

Twin, triplet and quadruplet teratogens in benthic foraminifera from Antalya

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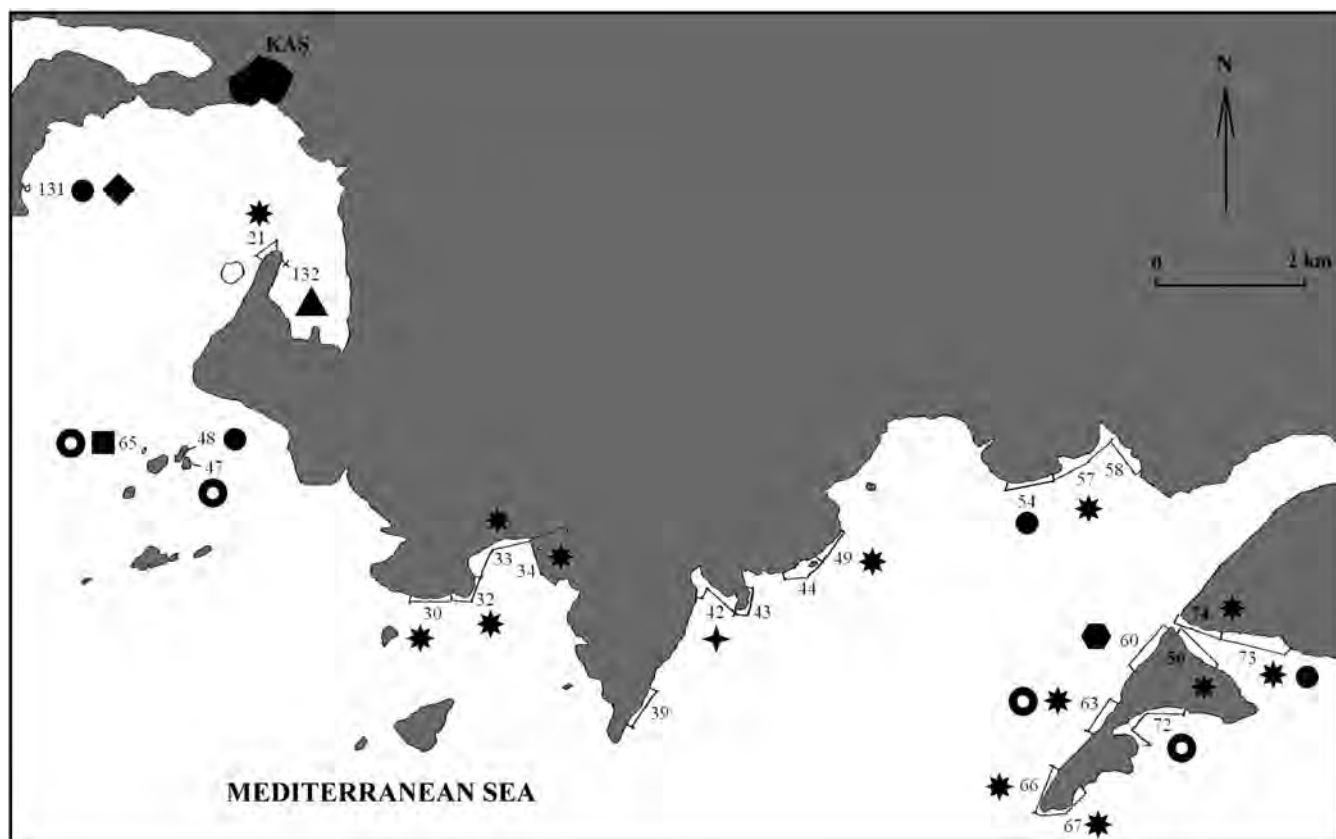
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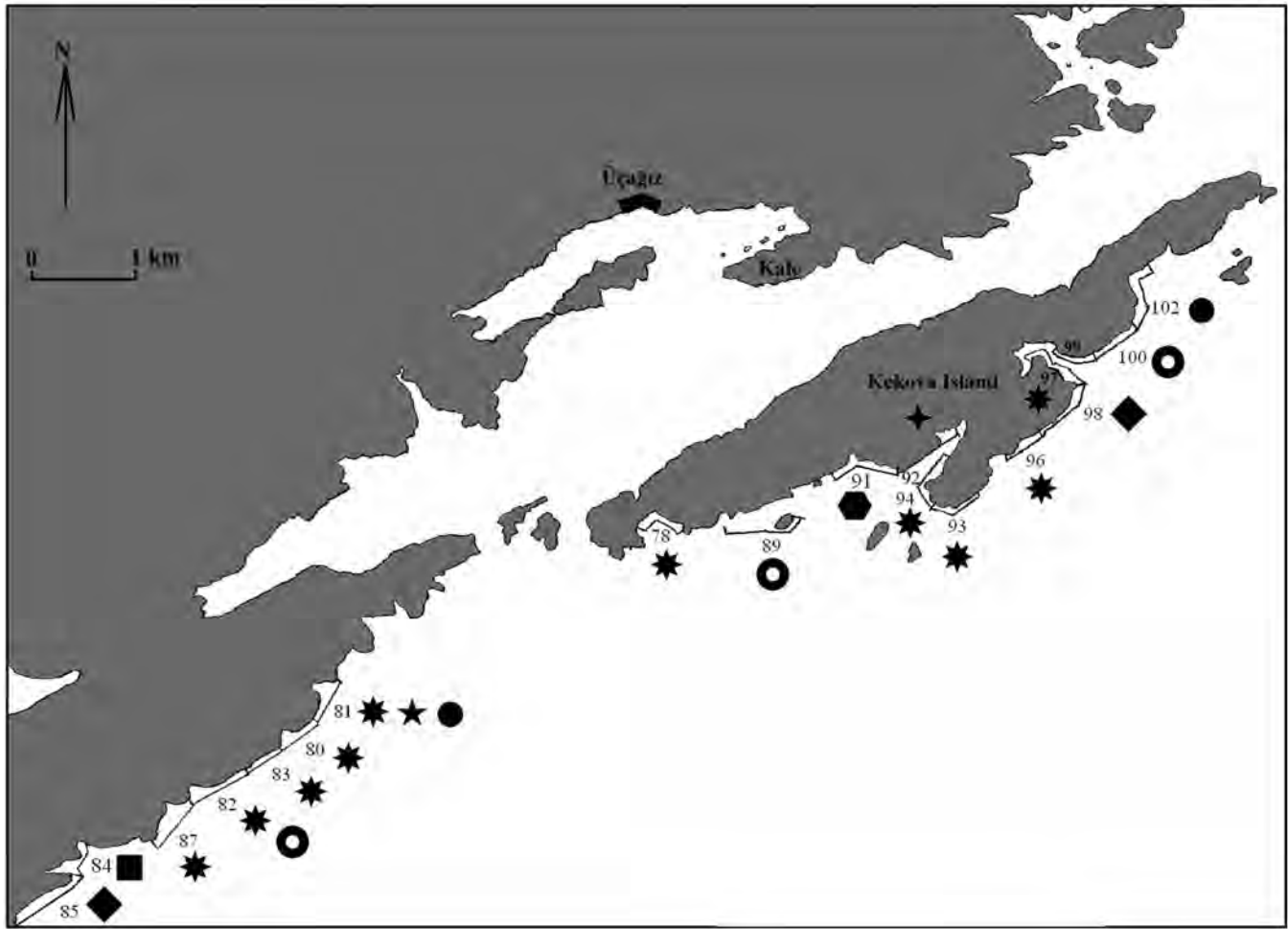
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ABSTRACT: We report twin and triplet forms of Recent benthic foraminifera from the southwestern coasts of Antalya (SW Turkey). Biological influences are possibly the primary cause for abnormal morphologies. During foraminifer reproduction, the number of individuals occupying the reproduction cyst, duration of the delay before the breaking of the cyst and the size of the cyst are all likely causes for the formation of twins, triplets and quadruplets. Thus, we assume that twins, triplets and quadruplet test formation in benthic foraminifera in our study area are caused by developmental accidents, and are not necessarily related to physical and chemical pressures from the environment.



TEXT-FIGURE 1

Sections in Fethiye P 23 d1, d2 and c1. * *Textularia bocki* Höglund, ▲ *Coscinospira hemprichii* Ehrenberg, ● *Peneroplis pertusus* (Forskål), ◆ *Peneroplis planatus* (Fichtel and Moll), ● *Sorites orbiculus* Ehrenberg, ■ *Sorites variabilis* Lacroix, ◆ *Cibicidella variabilis* (d'Orbigny), ○ *Amphistegina lobifera* Larsen.



TEXT-FIGURE 2

Sections in Fethiye P22 b3, b4, c1, c2 and d2. * *Textularia bocki* Höglund, ● *Peneroplis pertusus* (Forskål), ◆ *Peneroplis planatus* (Fichtel and Moll), ★ *Amphisorus hemprichii* Ehrenberg, ● *Sorites orbiculus* Ehrenberg, ■ *Sorites variabilis* Lacroix, ◆ *Cibicidella variabilis* (d'Orbigny), ○ *Amphistegina lobifera* Larsen

INTRODUCTION

The study covers a very large area between Üç Adalar and Kaş, on an east-west transect along the southwestern coastline of Antalya (SW Turkey) (text-figs. 1-4). This is a very shallow marine environment containing sediments rich with *Amphistegina* and *Textularia* individuals. The sediment is sandy due to *Amphistegina*'s abnormal abundance. Particularly, twins of *Textularia* are more dominant than twins of *Amphistegina*. A few individuals of *Coscinospira*, *Peneroplis*, *Sorites* and *Cibicidella*, which are fauna associated with *Amphistegina* and *Textularia*, also are found in twins, triplets and quadruplets.

Twin and triplet forms of benthic foraminifera from various locations and depths and their relation with past and modern environmental conditions have been investigated by many researchers worldwide (Rhumbler 1902; Heron-Allen 1915; Le Calvez 1938 and 1950; Berthold 1971; Röttger and Spindler 1976; Sharifi et al. 1991; Almogi-Labin et al. 1992; Meriç 1996; Yanko et al. 1998; Geslin et al. 1998; Stouff et al. 1999 a and b; Geslin et al., 2000; Meriç et al., 2001; Geslin et al., 2002). Geslin et al. (2000) emphasized quantitative studies and

SEM work on test abnormalities and provide a brief summary of abnormal occurrences. In Turkey, Meriç and his colleagues reported conjoined twin, triplet and quadruplet individuals from the western Black Sea and the Gulf of İzmit (eastern Marmara Sea) (Meriç 1996; Meriç et al. 2001). More recently, Meriç et al. (2006) recorded abnormal forms and investigated their possible causes in samples from the eastern Aegean Sea. However, this is the first study on twin occurrences in southwestern Turkey and the interpretation of prevailing paleo-environmental conditions by comparison with foraminifera from other Turkish regions.

MATERIALS AND METHODS

227 Recent sediment samples were collected from various localities along the southwestern coastline of Antalya during the summer of 2004. The localities are as follows: eastern Patara Beach (western Kalkan), Kalkan, Kaş, Kekova, Beşadalar (southeast Finike) and Üç Adalar (southeast Tekirova) (text-figs. 1-4). Sand samples were taken from water depths of 3.5-30m. We analyzed about 45 twin, triplet and quadruplet individuals. Twin forms are dominant. Only a few specimens include triplet and quadruplet forms.

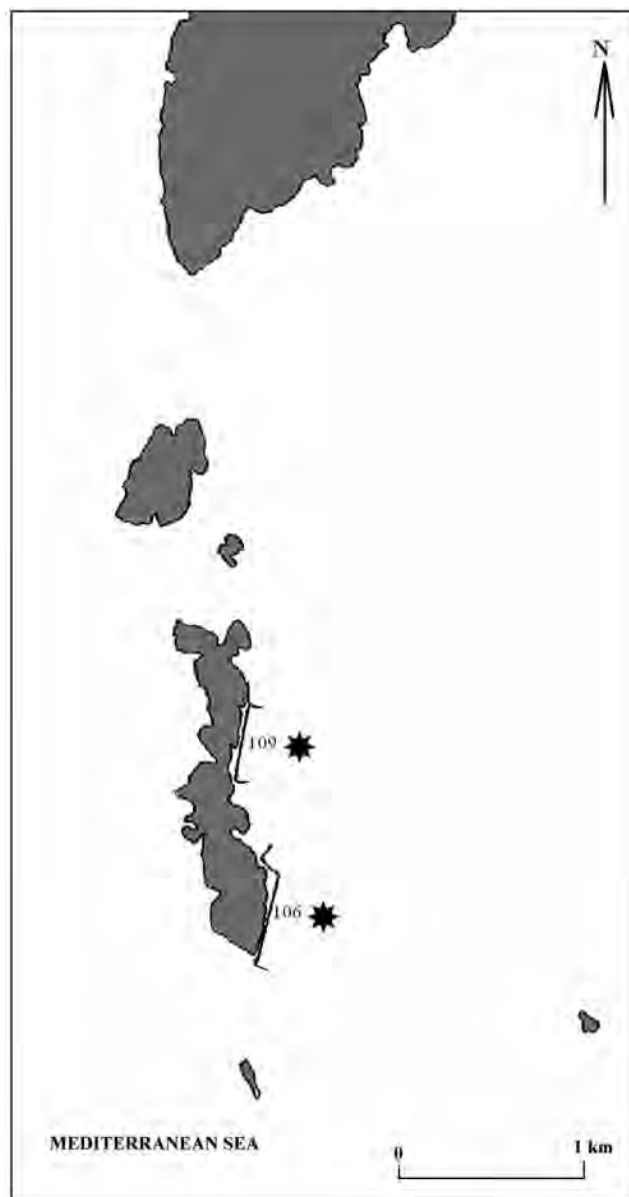
BUSAS (Boğaziçi University Diving Club) members collected our sediment samples by scuba diving. After collection, 5 grams of wet sample was weighed and kept 24 hours in 5 % hydrogen peroxide solution. Then, they were washed through a 0.063mm sieve and dried in the oven at 50°C. After that, foraminifers were separated from detrital sediments on the sieves with 2, 1, 0.5, 0.25, 0.125 mm mesh sizes. Twin and triplet tests are very rare and not more than one percent of any sample. Twin and triplet tests were analyzed and photographed using SEM (JEOL JSM-6360 LV Scanning Electron Microscope) (Türkiye Şişe Cam Fabrikaları Araştırma Merkezi, Davutpaşa-İstanbul). The specimens are in İstanbul University with the first author.

RESULTS

The major occurrences of twin, triplet and quadruplet tests of benthic foraminifers along the southwestern Antalya coastline (in Turkey) are as follows *Textularia bocki* Höglund, *Coscinospira hemprichii* Ehrenberg, *Peneroplus pertusus* (Forskal), *P. planatus* (Fichtel and Moll), *Sorites orbiculus* Ehrenberg, *Sorites variabilis* Lacroix, *Amphisorus hemprichii* Ehrenberg, *Cibicidella variabilis* (d'Orbigny) and *Amphistegina lobifera* Larsen (pl. 1-4, text-figs. 1-4). Table 1 lists location coordinates for specimens including twin, triplet and quadruplet forms. A total of 50 genera and 96 species have been identified in the study area. However, only 7 species contain twins, triplets and quadruplets. Although five of the species show large populations, and *Amphistegina* and *Textularia* are the most dominant species, twin, triplet and quadruplet forms in these species are very rare.

Twin, triplet and quadruplet occurrences in various species in our study region are: *Textularia bocki* Höglund (sample numbers: 21, 30, 32, 33, 34, 49, 56, 57, 58, 63, 66, 67, 73, 74 at SE Kaş; sample numbers: 78, 80, 81, 82, 83, 87, 93, 94, 96, 97 at Kekova Island; sample numbers: 106, 109 at Beşadalar; sample numbers: 124, 127, 128 at Üçadalar). Twins of the following species were found between 4-27 meters depth: *Coscinospira hemprichii* Ehrenberg (sample no: 132, 6m, locality: Kaş); *Peneroplus pertusus* (Forskal) (sample no: 60, 14m, SE Kaş; sample no: 91, 6m, Kekova); *P. planatus* (Fichtel and Moll) (sample no: 42, 9m at SE Kaş; sample no: 92, 12m at Kekova Island); *Sorites orbiculus* Ehrenberg (sample numbers: 48, 54, 65, 73, 131, between 6 and 12 m around Kaş; sample no. 81, 12m, sample no: 84, 14m, sample no: 99, 24m, sample 102, 24 m at Kekova Island); *Sorites variabilis* Lacroix (Sample no: 92, 12.00 meters, Kekova); *Amphisorus hemprichii* Ehrenberg (sample no: 81, 8m, Kekova); *Cibicidella variabilis* (d'Orbigny) (sample no: 131, 12m at SW Kaş; sample no: 85, 23m, sample no: 98, 12m at Kekova Island); *Amphistegina lobifera* Larsen (sample numbers 47, 63, 65, 72 between 24 and 26m at S, SE Kaş; sample numbers 82, 89, 100 between 12 and 24m at Kekova Island, sample no: 119, 24m at Üçadalar) (Plates 1-3).

Most twins show similar test size. However, some twin specimens have considerable size differences, such as *Textularia bocki* Höglund, (Plate 1, figs. 4, 5, 7, 10, 11; Plate 2, fig.14), *Coscinospira hemprichii* Ehrenberg (Plate 3, fig. 3), *Peneroplus pertusus* (Forskal) (Plate 3, fig. 5), *P. planatus* (Fichtel and Moll) (Plate 3, fig. 7), *Sorites orbiculus* Ehrenberg (Plate 3, fig.11), and *Amphistegina lobifera* Larsen (Plate 4, figs. 9-13). Twin formation was also reported for *Ammonia tepida* Cushman (Stouff et al. 1999b, Plate 4, figs. 1a and b, 2a; Geslin et al., 2000, fig. 3/5 and 9; 2002, Plate 2, fig. 4).



TEXT-FIGURE 3

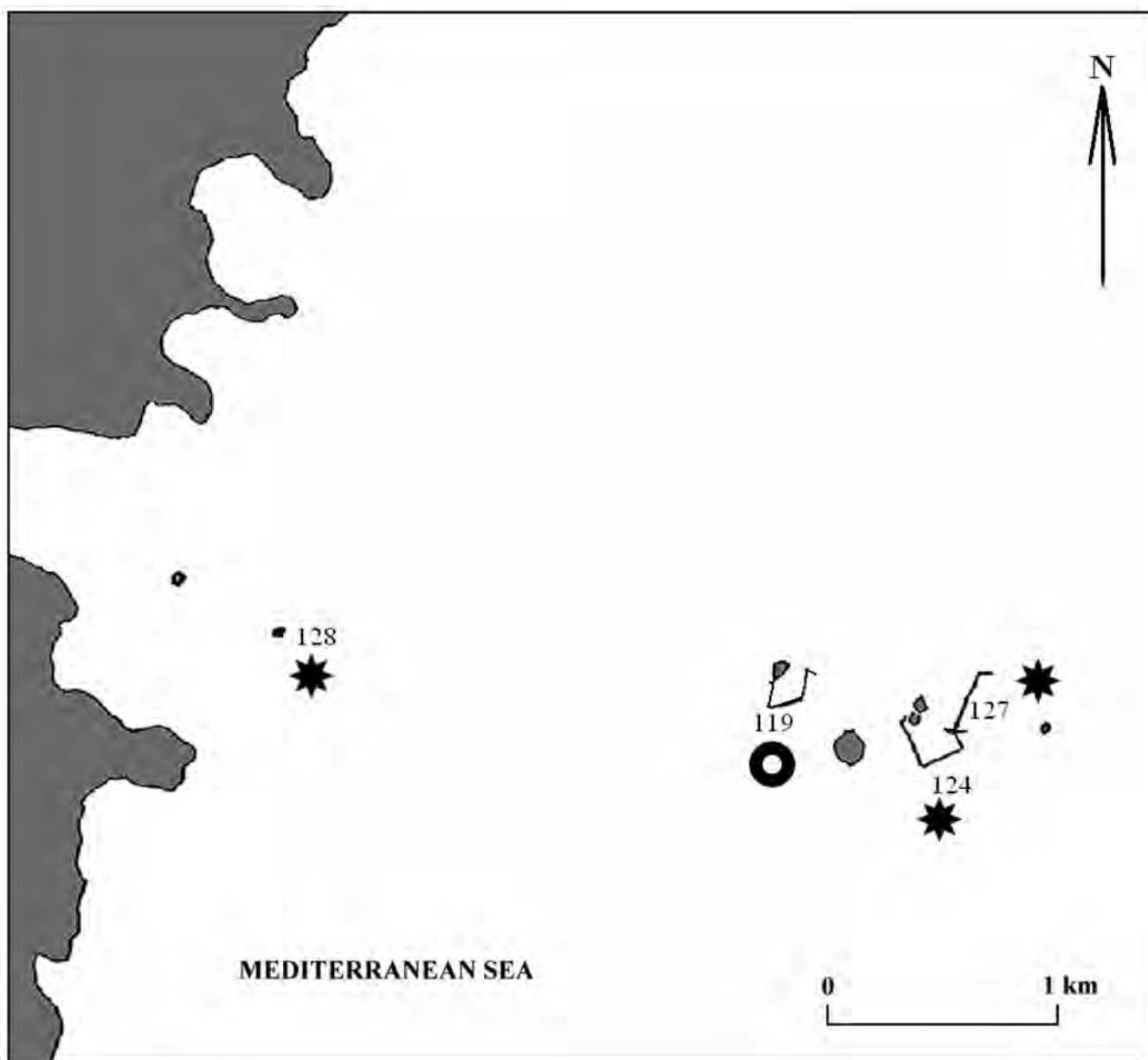
Sections around Beş Adalar in Antalya * *Textularia bocki* Höglund.

It is noteworthy that, although *Amphistegina lobifera* Larsen is an abnormally abundant foraminifer species in the study area, twin forms are more common in *Textularia*, which is the second dominant genus.

DISCUSSION

Causes for twin, triplet and quadruplet formation among benthic foraminifers may be the result of (1) biological accidents or (2) physical-chemical factors in the environment including human activities.

Biological origin for reproductive abnormalities: As discussed in Meriç et al. (2004), twins or triplets are primarily genetic accidents (Le Calvez 1950; Loeblich and Tappan 1964; Meriç et al. 2001). Le Calvez (1950) and Loeblich and Tappan (1964)



TEXT-FIGURE 4

Sections in Üç Adalar in Antalya P25 a1. * *Textularia bocki* Höglund, ● *Amphistegina lobifera* Larsen.

suggested that foraminifers show two or more embryonic developmental stages. Twin, triplet and quadruplet foraminifera is an anomalous situation often observed in the same generation. Foraminifera may produce twins, triplets or quadruplets because they share the same reproduction cyst. Often twins are of approximately equal size if they are the result of sharing the same cyst. Despite the separation of nuclei, cytoplasm remains connected during reproduction. Meriç et al. (2001, 2004) also indicated that accidents are likely the result of conditions affecting the reproduction cyst. Delay of cyst separation of each microspheric individual causes adhesion of juvenile magelospheric individuals (Le Calvez 1953). During a schizogonic reproduction, a cyst is formed around the microspheric test (Cole 1960). New chambers develop around the perieubryonic chambers of young individuals formed as a result of schizogony.

This takes place while new individuals are still in the cyst and the number of new chambers varies. For example, it is five for *Planorbulina mediterraneensis*, three or four for *Discorbis vilardeboanus*, three for *D. orbicularis*, two or three for *D. bertheloti*, and two for *D. araucana* (Le Calvez, 1953). After the rupture of the cyst, young individuals spread into the water and continue their life. If there is a delay in the rupture of the mother cyst, individuals continue their growth. The number of individuals in the cyst, duration of the delay before breaking the cyst and the size of the cyst are all likely causes for the formation of twins, triplets and quadruplets. Until recently, these associations were observed only in *Adelosina*, *Quinqueloculina*, *Miliolinella*, *Triloculina*, *Brizalina*, *Cassidulina*, *Bulimina*, *Eponides*, *Cibicoides*, *Hyalinea*, *Lobatula*, *Planorbulina*, *Aubignyna*, *Melonis*, *Ammonia* and *Elphidium* (Le Calvez

TABLE 1
Coordinates of study stations.

STUDY AREA	SECTION NO.	Start		End	
KAŞ	21	36. 10958	29. 38428	36. 10784	29. 38298
	30	36. 08792	29. 39824	36. 08794	29. 39495
	32	36. 08792	29. 39821	36. 08958	29. 39965
	33	36. 08958	29. 39965	36. 09127	29. 40464
	34	36. 09096	29. 40443	36. 08833	29. 40636
	39	36. 08020	29. 41162	36. 08261	29. 41438
	42	36. 08739	29. 41687	36. 08717	29. 41942
	43	36. 08717	29. 41942	36. 08819	29. 42072
	44	36. 08881	29. 42371	36. 08958	29. 42639
	47	36. 09662	29. 37703	36. 09797	29. 37771
	48	36. 09864	29. 37788	36. 09756	29. 37652
	49	36. 08958	29. 42639	36. 09238	29. 42833
	56	36. 08236	29. 45630	36. 08435	29. 45386
	57	3.608.435	29. 44407	36. 09664	29. 44857
	58	36. 09664	29. 44857	36. 09459	29. 45091
	131	36. 11513	29. 36601		
	132	36. 11000	29. 38567		
KEKOVA	60	36. 08261	29. 45092	36. 08083	29. 44903
	63	36. 08867	29. 44739	36. 07681	29. 44491
	65	36. 09837	29. 37457		
	66	36. 07681	29. 44491	36. 07340	29. 44271
	67	36. 07340	29. 44271	36. 07489	29. 44644
	72	36. 07941	29. 45440	36. 07950	29. 45159
	73	36. 08378	29. 46068	36. 08429	29. 45712
	74	36. 08429	29. 45712	36. 08517	29. 45400
	78	36. 10081	29. 51017	36. 10202	29. 50805
	80	36. 09303	29. 48773	36. 09109	29. 48493
	81	36. 09489	29. 49026	36. 09303	29. 48773
	82	36. 08846	29. 47896	36. 08957	29. 48227
	83	36. 08957	29. 48227	36. 09109	29. 48493
	85	36. 08207	29. 46597	36. 08360	29. 46974
	87	36. 08846	29. 47896	36. 08577	29. 47600
	89	36. 10136	29. 51431	36. 10271	29. 51815
	92	36. 10416	29. 52518	36. 10571	29. 52817
	93	36. 10243	29. 52625	36. 10241	29. 52937
	94	36. 10486	29. 52732	36. 10243	29. 52625
	96	36. 10447	29. 53219	36. 10626	29. 53505
	97	36. 10834	29. 53643	36. 10981	29. 53361
	98	36. 10626	29. 53505	36. 10834	29. 53643
	99	36. 10968	29. 53823	36. 10993	29. 53483
	100	36. 10968	29. 53823	36. 11158	29. 54166
	102	36. 11158	29. 54166	36. 11429	29. 54216
BEŞADALAR	106	36. 10498	30. 24456	36. 10798	30. 24519
	109	36. 11024	30. 24434	36. 11315	30. 24457
ÜÇADALAR	119	36. 27770	30. 32711	36. 27770	30. 32830
	124	36. 27621	30. 33050	36. 27500	30. 33220
	127	36. 27554	30. 33271	36. 27716	30. 33271
	128	36. 27766	30. 31413		

1950; Meriç 1996; Meriç et al. 2001 and 2004). However, we identified twins, triplets and quadruplets in species of *Textularia*, *Coscinospira*, *Peneroplis*, *Amphisonis*, *Sorites*, *Cibicides* and *Amphistegina*. Le Calvez (1953) suggest that occurrences of twins, triplets and quadruplets are the result of cytoplasm mixing (plastogamy) or nucleus combination (caryogamy). Thus, we assume that twins, triplets and quadruplet test formation in benthic foraminifera are primarily caused by the developmental accidents.

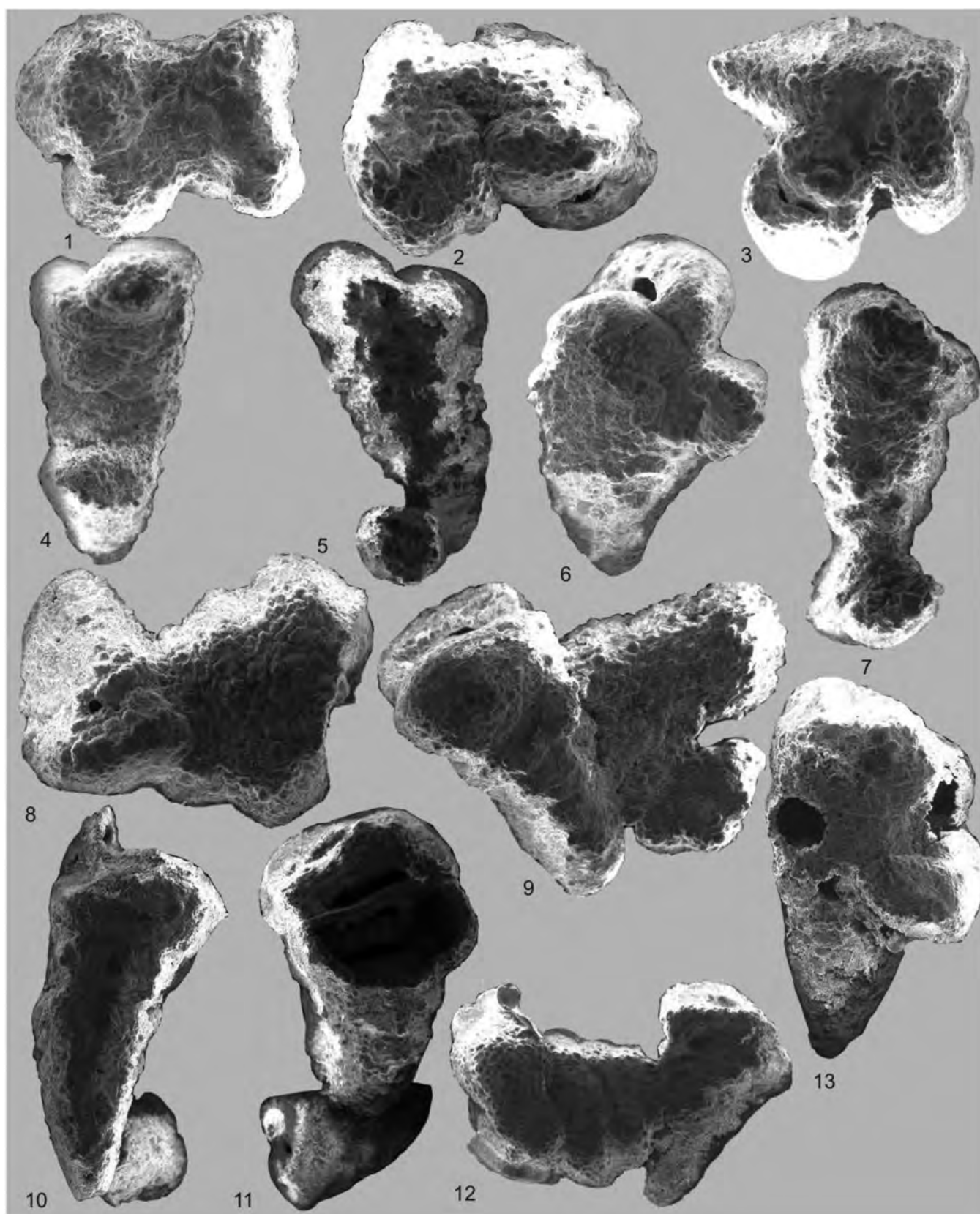
Environmental origin for reproductive abnormalities: Anthropogenic pollution (e. g. thermal, heavy metal, chemical, hydrocarbon, domestic effluent impacts) result in unsuitable environments for organisms, but twin, triplet and quadruplet forms have also been observed in ancient times when these anthropogenic factors were less prevalent. Le Calvez's (1938 and 1950) conclusions seem to remain valid in that developmental accidents are probably the primary cause of twin, triplet and quadruplet formation in benthic foraminifera. Individual groups called polyvalent and teratologic are present in contemporary sediments and have been also found in Upper Cretaceous, Tertiary, Quaternary and Recent deposits (Coleman 1963; van der Vlerk 1966; Butterlin 1971; Meriç 1972, 1976,

1979, 1992 and 1996; Meriç, et al. 1997, 2001, 2004; Matsumaru et al. 2000; Özgen-Erdem et al. 2003). Anthropogenic effects can not be cause for twin occurrences in ancient times. Also, our study area is a popular tourist attraction which inhibits industrial activities. Agricultural effects in the surrounding regions may be a cause. However, Meriç (1996), and Meriç et al. (2001, 2004) reported twins and triplets in the western Black Sea and Gulf of Izmit and eastern Aegean Sea where no anthropogenic effects were observed.

Physical factors such as currents may also be important in the formation of twins, triplets and quadruplets because physical oceanography governs environmental characteristics of foraminiferal habitats. Chemical factors affecting foraminifera may include changes in salinity, pH, Eh, sulfur, oxygen, and major and trace elements. Debenay and Pages (1987), Debenay (1990), Geslin et al. (1998), Stouff et al. (1999 a and b) and Geslin et al. (2000 and 2002) recorded twin and triplet occurrences driven by environmental factors, particularly related to salinity, by growing cultures in hypersaline conditions in the laboratory. Almogi-Labin et al. (1992) gave examples of abnormalities caused by unusually hypersaline conditions in a lake near the Dead Sea. Meriç et. al (2006) also illustrated examples

PLATE 1

- 1 *Textularia bocki* Höglund. Twin forms, side view, ×60, Kaş-Antalya, Station 21/12m.
- 2 *Textularia bocki* Höglund. Twin forms, side view, ×48.5, Kaş-Antalya, Station 30/14m.
- 3 *Textularia bocki* Höglund. Twin forms, side view, ×41.5, Kaş-Antalya, Station 32/12m.
- 4 *Textularia bocki* Höglund. Twin forms, side view, ×33.5, Kaş-Antalya, Station 34/5m.
- 5 *Textularia bocki* Höglund. Twin forms, side view, ×35, Kaş-Antalya, Station 49/8m.
- 6 *Textularia bocki* Höglund. Twin forms, side view, ×44, Kaş-Antalya, Station 56/4m.
- 7 *Textularia bocki* Höglund. Twin forms, side view, ×52, Kaş-Antalya, Station 63/12m.
- 8 *Textularia bocki* Höglund. Twin forms, side view, ×45.5, Kaş-Antalya, Station 63/24m.
- 9 *Textularia bocki* Höglund. Twin forms, side view, ×43, Kaş-Antalya, Station 73/8m.
- 10 *Textularia bocki* Höglund. Twin forms, side view, ×33, Kaş-Antalya, Station 67/15m.
- 11 *Textularia bocki* Höglund. Twin forms, side view, ×30, Kaş-Antalya, Station 74/23m.
- 12 *Textularia bocki* Höglund. Twin forms, side view, ×28.5, Kekova-Antalya, Station 78/24m.
- 13 *Textularia bocki* Höglund. Twin forms, side view, ×40, Kekova-Antalya, Station 81/5m.



of twins and triplets from Çamaltı-Saltan (Izmir) in Turkey, which supports the idea that twin and triplet formation may be enhanced under hypersaline conditions. However, in the present study, twins and triplets are seen in normal marine conditions.

CONCLUSION

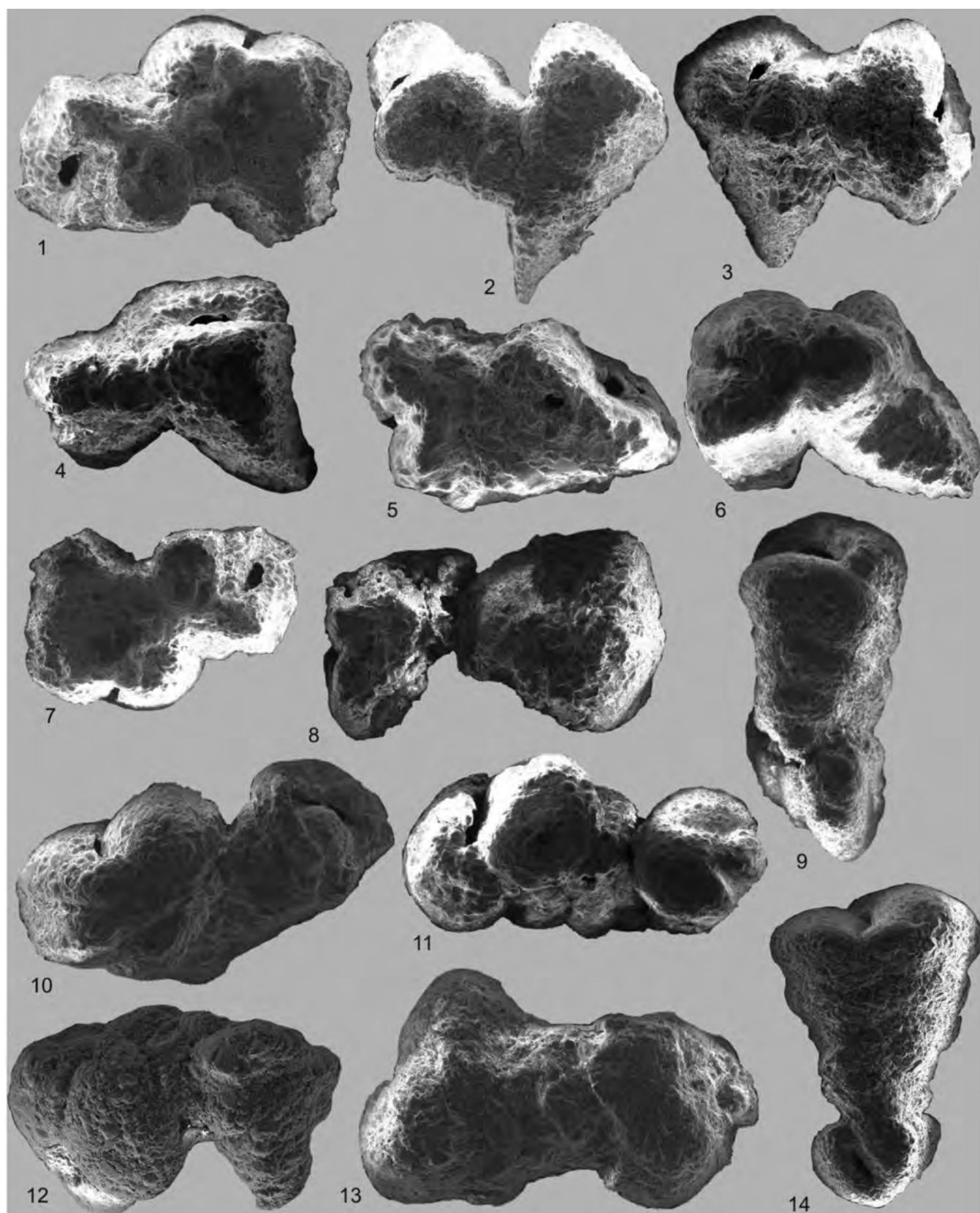
We describe examples of accidental-genetic twin, triplet and quadruplet formation in benthic foraminifera from southwestern Turkey. Twin, triplet and quadruplet formations are likely the result of various factors both biological and environmental. In our study area, however, biologic origin for the formation of twins, triplets and quadruplets seems to be most plausible because data for environmental factors is not available. Nonetheless it is clear that (1) percentages of twin, triplet, and quadruplet formations within a given population (2) salinity, and (3) location characteristics should all be taken into consideration when investigating causes of twin, triplet and quadruplet formation in benthic foraminifera.

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PLATE 2

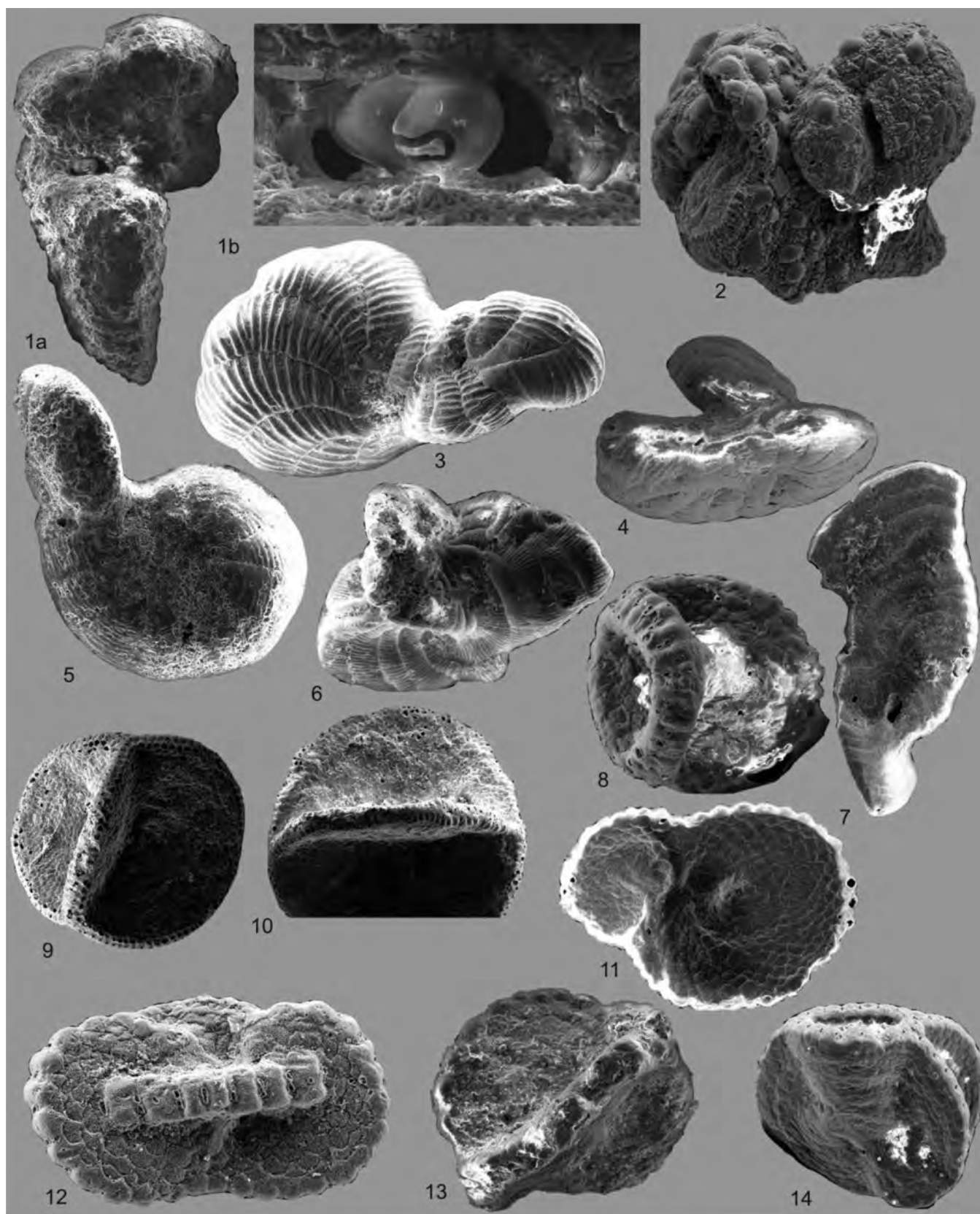
- 1 *Textularia bocki* Höglund. Twin forms, side view, ×36, Kekova-Antalya, Station 80/6m.
- 2 *Textularia bocki* Höglund. Twin forms, side view, ×27, Kekova-Antalya, Station 81/8m.
- 3 *Textularia bocki* Höglund. Twin forms, side view, ×40, Kekova-Antalya, Station 81/8m.
- 4 *Textularia bocki* Höglund. Twin forms, side view, ×41, Kekova-Antalya, Station 82/12m.
- 5 *Textularia bocki* Höglund. Twin forms, side view, ×69, Kekova-Antalya, Station 83/6m.
- 6 *Textularia bocki* Höglund. Twin forms, side view, ×41, Kekova-Antalya, Station 87/14.5m.
- 7 *Textularia bocki* Höglund. Twin forms, side view, ×32.5, Kekova-Antalya, Station 93/12m.
- 8 *Textularia bocki* Höglund. Twin forms, side view, ×36.5, Kekova-Antalya, Station 94/12m.
- 9 *Textularia bocki* Höglund. Twin forms, side view, ×44.5, Kekova-Antalya, Station 97/12m.
- 10 *Textularia bocki* Höglund. Twin forms, side view, ×52.5, Kekova-Antalya, Station 96/12m.
- 11 *Textularia bocki* Höglund. Twin forms, side view, ×37, Beşadalar-Antalya, Station 109/12m.
- 12 *Textularia bocki* Höglund. Twin forms, side view, ×46.5, Üçadalar-Antalya, Station 124/27m.
- 13 *Textularia bocki* Höglund. Twin forms, side view, ×57, Kaş-Antalya, Station 63/12m.
- 14 *Textularia bocki* Höglund. Twin forms, side view, ×35.5, Üçadalar-Antalya, Station 128/17m.



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PLATE 3

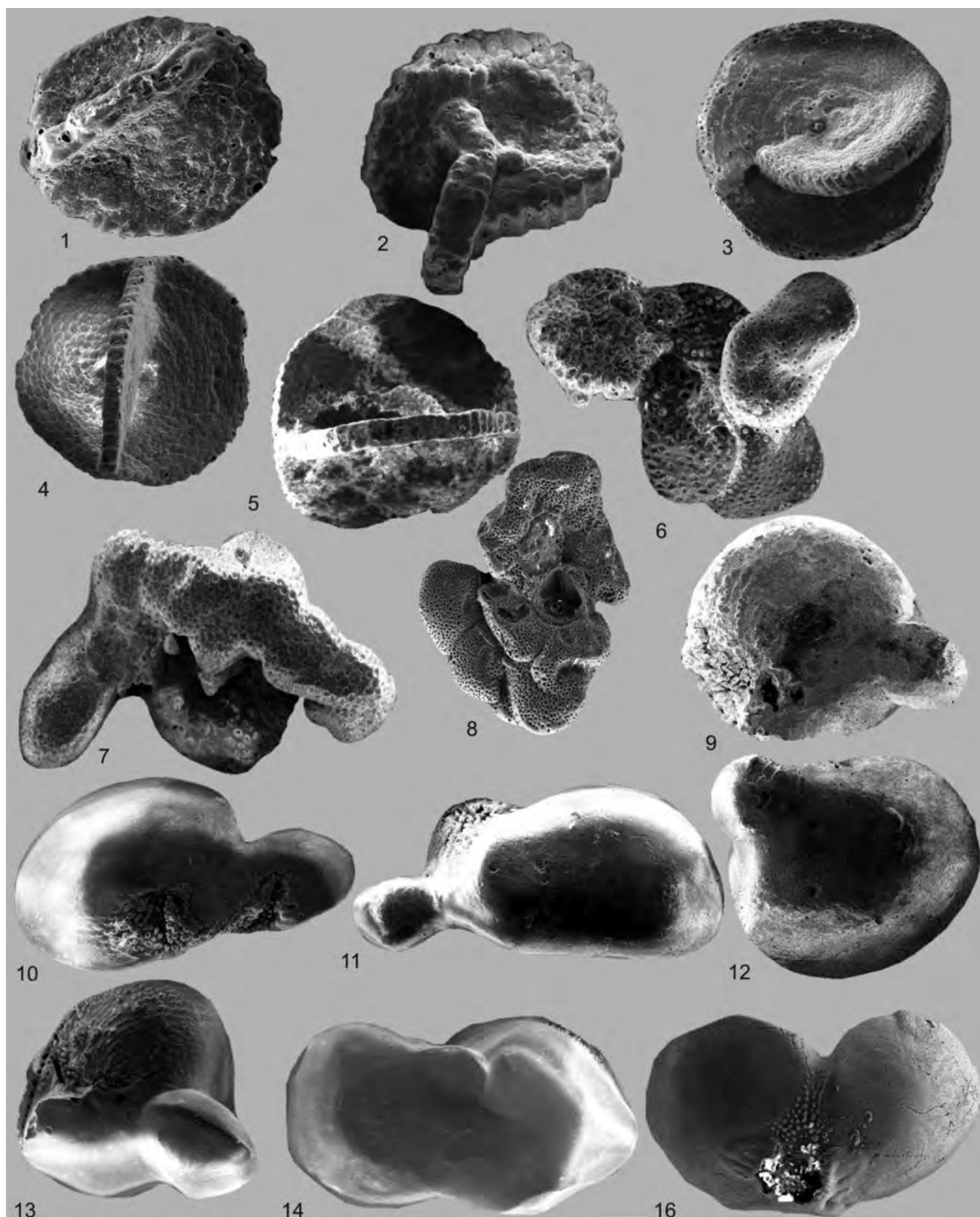
- 1 *Textularia bocki* Höglund. Twin forms, side view, a ×46 and b ×300, Beşadalar-Antalya, Station 106/12m. A juvenile *Triloculina bermudezi* Acosta is observed on the aperture of the top individual.
- 2 *Textularia bocki* Höglund. Twin forms, side view, ×61, Beşadalar-Antalya, Station 106/12m.
- 3 *Coscinospira hemprichii* Ehrenberg. Twin forms, side view, ×55.5, Kaş-Antalya, Station 132/6m.
- 4 *Peneroplis pertusus* (Forskål). Twin forms, side view, ×82, Kaş-Antalya, Station 60/14m.
- 5 *Peneroplis pertusus* (Forskål). Twin forms, side view, ×54, Kekova-Antalya, Station 91/6m.
- 6 *Peneroplis planatus* (Fichtel and Moll). Triplet forms, side view, ×27, Kaş-Antalya, Station 42/9m.
- 7 *Peneroplis planatus* (Fichtel and Moll). Twin forms, side view, ×44.5, Kekova-Antalya, Station 92/12m.
- 8 *Sorites orbiculus* Ehrenberg. Twin forms, side view, ×43, Kaş-Antalya, Station 48/12m.
- 9 *Amphisorus hemprichii* Ehrenberg. Twin forms, side view, ×15, Kekova-Antalya, Station 10. 81/8m.
- 11 *Amphisorus hemprichii* Ehrenberg. Twin forms, side view, ×13, Kekova-Antalya, Station 12. 81/8m.
- 13 *Sorites orbiculus* Ehrenberg. Twin forms, side view, ×33, Kaş-Antalya, Station 73/8m.
- 14 *Sorites orbiculus* Ehrenberg. Quadruplet forms, side view, ×59, Kekova-Antalya, Station 102/24m.
- 15 *Sorites orbiculus* Ehrenberg. Twin forms, side view, ×63, Kaş-Antalya, Station 54/15m.
- 16 *Sorites* cf. *S. orbiculus* Ehrenberg. Twin forms, side view, ×46, Kaş-Antalya, Station 131/19m.



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PLATE 4

- 1 *Sorites orbiculus* Ehrenberg. Twin forms, side view, ×57, Kekova-Antalya, Station 81/12m.
- 2 *Sorites orbiculus* Ehrenberg. Twin forms, side view, ×50, Kekova-Antalya, Station 99/24m.
- 3 *Sorites orbiculus* Ehrenberg. Twin forms, side view, ×18, Kaş-Antalya, Station 65/6m.
- 4 *Sorites orbiculus* Ehrenberg. Twin forms, side view, ×28, Kekova-Antalya, Station 84/14m.
- 5 *Sorites variabilis* Lacroix. Twin forms, side view, ×29, Kekova-Antalya, Station 92/12m.
- 6 *Cibicidella variabilis* (d'Orbigny). Twin forms, side view, ×52, Kekova-Antalya, Station 98/12m.
- 7 *Cibicidella variabilis* (d'Orbigny). Twin forms, side view, ×53, Kaş-Antalya, Station 131/12m.
- 8 *Cibicidella variabilis* (d'Orbigny). Triplet ? forms, side view, ×43, Kekova-Antalya, Station 85/23m.
- 9 *Amphistegina lobifera* Larsen. Twin forms, side view, ×36, Kaş-Antalya, Station 47/24m.
- 10 *Amphistegina lobifera* Larsen. Twin forms, side view, ×48, Kaş-Antalya, Station 63/24m.
- 11 *Amphistegina lobifera* Larsen. Twin forms, side view, ×45, Kekova-Antalya, Station 82/26m.
- 12 *Amphistegina lobifera* Larsen. Twin forms, side view, ×35, Kaş-Antalya, Station 65/24m.
- 13 *Amphistegina lobifera* Larsen. Twin forms, side view, ×34, Kaş-Antalya, Station 72/24m.
- 14 *Amphistegina lobifera* Larsen. Twin forms, side view, ×31, Kekova-Antalya, Station 89/12m.
- 15 *Amphistegina lobifera* Larsen. Twin forms, side view, ×29, Üçadalar-Antalya, Station 119/24m.



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