditrupa* lives in sublittoral soft bottoms and may settle relatively high-energy environments with shifting substrates due to its capability to escape sedimentation. The tests of *Arbacina*, as well as the shells of shallow waters forms, are often abraded pointing out a lasting exposition in rough waters, brachiopods, crinoids and the other typical Circalittoral forms do not show similar abrasion patterns. Both shallow and deep waters specimens acted as secondary hardground for encrusting organisms, showing a lasting exposure on calm bottoms; twelve specimens of *Arbacina* (10% of the sample) bear bryozoans; serpulids are rather frequent too (8%). Basing on these observations it seems likely that the *Arbacina*-bearing shell beds represent proximal deposits in a middle shelf environment. Most of the regular echinoids, *Arbacina* and *Paracentrotus* in particular, lived in shallow and more agitated parts of the basin and were transported into deeper bottoms. Brachiopods, crinoids and *Cidaris cidaris* might represent a part of the autochthonous fauna which was incorporated during the displacement. The associated shallow water fauna is typical of well-aerated sublit-

toral environment, the presence of sea-grass and bryozoan thickets is indicated by the foraminifera, by the echinoid fauna and by the great amount of bryozoan debris.
These environmental features correspond well to the results of paleoecological studies concerning other *Arbacina*-bearing localities: the holotype was collected at Monte Mario inside a sandy layer rich in bryozoans and calcareous algas, attributed to the basal part of lower Pleistocene (Malatesta, 1985); Checchia Rispoli (1923) suggested a sublittoral deposition. At Anzio the echinoids are present in bioclastic calcarenites rich in bryozoans and calcareous algas attributed to the upper Pliocene; the benthos is dominated by Infralittoral species indicating a well oxygenated environment (Carboni & Di Bella, 1997). Menesini (1967) recorded *Arbacina* in the Tortonian sandstones of Ponsano (near Siena): in these sediments Foresi et al. (1997) recognised a shallow waters deposition in the Infralittoral.

Relationship between *Genocidaris* and *Arbacina*

Genus *Genocidaris* A. AGASSIZ, 1869 differs from *Arbacina* POMEL, 1869 with respect to a few morphological elements (Mortensen, 1943; Fell in Moore, 1966):
presence of indentations around the bases of the primary tubercles in *Genocidaris*; indentations are absent instead in *Arbacina*
presence of small depressions on the plates in *Arbacina*, above all along the horizontal sutures; these depressions are rare in *Genocidaris*.
The observation of specimens belonging to *Genocidaris* from Plio-Pleistocene localities of Emilia (Borghi, 1995) and from present Mediterranean allows a morphological comparison with *Arbacina* and a preliminary investigation on the reliability of the distinctive morphological characters separating these two genera.
The shape of the test in *Arbacina* is very similar to that of *Genocidaris* (pl.1, fig. 1 and 2; pl. 2, fig. 1 and 2); a few *Genocidaris* from Castell'Arquato even show the unusual elevated outline corresponding to the holotype of *Arbacina* described by Merian (pl.2, fig. 5).
The features of the apical system of *Arbacina* (pl 1, fig. 7) correspond to those shown by fossil (pl. 3, fig. 4) and living *Genocidaris* (pl. 3, fig. 5). It was not possible to verify the presence in *Arbacina* of the large periproctal plate, which is characteristic of fossil (Borghi, 1995) and recent *Genocidaris* (pl. 2, fig. 7).
All of the examined fossil and recent *Genocidaris* bear more or less strong indentations; nevertheless a few large specimens from Emilia and Puglia show a part of the primary tubercles non indented (pl. 3, fig. 3 and pl.4, fig. 2); also living specimens seldom bear almost smooth bases (pl. 4, fig. 3). On the other hand, Cotteau (1895) signalled the presence of small incisions around the bases of the primary tubercles in a few well preserved specimens of *Arbacina* from the Miocene of Sardinia. We noticed slight indentations in a few tests of *A. romana* from Anzio (pl. 1, fig. 4) and from Favignana; small depressions are often present also around the primary tubercles, seldom notching their base. Two

specimens of *Arbacina catenata* from the Miocene of France, figured by Philippe (1998; pl. 8, fig. 1 c and 2 c), appear to be indented, too. Therefore there may be faint indentations in *Arbacina* contrary to the statement of Mortensen (1943); indentations alone cannot warrant a separation between *Arbacina* and *Genocidaris*, at least dealing with isolated specimens or small samples.

Some fossil specimens of *Genocidaris* from Emilia and a few living ones from present Mediterranean (Capraia and Favignana Islands) bear faint but distinct crenulations around the primary tubercles (pl. 2, fig. 4); we noticed similar crenulations also in a few well preserved specimens of *Arbacina romana* from the Pliocene of Balerma (Spain). The presence of crenulations was not reported by Mortensen (1943).

The lack of sutural depressions on the plates is rather frequent in the sample of *Arbacina* from Favignana, above all concerning small tests. Philippe (1998) suggests attaching moderate importance to this morphological character since a part of the specimens belonging to *A. catenata* and even to the type-species *A. monilis* (DESMAREST) is deprived of depressions. Similar depressions are present in fossil *Genocidaris* from Emilia and, though less frequently, in living individuals, too. Also in *Genocidaris* these "depressions" often consist in small areas deprived of tuberculation without a significant reduction in thickness of the plate; deep pits scattered on the plates and along the horizontal sutures are rather infrequent (pl. 4, fig. 1).

The presence of ridges (catenae) do not constitute a peculiar character of *Arbacina* since they are frequent also in fossil and recent *Genocidaris* (pl. 3, fig. 3 and 7).

Two specimens from Favignana still bear patterns of the original coloration (pl. 4, fig. 4): the size and the arrangement of the clear spots correspond well to those present in fossil and living *Genocidaris* (pl. 2, fig. 2 and 5; pl. 4, fig. 6); the maculae in *Arbacina*, as well as in *Genocidaris*, are located higher up in the ambulacral series than in the interambulacral ones. This pigmentation is peculiar to *G. maculata* and gave rise to its specific denomination.

The features of the auricles and of the gill slits correspond too.

Taking into account these morphological correspondences, some doubts rise on the reliability of the distinction between *Arbacina* and *Genocidaris* at the generic level. Mortensen himself (1943) remarked that "*it is even debatable to maintain separate these two genera*". At least a part of the morphological features in echinoids develop independent of time and seem to be controlled mostly by ecological factors; according to Jeffery *et al.* (2003), this is true in particular dealing with temnopleurids. This could explain the different development of indentations and crenulations and the presence or absence of sculptures (depressions) on the plates in *Arbacina* and *Genocidaris*. More detailed investigations (in progress) are required to clarify this question. Meanwhile it seems correct to retain the distinction between these two genera and to operate the classification basing on the occurrence frequency of the diagnostic characters inside a rep-

resentative sample of a population.
Arbacina and *Genocidaris* has traditionally been classified as temnopleurids on account of their test sculpturing. Jeffery *et al*. (2003) in their study on the phylogenetic relationship between a series of temnopleurids, using morphological and molecular data sets, suggest that *Genocidaris* is more closely related to the Echinidae than to the Temnopleuridae and that the presence of a weak sculpture may constitute a simple homophaseous occurrence. The observation of the fossil samples from Favignana and from Emilia corroborates this hypothesis, since it is ascertained that the presence of true sculptures in *Arbacina* and, above all, in *Genocidaris* is not a common feature and that the "depressions" are often areas deprived of the secondary tuberculation.

Conclusions

Large populations of *Arbacina romana* were present during the upper Pliocene and the lower Pleistocene in the shallow waters of the Western Ionian Sea and of the Tyrrhenian Sea. The examined samples from seven Italian localities show a noticeable morphological correspondence, confirming the attribution to a sole species. New knowledge on the morphology of *Arbacina*, concerning the colour patterns, the shape and the arrangement of the depressions and the presence of faint indentations at the base of the primary tubercles, confirms the close affinity to *Genocidaris*.
The distinction between these two genera is retained, until further examinations can be made; for a reliable classification it is necessary to take into account the occurrence-frequency of the diagnostic characters inside a representative sample of a population.

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Explanation of the Plates
Spiegazione delle Tavole

Plate 1

Arbacina romana:

Fig 1 Specimen Ar 2: apical view; diameter of the test: 12 mm - lower Pleistocene, Favignana Is.

Fig. 2 Side view of the same specimen (Ar 2) - lower Pleistocene, Favignana Is.

Fig. 3 Oral view of the same specimen (Ar 2) - lower Pleistocene, Favignana Is.

Fig. 4 Small depressions (marked by arrows) surrounding and faintly indenting the base of a primary tubercle; diameter of the test: 11.8 mm - upper Pliocene, Anzio (Rome)

Fig. 5 Close up view of well developed catenae connecting a primary tubercle to the couple of secondary ones in the underlying plate - lower Pleistocene, Favignana Is.

Fig. 6 Detail of the most common arrangement of the tuberculation; the base of primary and secondary tubercles is not indented - lower Pleistocene, Favignana Is.

Fig. 7 Specimen Ar 79: close up view of the apical system; small points mark the borders of the plates; diameter of the test: 8.5 mm - lower Pleistocene, Favignana Is.

Tavola 1

Arbacina romana:

Fig. 1 Esemplare Ar 2: vista apicale; diametro del guscio: 12 mm - Pleistocene inferiore, Favignana.

Fig. 2 Vista laterale dello stesso esemplare (Ar 2) - Pleistocene inferiore, Favignana.

Fig. 3 Vista del lato orale dello stesso esemplare (Ar 2) - Pleistocene inferiore, Favignana.

Fig. 4 Piccole depressioni (indicate da freccette) che attorniano e intaccano leggermente la base di un tubercolo primario; diametro del guscio: 11,8 mm - Pliocene superiore, Anzio (Roma).

Fig. 5 Particolare di catene ben sviluppate che collegano il tubercolo primario a due secondari appartenenti alla piastra sottostante - Pleistocene inferiore, Favignana.

Fig. 6 Particolare della tubercolazione secondaria più comune; la base dei tubercoli primari e secondari non è indentata - Pleistocene inferiore, Favignana.

Fig. 7 Esemplare Ar 79: dettaglio del sistema apicale; una serie di punti evidenzia i margini delle piastre; diametro del guscio: 8,5 mm - Pleistocene inferiore, Favignana.

Plate 2

Genocidaris maculata:

Fig 1 Apical view (Gm 66); diameter of the test: 11.4 mm - upper Pliocene, Castell'Arquato.
Fig. 2 Lateral view of the same specimen (Gm 66) - upper Pliocene, Castell'Arquato.
Fig. 3 Oral view of the same specimen (Gm 66) - upper Pliocene, Castell'Arquato.
Fig. 4 Presence of faint crenulations around a primary tubercle; S.E.M. photo: the scale bar equals 0.1 mm - upper Pliocene, Stirone River (Parma).
Fig. 5 Specimen (Gm 109) showing an infrequent elevated profile; diameter of the test: 9.5 mm - upper Pliocene, Stirone River.
Fig. 6 S.E.M. photo of a primary spine; length: 1.4 mm - upper Pliocene, Castell'Arquato.
Fig. 7 Suranal plate; diameter: 1.2 mm - upper Pliocene, Stirone River.

Tavola 2

Genocidaris maculata:

Fig 1 Vista apicale (Gm 66); diametro del guscio: 11.4 mm - Pliocene superiore, Castell'Arquato.
Fig. 2 Vista laterale dello stesso esemplare (Gm 66) - Pliocene superiore, Castell'Arquato.
Fig. 3 Vista del lato orale dello stesso esemplare (Gm 66) - Pliocene superiore, Castell'Arquato.
Fig. 4 Presenza di crenulazioni su un tubercolo primario; foto S.E.M.: la barretta equivale a 0,1 mm - Pliocene superiore, Torrente Stirone (Parma).
Fig. 5 Esemplare (Gm 109) con un insolito profilo elevato del guscio, diametro del guscio: 9,5 mm - Pliocene superiore, Torrente Stirone.
Fig. 6 Foto S.E.M. di una spina primaria; lunghezza: 1,4 mm - Pliocene superiore, Castell'Arquato.
Fig. 7 Piastra suranale; diametro: 1,2 mm - Pliocene superiore, Castell'Arquato.

Plate 3

The scale bar in this table equals 0.5 mm

Genocidaris maculata:

Fig 1 Detail of a specimen showing strongly indented tubercles, catenae and faint sutural depressions; diameter of the test at the ambitus: 11.8 mm - upper Pliocene, Castell'Arquato.
Fig. 2 Specimen showing strongly indented tubercles and small sutural depressions; diameter of the test at the ambitus: 5.4 mm - middle Pliocene, Salsomaggiore (Campore quarry).

Fig. 3 Close up view of non-indented tubercles; catenae and sutural depressions are present on the plates; diameter of the test: 11.6 mm - upper Pliocene, Castell'Arquato.
Fig. 4 Specimen Gm 9: close up view of the apical system - upper Pliocene, Stirone River.
Fig. 5 Living specimen: close up view of the apical system - Recent, Pantelleria Is.
Fig. 6 Apical view of a living specimen bearing spines; diameter of the test including the spines: 7.5 mm - Recent, Pantelleria Is.
Fig. 7 Specimen Gm 17: presence of catenae and naked areas in the interambulacral mid zone and along the sutures; diameter of the test: 12.4 mm - upper Pliocene, Castell'Arquato.

Arbacina romana:
Fig. 8 Section of an interambulacral plate taken along the horizontal suture: the variation in thickness of the plate in correspondence of the depressions is almost absent; diameter of the test (Ar 88): 10.2 mm; redrawn from a 40 x microscope photo graph - lower Pleistocene, Favignana Is.
Fig 9 Close up view of the most common features of *Arbacina*: tubercles lacking inden tations and presence of catenae - lower Pleistocene, Favignana Is.
Fig. 10 Detail of interambulacral plates: the primary tubercles are surrounded by depressions but the base is smooth - lower Pleistocene, Favignana Is.

Tavola 3

La barra di scala di questa tavola indica 0,5 mm.

Genocidaris maculata:
Fig. 1 Dettaglio di un esemplare con basi dei tubercoli fortemente indentate, catene e depressioni suturali poco marcate; diametro del guscio all'ambitus: 11,8 mm - Pliocene superiore, Castell'Arquato.
Fig. 2 Esemplare che mostra basi dei tubercoli fortemente indentate e depressioni suturali poco profonde; diametro del guscio: 5,4 mm - Pliocene medio, Salsomaggiore (cava di Campore).
Fig. 3 Dettaglio di piastre che mostrano tubercoli non indentati; catene e depressioni suturali; diametro del guscio: 11,6 mm - Pliocene superiore, Castell'Arquato.
Fig. 4 Dettaglio del sistema apicale dell'esemplare Gm 9 - Pliocene superiore, Castell'Arquato.
Fig. 5 Dettaglio del sistema apicale di un esemplare attuale - isola di Pantelleria.
Fig. 6 Esemplare vivente munito degli aculei; diametro del guscio comprese le spine: 7,5 mm – attuale, isola di Pantelleria.

Fig. 7 Esemplare Gm 17: mostra catene e piccole aree prive di tubercolazione nella zona interambulacrale mediana e lungo le suture; diametro del guscio: 12,4 mm - Pliocene superiore, Castell'Arquato.

Arbacina romana:

Fig. 8 Schema di una piastra interambulacrale sezionata lungo la linea di sutura orizzontale e vista dal lato apicale: le depressioni sono poco profonde e la variazione dello spessore della piastra è quasi trascurabile; disegno tratto da un ingrandimento 40 x dell'esemplare Ar 88, diametro del guscio: 10,2 mm - Pleistocene inferiore, Favignana.

Fig. 9 Dettaglio dei caratteri più comuni in *Arbacina*: mancanza di indentazioni alla base dei tubercoli e presenza delle catene - Pleistocene inferiore, Favignana.

Fig.10 Dettaglio di piastre interambulacrali: i tubercoli primari sono circondati da minute depressioni ma la base del tubercolo rimane liscia - Pleistocene inferiore, Favignana.

Plate 4

The scale bar in this table equals 0.1 mm

Genocidaris maculata:

Fig. 1 Close up view of an ambulacral area of Gm 13: small rather deep depressions are scattered on the plates - upper Pliocene, Castell'Arquato

Fig 2 Adapical plates of specimen Gm 46: the base of the primary tubercles is not indented - upper Pliocene, Castell'Arquato.

Fig. 3 Primary tubercle bearing faint indentations (Gm 48), the base is almost smooth - Recent, Otranto.

Fig. 6 Specimen (Gm 30) bearing the typical coloration pattern of this species; diameter of the test: 9.5 mm - upper Pliocene, Stirone River.

Arbacina romana:

Fig. 4 Specimen Ar 65 showing patterns of the original coloration; diameter at the ambitus: 7.5 mm - lower Pleistocene, Favignana Is.

Fig. 5 Typical features of *Arbacina* at Favignana (specimen Ar 2): primary tubercles showing a smooth base, lack of deep depressions on the plates, catenae extending to the couple of secondary tubercles situated on the underlying plate - lower Pleistocene, Favignana Is.

Tavola 4

La barra di scala indica 0,1 mm.

Genocidaris maculata:

Fig. 1 Area ambulacrale dell'esemplare Gm 13: piccole ma profonde depressioni sono sparse sulle piastre - Pliocene superiore, Castell'Arquato.

Fig 2 Dettaglio delle piastre adapicali dell'esemplare Gm 46: la base dei tubercoli primari non è indentata - Pliocene superiore, Castell'Arquato.

Fig. 3 Tubercolo primario che mostra la base quasi liscia (Gm 48) – esemplare attuale, Otranto.

Fig. 6 Esemplare Gm 30 che conserva la disposizione della colorazione originale tipica di questo genere; diametro del guscio: 9,5 mm - Pliocene superiore, Castell'Arquato.

Arbacina romana:

Fig. 4 Esemplare Ar 65 che conserva la disposizione della colorazione originale; diametro del guscio: 7,5 mm - Pleistocene inferiore, Favignana.

Fig. 5 Dettaglio delle caratteristiche più frequenti di *Arbacina* a Favignana: tubercoli primari con base liscia, mancanza di depressioni profonde, le catene si estendono a una coppia di tubercoli secondari posti lungo il bordo superiore della piastra sottostante (Ar 2) - Pleistocene inferiore, Favignana.

Tavola 1 - Plate 1

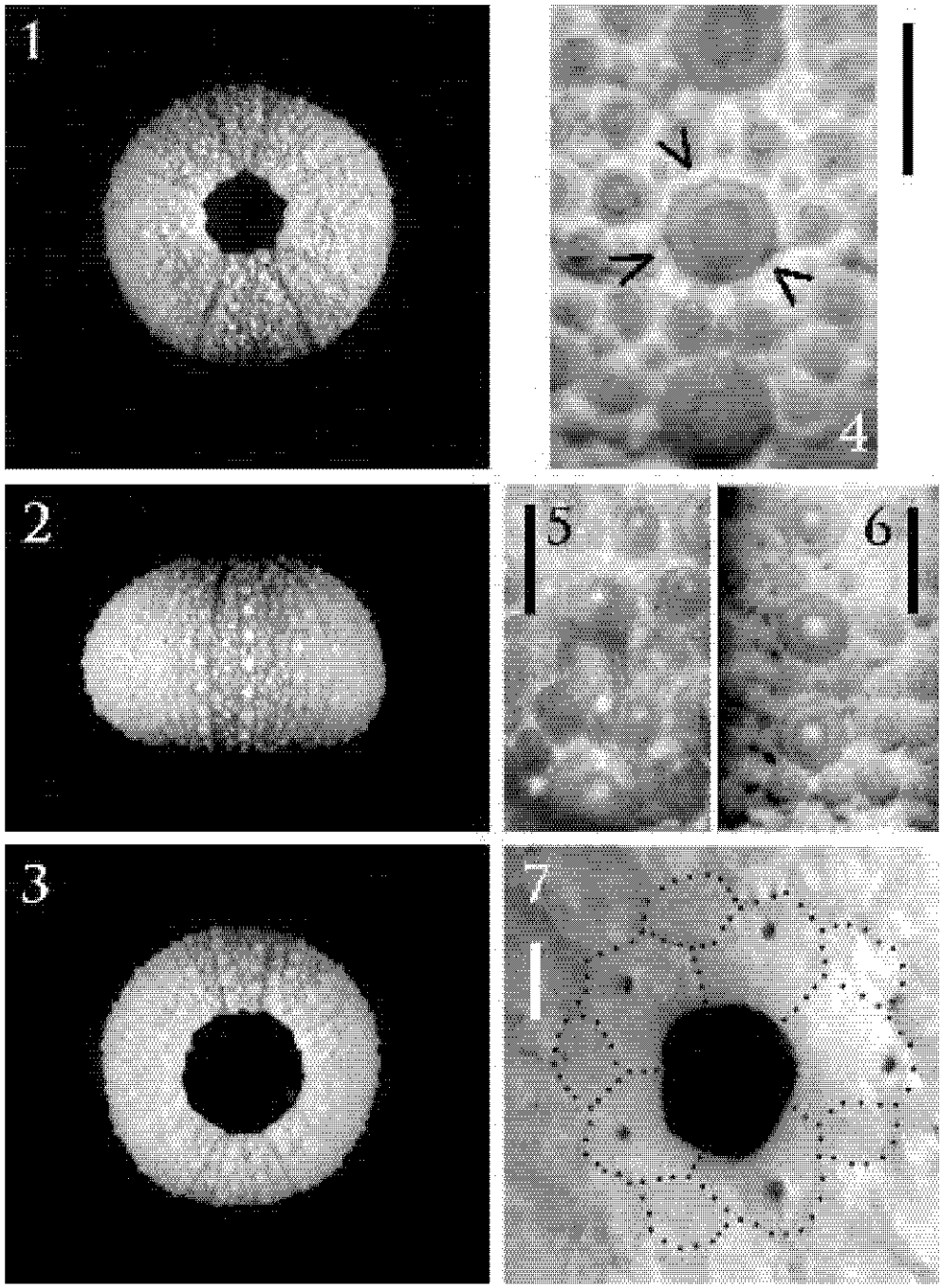

Tavola 2 - Plate 2

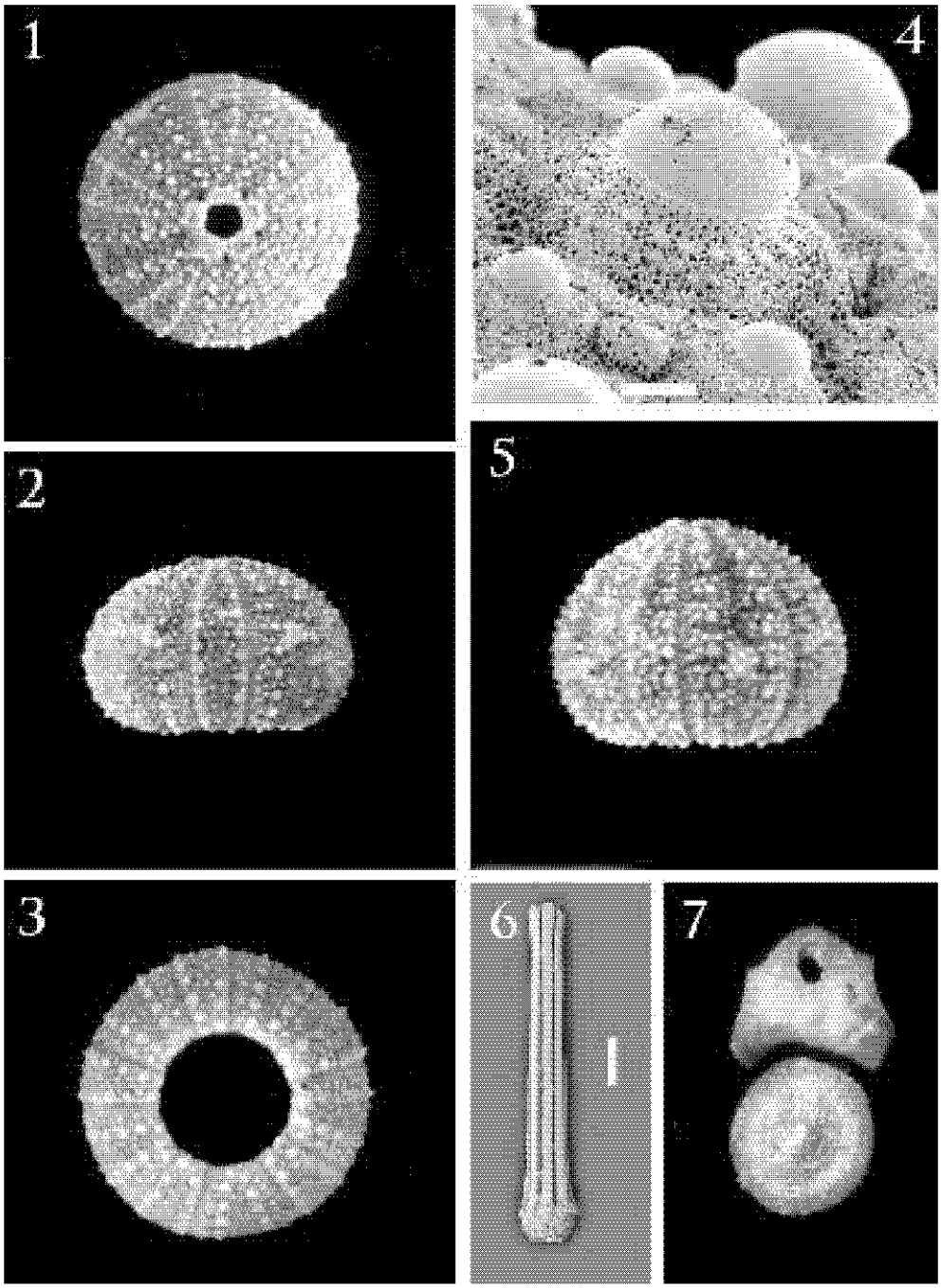

Tavola 3 - Plate 3

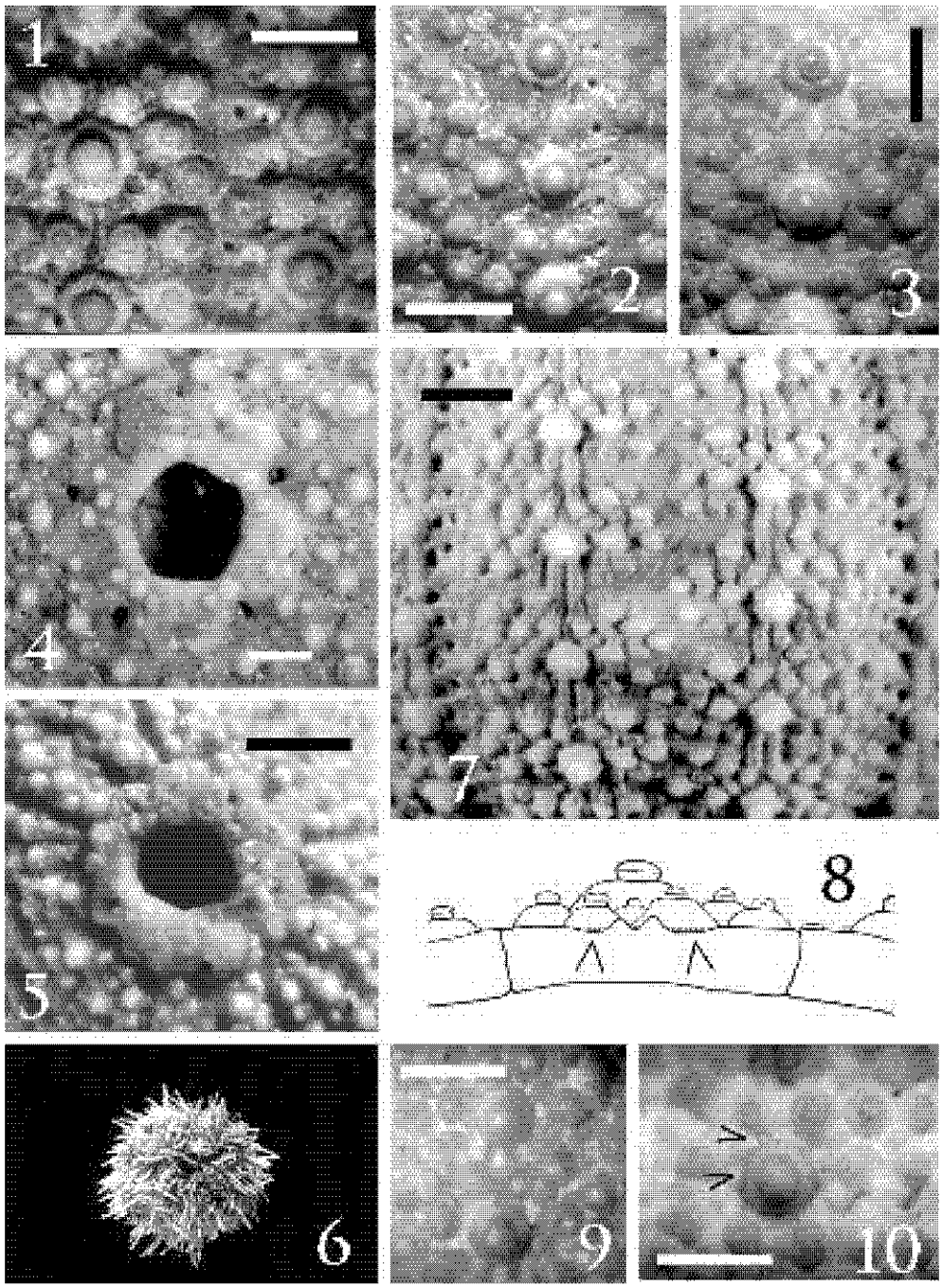

Tavola 4 - Plate 4