Intertidal Foraminifera of Indian coast - a scanning electron photomicrograph-illustrated catalogue

G. Subhadra Devi [1] & K.P. Rajashekhar [2]

[1,2] Department of Applied Zoology, Mangalore University, Mangalore, Karnataka 574199, India
Present Address: [1] Depatrment of Zoology, Carmel College for Women, Nuvem-Salcete, Goa 403601, India
Email: [2] (Corresponding author) drrkpatil@yahoo.com

Date of online publication 26 January 2009
ISSN 0974-7907 (online) | 0974-7893 (print)

Editor: R. Ramanibai

Manuscript details:
Ms # o1977
Received 08 April 2008
Final received 20 November 2008
Finally accepted 02 December 2008

Citation: Devi, G.S. & K.P. Rajashekhar (2009). Intertidal Foraminifera of Indian coast - a scanning electron photomicrograph-illustrated catalogue. *Journal of Threatened Taxa* 1(1): 17-36.

Author Details: Dr. G. Subhadra Devi is a Reader at the Carmel College for Women in Goa, India and teaches Zoology. She is interested in marine biodiversity and is currently working on foraminifera in the coral reefs of Lakshdweep archipelago.
Dr. Rajashekhar K. Patil is Professor of Applied Zoology at Mangalore University, Karnataka, India. He is studying foraminifera of Mangroves to understand the dynamics of Mangroves and patterns of Monsoons.

Author Contribution: Both the authors have made equal contributions to the study and the current paper.

Acknowledgement: We are grateful to Dr. Rajiv Nigam of Geological Oceanography Division, National Institute of Oceanography, Goa, India, for his valuable suggestions and support. We express our sincere thanks to Dr. Shyam Prasad and Mr. Vijay Kedekar, National institute of Oceanography, Goa, for Scanning Electron Microphotography. The study was supported by FIP Fellowship by University Grants Commission, New Delhi, to GSD. Grants from DST-FIST programme are gratefully acknowledged.

Abstract: Foraminifera (forams) are very useful in deducing diverse environmental parameters such as palaeoclimate, oil deposits, oceanography, pollution monitoring and palaeomonsoons. Forams are calcareous, shell-secreting protists and are likely to be adversely affected due to anthropogenic ocean acidification caused by CO_2 emission. Considering their significance and status, we have surveyed the occurrence of intertidal forams along the Indian Coast and Amini atoll of Lakshdweep Islands. Scanning electron microscopic observations have been carried out and are presented here. The foram assemblage is distinct from the tropical sites surveyed elsewhere while some of the species are common, suggesting that the local oceanographic conditions are major determinants in distribution of foram species. A total of 151 species of Foraminifera belonging to 65 genera, 41 families and 7 suborders were recorded in the present study. Only 4 species were planktonic and the rest were benthic. Rotalina and Miliolina were found to be dominant suborders. This paper contains SEM images of 142 identified species and surface details of some of species. The observations will serve the needs of researchers working with forams, especially in identification and morphological analysis.

Keyword: Foraminifera, Diversity, Intertidal, Indian Coast, SEM

Introduction

The diversity of marine life is being affected dramatically due to many causes. Increased atmospheric CO_2 emission leads to its increased dissolution in ocean water causing acidification. Such anthropogenic ocean acidification exerts a great impact on calcifying organisms (Orr et al. 2005). Foraminifera (forams) are one such shell-secreting group. Among the many marine taxa that are surveyed for their diversity, there is a bias towards commercially important organisms and higher vertebrates (Nee 2004). Protists are one of such groups which are least studied, despite being diverse and abundant. Foraminifera or forams in short are the most abundant, diverse and widely distributed Protists in the marine realm. The estimated living species are about 10,000 (Vickerman 1992). Of these, about 40 species are planktonic and the rest are benthic. Foraminifera are found in all marine environments (Todo et al. 2005). Diversity of Foraminifera is highest in tropical waters and gradually declines towards poles (Brasier 1980). The distribution of Foraminifera is not random, but is controlled by environmental gradient. The factors which influence their distribution and abundance include bathymetry, sediment texture, and physicochemical characteristics of sediment as well as water. Therefore, these organisms provide one of the best sources of proxy oceanic and climatic information.

The calcareous test of forams that protects the single cell incorporates important physico-chemical properties of the ambient environment during the life and gets preserved after the death of the organism. The tests are built of hollow chambers separated by partitions, with small openings called foramina that connect the chambers. Due to their tests, forams have a good potential to be fossilized. They are the most widely used fossil organisms for biostratigraphy and age dating. Abundance, species richness, species assemblage, test morphology and chemical composition of tests of foraminifera have been used to interpret palaeoenvironmental conditions, such as global sea level variations (Anthony et al. 2006), palaeomonsoons (Weldeab et al. 2007), palaeodepth (Nigam & Henriques 1992), palaeotemperature (Zachos et al. 2005), tsunami (Gadi & Rajashekhar 2007), pollution studies (Debenay et al. 2001). Benthic foraminifera have proved to be good indicators of methane releases in marine environment (Hill et al. 2003). Scott et al. (2001) have emphasized the importance of foraminifera in monitoring coastal environment.

The recent reviews of Bhalla et al. (2007) and Khare et al. (2007) on foraminiferal studies in near shore regions of western and eastern coasts of India reveal that most of the studies are related to taxonomic and ecological aspects and palaeoenvironmental interpretations. A few studies have been undertaken along the eastern coast of India on applied aspects of Foraminifera. Taxonomic and ecological studies on foraminifera from west coast of India were carried out by some researchers. Bhalla & Nigam (1979) and Bhalla & Gaur (1987) worked on foram diversity of Calangute and Colva beach sands respectively. Bhalla & Raghav (1980) studied the ecology of Foraminifera of Malabar coast and suggested that salinity is the chief governing factor. Raj & Chamyal (1998) studied the ecology of foraminifera of Mahi valley of Gujarat. Shareef & Venkatachalapathi (1988) reported 40 and 41 species of foraminifera from Bhatkal and Devgad islands, respectively. Nigam (2005) addressed the question as to how environmental issues can be solved through Foraminifera. Some studies were carried out on taxonomy and ecology of Forminifera from beaches and estuaries of east coast of India. Foraminiferal diversity in relation to different ecological conditions was reported by Bhalla (1968) from Vishakhapatnam beach sands, Hamsa (1973) and Kathal & Bhalla (1998) from Palk Bay and Gulf of Mannar, Narappa et al. (1981) from Godavari river system, and Kathal et al. (2000) from Kanyakumari, and Satyanarayana et al. (2007) from Nagapattinam. Very scanty literature is available on Foraminifera of Lakshadweep (Gupta 1973; Rao et al. 1987; Saraswati 2007). To utilize these marine protists efficiently, adequate knowledge of their diversity and distribution pattern in modern environment is of utmost importance. Therefore, a study of intertidal forams was undertaken comparing the east and west-coast and the sensitivity of forams to monsoons. This paper presents the scanning electron photomicrographs of inter tidal forams along the Indian coast, so as to benefit researchers in diverse areas who use Foraminifera.

Study Area

India has a coastline of 7,517km. The West and East coasts of India exhibit a number of dissimilarities in terms of oceanography. Bathymetry of the West Coast shows that the continental shelf is narrow and broadens northwards off the Gujarat coast. The continental shelf of the east coast is much narrower than the West Coast. The West Coast is characterised by heavy surf, rocky shores and sandy beaches. The rivers, which originate in the Western Ghats are short and rapid and westward flowing into Arabian Sea, forming estuaries rather than deltas. The elevation of the Eastern Ghats is lower than that of the Western Ghats. Most of the rivers flow eastwards, form deltas and discharge into the Bay of Bengal. The west coast experiences intense upwelling during southwest monsoon which brings the nutrients from deeper waters to upper ocean. The east coast is characterised by a weak upwelling during the northeast monsoon. Sea surface temperatures of Bay of Bengal are 1.5 to 2.0^{0}C higher than that of Arabian Sea. The salinity of the upper water column is more in the Arabian Sea than in Bay of Bengal. These dissimilarities are expected to provide variations in ecological conditions influencing foraminiferal distribution and their diversity. Hence the following sites of west- and east coasts of were chosen for the present study.

West Coast of India

The following 8 sites of west coast of India were chosen for the present study (Figure 1):

1. Juhu beach, Mumbai, (W1), is on the west coast of India, in Maharashtra on the eastern shore of the Arabian Sea. The location is highly polluted and has considerable organic matter input.
2. Malvan (W2) is located in Sindhudurg District of Maharashtra. This site is less polluted and is partly a rocky beach.
3. Baga (W3) is a beach and has large grain sediments and has lesser clay. It is situated along the north Goa coast.
4. Calangute (W4) beach extends for 7km, stretching along the north Goa coast.
5. Majorda (W5) is a part of 30km long stretch of uninterrupted beach from Velsao to Cavellossium in South Goa.
6. Ankola - Belikeri beach (W6) is situated 8km away from Ankola it is pristine and less impacted by anthropogenic activities.
7. Murudeshwar beach (W7) is wide and long, dotted with occasional rocks. The gradient of the shore is shallow.
8. Kozhikode - Beypore (W8) beach is located about 10km south of Kozhikode town at the mouth of the Chaliyar River in North Kerala. It is a site that is influenced by estuarine conditions.
9 Amini (W9)is one of the islands of Lakshadweep Archipelago. The unique feature of the Amini island is that it is encircled by a lagoon. The depth of the lagoon varies from 1.0- 2.5m.
10. Kochi - Cherai beach (W10) is a beach in the Cherai village. The beach has a narrow water way formed due to Vypeen Island.
11. Kollam (W11) is a shore with a steep gradient.
12. Shankhumugham (W12) is close to the southern tip of the peninsula and is a shallow water sandy beach near Thiruvananathapuram.

East Coast

The following sites were chosen for the present study (Figure 1):

1. Bali Island is one of the islands of Sunderbans (E1). The Indian Sundarbans at the apex of the Bay of Bengal is a deltaic complex of approximately 426,300ha formed by the depositional activities of the Ganges and the Brahmaputra. A group of 108 islands and a dense network of rivers, canals and creeks comprise the area. The intertidal zone of Bali island registers a gradual change in the textural characteristics from high water level to low level, indicating a sediment change from sandy to silty and clay nature
2. Digha (E2) is in Purba Medinipur district of West Bengal. It is located 187km away from Kolkata. Digha has considerable amount of clay.
3. Paradwip (E3) is located on the Bay of Bengal and is sandy.
4. Puri (E4) beach is long and wide extending for miles and is uninterrupted by rocky outcrops.
5. Bheemunipatnam beach (E5) is about 25km from Vishakhapatnam. This beach is located at the mouth of the river Gosthani in Andhra Pradesh.
6. Vishakhapatnam - Ramakrishna beach (E6) is a long stretch of beach with brown sands in Andhra Pradesh.
7. Chennai - Besant Nagar beach (E7). Here, the river Adyar meets the sea. It has impact of a populated city on it and is influenced by Adyar river discharge.
8. Nagapattinam (E8) is a long stretch of beach in Tamil Nadu. The width of the continental shelf of the coast near

Table 1. The sites of collection and their longitude and latitudes are listed below.

Site	Longitude	Latitude
West Coast		
Mumbai (Juhu Beach)	18.552N	72.541E
Malvan	17.053N	73.451E
Calangute	15.324N	73.454E
Majorda	15.182N	73.546E
Ankola	14.435N	74.163E
Murudeshwar	14.061N	74.270E
Kozhikode	11.104N	75.501E
Kochi (Cherai Beach)	09.588N	76.175E
East Coast		
Nagapattinam	10.481N	79.515E
Chennai (Besant beach)	13.001N	80.273E
Vishakpatnam	17.422N	83.153E
Bheemunipatnam	17.883N	83.435E
Puri	19.481N	85.523E
Paradeep	20.553N	86.342E
Digha	21.512N	87.476E
Bali Island (Sunderbans)	21.136N	88.054E
Lakshdweep		
Amini Atoll	11.075N	72.443E

Table 2. Number of Foraminiferal species observed at different sites along the Indian coast

West Coast (sites)	Number of Species	East Coast (sites)	Number of Species
W1 - Mumbai (Juhu)	29	E1 - Sunderbans	21
W2 - Malvan	26	E2 - Digha	17
W3 - Baga	46	E3 - Paradweep	21
W4 - Calangute	29	E4 - Puri	15
W5 - Majorda	20	E5 - Bheemunipatnam	19
W6 - Ankola	23	E6 - Vishakhapatnam	29
W7 - Murudeshwar	36	E7 - Chennai	20
W8 - Kozhikode	21	E8 - Nagapattinam	14
W9 - Amini Island	22	E9 - Rameswaram	52
W10 - Kochi	16	E10 - Dhanushkodi	33
W11 - Kollam	29		
W12 - Shankhumugham	24		

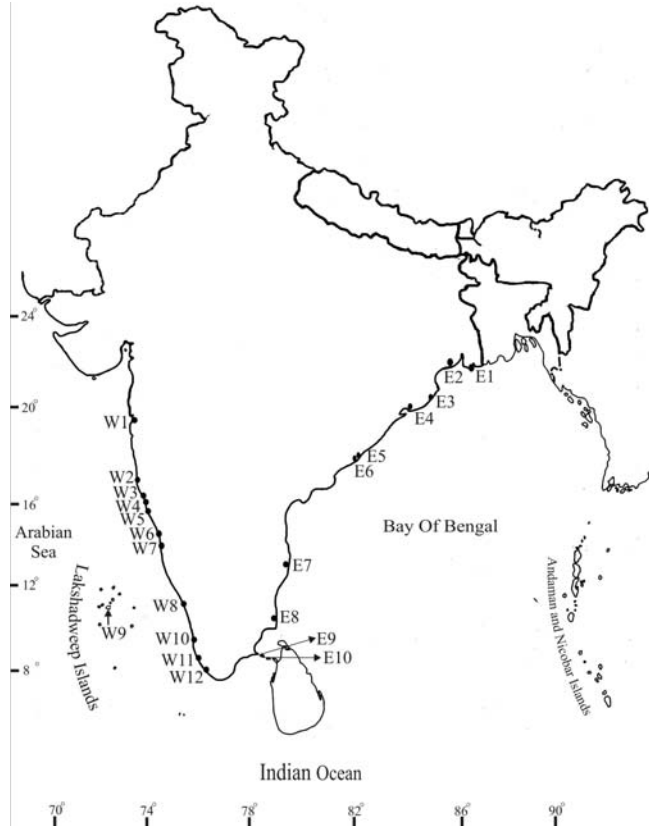

Figure 1. Sampling sites for Foraminifera on west and east coasts of India.
W1 - Mumbai; W2 - Malvan; W3 - Baga; W4 - Calangute; W5 - Majorda; W6 - Ankola; W7 - Murdeshwar; W8 - Kozhikode; W9 - Amini Island; W10 - Kochi; W11 - Kollam; W12 - Shankhumugham; E1 - Sunderbans; E2 - Digha; E3 - Paradip; E4 - Puri; E5 - Bheemunipatnam; E6 - Vishakapatnam; E7 - Chennai; E8 - Nagapattinam; E9 - Rameswaram; E10 - Dhanushkodi

Nagapattinam is narrow.

9. Rameswaram (E9) is an island in the Gulf of Mannar at the very tip of the Indian peninsula. The island is spread in an area of 61.8km^2.

10. The southernmost tip of the Rameswaram island is called Dhanushkodi (E10). It is 18km away from Rameshwaram.

The sites studied thus include locations that are estuarine or influenced by human habitat while some are pristine.

Methods

Intertidal sediment samples were collected during a period of two years, from October 2004 to September 2006. Samples were dried at 60^{0}C and soaked in water overnight to remove salts. The sediments were treated with 10% Sodium hexa-meta-phosphate overnight to dissociate clumped aggregates. To disintegrate the organic matter the samples were treated with 5ml of hydrogen peroxide. Afterwards, the samples were washed through a 63µm (230 ASTM) sieve under low water pressure. The sand fraction was collected and dried at 60^{0}C. Finally dried samples were examined for foram specimens. Individual, intact species were isolated under Olympus SZ 11 stereomicroscope. Individual specimens were mounted on brass stubs (0.5mm diameter) using double-sided adhesive carbon tape and coated with gold for about 2 minutes (SPI-Module Gold Sputter Coater). Specimens were observed using JEOL JSM-5800VS scanning electron microscope.

To identify live specimens, samples fixed in 70% alcohol were stained with Rose Bengal (Walton, 1952). The species were identified and classified by following Loeblich & Tappan (1987). Recent literature by various authors was also considered for identification. Diagnostic morphological features of the tests such as shell ornamentation, chamber arrangement and shape and position of aperture were considered for identification of species.

Results

A list of Foraminifera recorded in the present study from the inter-tidal regions of Indian Coast including Amini island of Lakshadweep along with their taxonomic status is reported in Table 3. Images SEM 1-13 of scanning electron microphotographs reveal the morphological features of the tests of Foraminifera recorded in the present study. The study revealed the occurrence of 151 species of Foraminifera belonging to 65 genera, 41 families and 7 suborders. All foraminiferal species belong to the order Foraminifera under Protista. Among the seven suborders, Rotaliina was represented by maximum number of species 72 belonging to 36 genera and 21 families. Rotaliinids have calcareous multilocular tests.

Table 3. Occurrence of Foraminifera along the Indian coasts.

No.	Species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
1.	*Miliammina fusca*	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-
2.	*Miliammina* sp.	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
3.	*Cibrostomoides* sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
4.	*Haplophragmoides canariensis*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
5.	*Cyclammina cancellata*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
6.	*Trochamminoides proteus*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
7.	*Trochammina inflata*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
8.	*Siphotrochammina lobata*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
9.	*Siphotexularia flintii*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.	*Clavulina angularis*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
11.	*Trochalina conica*	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
12.	*Cornuspira involvens*	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
13.	*Fisherina rhodiensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
14.	*Edenotostoma cultrata*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-
15.	*Spiroloculina aequa*	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.	*Spiroloculina antilarium*	-	-	+	+	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
17.	*Spiroluculina communis*	+	+	+	-	-	+	+	-	-	-	+	+	-	-	-	-	-	-	-	-	+	+
18.	*Spiroloculina corrugata*	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
19.	*Spiroloculina costifera*	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+
20.	*Spiroluculina depressa*	+	-	+	-	-	-	+	+	-	-	-	+	-	+	+	-	+	-	-	+	+	-
21.	*Spiroluculina excavata*	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
22.	*Spiroluculina exima*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23.	*Spiroloculuna indica*	-	-	-	+	-	-	-	-	-	-	-	-	+	-	+	-	-	+	-	-	+	-
24.	*Spiroloculina lucida*	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-	+	-
25.	*Spiroloculina nobilis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
26.	*Spiroloculina orbis*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-
27.	*Spiroloculina robusta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
28.	*Spiroloculina scita*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
29.	*Spiroloculina tricarinata*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30.	*Spiroloculina* sp.$_1$	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31.	*Spiroloculina* sp.$_2$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
32.	*Spiroluculina* sp.$_3$	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+
33.	*Quinqueloculina agglutinans*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+
34.	*Quinqueloculina cultrata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
35.	*Quinqueloculina intricata*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36.	*Quinqueloculina laevigata*	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37.	*Quinqueloculina lamarkiana*	-	-	+	+	-	+	+	+	-	-	-	-	+	+	-	-	+	+	-	-	+	+
38.	*Quinqueloculina ludwigi*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
39.	*Quinqueloculina parkeri*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-
40.	*Quinqueloculina pseudoreticulata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
41.	*Quinqueloculina schlumbergeri*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42.	*Quinqueloculina seminulum*	-	+	+	+	-	+	+	-	-	+	+	-	+	+	+	-	+	+	+	+	+	-
43.	*Quinqueloculina strigillata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
44.	*Quinqueloculina tropicalis*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45.	*Quinqueloculina venusta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
46.	*Quinqueloculina vulgaris*	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
47.	*Quinqueloculina* sp.$_1$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
48.	*Quinqueloculina* sp.$_2$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
49.	*Cruciloculina triangularis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
50.	*Triloculina echinata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
51.	*Triloculina insignis*	+	-	+	+	-	+	-	+	+	-	-	-	+	-	+	+	-	-	-	-	+	-
52.	*Triloculina oblonga*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
53.	*Triloculina rotunda*	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-
54.	*Triloculina schreiberiana*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
55.	*Triloculina terquemiana*	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56.	*Triloculina tricarinata*	-	+	+	+	-	+	+	+	-	+	-	-	+	-	+	-	+	+	+	-	+	+
57.	*Triloculina trigonula*	+	-	+	-	+	-	-	-	+	+	-	-	+	+	+	+	-	+	-	+	+	-
58.	*Triloculina* sp.$_1$	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
59.	*Triloculina* sp.$_2$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
60.	*Triloculina* sp.$_3$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
61.	*Miliolinella australis*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62.	*Miliolinella labiosa*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
63.	*Miliolinella subrotunda*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
64.	*Miliolinella* sp.$_1$	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
65.	*Miliolinella* sp.$_2$	-	—	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
66.	*Pyrgo denticulata*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
67.	*Rupertianella rupertiana*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	+
68.	*Peneroplis pertusus*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
69.	*Aphisorus hemprichii*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
70.	*Marginopora vertebralis*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
71.	*Lagena leavis*	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
72.	*Lagena striata*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73.	*Lagena sulcata*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
74.	*Fissurina laevigata*	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75.	*Conorboides advena*	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
76.	*Globigerina bulloides*	+	+	-	+	+	+	+	+	-	+	-	-	-	-	+	+	+	+	+	+	-	-
77.	*Globigerinoides ruber*	+	+	+	-	+	+	+	+	-	-	-	-	-	-	+	-	-	+	-	-	-	-
78.	*Globigerinoides sacculifer*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

No.	Species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
79.	*Orbulina universa*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
80.	*Bolivina kuriani*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
81.	*Bolivina limbata*	+	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
82.	*Bolivina ordinaria*	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
83.	*Bolivina striatula*	+	+	-	+	-	+	+	-	-	-	-	-	+	+	+	-	+	+	-	+	-	-
84.	*Bolivina variabilis*	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
85.	*Loxostomum limbatum*	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-
86.	*Bulimina marginata*	+	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
87.	*Siphouvigerina porrecta*	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
88.	*Siphouvigerina virgula*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
89.	*Cancris auriculus*	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+
90.	*Cancris indicus*	-	-	+	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-
91.	*Physalidia simplex*	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
92.	*Eponides repandus*	+	-	+	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+
93.	*Poroeponides lateralis*	-	-	+	-	+	+	+	+	-	-	-	+	-	-	-	+	+	-	-	-	-	-
94.	*Discorbis* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
95.	*Neoconorbis* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
96.	*Rosalina brady*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
97.	*Rosalina* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
98.	*Discorbina sp.*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.	*Hyalinea balthica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+
100.	*Planulina* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+
101.	*Cibicides lobatulus*	-	-	+	-	-	-	+	-	-	-	-	-	+	-	+	-	-	+	+	-	-	-
102.	*Cibicides refulgens*	-	-	+	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
103.	*Cibicides* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+
104.	*Caribeanella polystoma*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-
105.	*Planorbulina* sp.$_1$	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
106.	*Planorbulina* sp.$_2$	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
107.	*Cymbaloporetta bradyi*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-
108.	*Cymbaloporetta squammosa*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
109.	*Rupertina* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
110.	*Amphistegina lessoni*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
111.	*Amphistegina madagascariensis*	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+	-	+	+
112.	*Amphistegina radiata*	-	+	-	-	+	-	-	+	+	+	+	+	-	-	-	-	-	+	+	-	+	+
113.	*Nonion asterizens*	-	-	+	+	-	-	+	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-
114.	*Nonion boueanum*	+	+	+	+	-	+	+	+	-	-	-	-	+	-	+	-	-	-	+	+	+	-
115.	*Nonion elongatum*	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
116.	*Nonion grateloupi*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
117.	*Nonion incisum*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
118.	*Nonion monicana*	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
119.	*Nonion scaphum*	+	+	+	+	+	+	+	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-
120.	*Nonionella opima*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121.	*Nonionella stella*	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
122.	*Protelphidium granosum*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
123.	*Melonis* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
124.	*Gyroidina neosoldanii*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
125.	*Hanzawaia concentrica*	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	+	-
126.	*Bucella hannai*	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
127.	*Pararotalia calcar*	-	-	-	+	-	+	+	-	-	-	+	-	-	-	-	-	+	+	-	-	+	-
128.	*Ammonia beccarii*	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
129.	*Ammonia dentata*	+	+	+	+	-	+	+	+	-	+	-	+	+	-	+	+	+	-	+	+	+	+
130.	*Ammonia tepida*	+	+	+	+	-	-	+	+	-	-	-	+	-	+	-	+	+	+	-	-	+	+
131.	*Asterorotalia dentata*	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
132.	*Asterorotalia trispinosa*	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	+	+	+	+	+	-
133.	*Rotalidium annectans*	+	+	+	+	+	-	+	-	-	+	+	+	-	-	-	-	+	+	-	-	-	-
134.	*Rotaliniodes papillosus*	-	+	+	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
135.	*Calcarina calcar*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
136.	*Elphidium advenum*	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	+	-
137.	*Elphidium craticulatum*	-	-	+	-	-	-	-	-	-	+	+	-	-	-	-	+	-	+	+	-	-	+
138.	*Elphidium crispum*	+	-	+	-	+	+	-	+	+	-	-	-	-	-	-	+	+	+	-	-	+	-
139.	*Elphidium discoidale*	+	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	-	+	+
140.	*Elphidium discoidale multiloculatum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
141.	*Elphidium hispidulum*	+	-	-	-	-	+	-	-	-	-	+	+	+	+	+	-	+	+	+	+	+	+
142.	*Elphidium incertum*	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-
143.	*Elphidium indicum*	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
144.	*Elphidium jenseni*	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
145.	*Elphidium macellum*	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+	-	-
146.	*Elphidium norvangi*	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-
147.	*Elphidium poeyanum*	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-
148.	*Elphidium simplex*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
149.	*Ozawaia* sp.	-	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
150.	*Operculina ammonoides*	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+
151.	*Operculina granulosa*	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

\+ indicates present ; - indicates not found in the present study

W1 - Mumbai; W2 - Malvan; W3 - Baga; W4 - Calangute; W5 - Majorda; W6 - Ankola; W7 - Murudeshwar; W8 - Kozhikode; W9 - Amini Island; W10 - Kochi; W11 - Kollam; W12 - Shankhumugham; E1 - Sunderbans; E2 - Digha; E3 - Paradwip; E4 - Puri; E5 - Bheemunipatnam; E6 - Vishakhapatnam; E7 - Chennai; E8 - Nagapattinam; E9 - Rameswaram; E10 - Dhanushkodi

The suborder Miliolina was found to be second in species richness with 59 species belonging to 13 genera and 8 families. In this suborder the tests of the foraminiferal species are porcelaneous. Textularina was represented by 10 species. They belong to 9 genera and 7 families. They have agglutinated tests. Under the suborder Lagenina 4 species belonging to 2 genera and 2 families were recorded. Tests are monolamellar. Globigerinina was represented by 4 species of planktonic Foraminifera belonging to 3 genera and 1 family. Tests are calcareous and hyaline in nature. The suborders Involutinina and Robertinina were represented by single species, single genus and single family. Presence of calcareous tests with tubular second chamber is the characteristic feature of the sub order Involutinina. Tests are planispirally to trochospirally enrolled in Robertinina. Out of 151 species, only 4 were planktonic and the remaining were benthic forms. The number of species found in each site is provided in Table 2. The occurrence of individual species in each site surveyed is provided in Table 3. The variations between the west- and east-coast are due to variations in the physicochemical properties between Arabian and the Bay of Bengal. A detailed account of these differences is provided elsewhere (Gadi & Rajashekhar, Communicated). Clear, Monsoon related fluxes in diversity do occur in some species.

Conclusion

The assemblage of Foraminifera as observed in the present study reveal the following important points. The diversity of foraminifera depends largely on the ecological conditions at a site. The latitude being the same, they differ considerably between the West and East coasts of India. The dominant species however are the same, though their ranking in abundance differs. The relative density and diversity of forams differs between East and West coast. Observations suggest occurrence of morphogroups. The assemblage differs considerably from regions studied and reported from elsewhere and it also differs from other tropical sites where comparable studies have been undertaken (Javaux & Scott 2003). However, near shore forams of other regions are comparable to the assemblage found in the present study. Studies on fossil forams carried out by Talib & Gaur (2008) in Jumara Dome, Kutch, India revealed 51 species. Comparison of our observations with that of Talib & Gaur (2008) shows that the present day fauna is considerably different than the fauna of forams of the Oxfordian age (~160 Myr) and suggests rapid speciation.

We have developed an SEM illustrated catalogue for future reference and comparison as Arabian Sea has good prospects of natural gas and oil deposits, for survey of which fossil forams are used. Robust and well defined SW monsoons are also a characteristic climatic feature that influences Arabian Sea. The SEM images obtained in the present study will facilitate researchers in proper identification of foraminiferal species. The surface characteristics revealed will help morphological analysis from polluted areas and regions affected by high energy waves. The present study gives an overview of the foram diversity and records the dominant species found along the Indian coast. Environmental conditions and the subtleties of variations in oceanography of Arabian Sea and the Bay of Bengal are reflected in their distribution.

References

Anthony, C., W. Massey, R. Gehrels, D.J. Charman & S.V. White (2006). An Intertidal foraminifera-based transfer function for reconstructing holocene sea-level change in Southwest England. *The Journal of Foraminiferal Research* 36: 215-232.

Bhalla, S.N. (1968). Recent foraminifera from Vishakhapatnam beach sands and its relation to the known foramgeographical provinces in the Indian Ocean. *Bulletin, National Institute of Science, India* 376-392.

Bhalla, S.N. & K.N. Gaur (1987). Recent foraminifera from Colva beach sands, Goa. *Journal of Paleontological Society* 32: 122-130.

Bhalla, S.N., N. Khare, D.H. Shanmukha & P.J. Henriques (2007). Foraminiferal studies in near shore regions of western coast of India and Laccadives Islands: A review. *Indian Journal of Marine Sciences* 36: 272-287.

Bhalla, S.N. & R. Nigam (1979). A note on recent foraminifera from Calangute beach sands, Goa. *Bulletin Indian Geological Association* 12: 239-240.

Bhalla, S.N. & K.S. Raghav (1980). Recent foraminifera from beach sands of Malabar coast. *Indian Journal of Marine Science* 9: 288-290.

Brasier, M.D. (1980). *Microfossils*. George Allen and Unwin Ltd., Publications, 90-121pp.

Debenay, J.P., E. Geslin, B.B. Eichler, W. Duleba, F. Sylvestre & P. Eichler (2001). Foraminiferal Assemblages in a Hypersaline lagoon, Araruama (R.J.) Brazil. *The Journal of Foraminiferal Research* 1: 133-151.

Gadi, S.D. & K.P. Rajashekhar (2007). Changes in inter-tidal foraminifera following tsunami inundation of Indian Coast. *Indian journal of Marine sciences* 36: 35-42.

Guptha, M.V.S. (1973). A preliminary report on theforaminiferal assemblages from the lagoon sediment of Kavaratti Atoll (Laccadives). *Indian Journal of Marine Science* 42:781-782.

Hamsa, A.K.M.S. (1973). Foraminifera of the Palk Bay and Gulf of Mannar. *Journal of Marine Biological Association* 14: 418-423.

Hill, T.M., J.P. Kennett & H.J. Spero (2003). Foraminifera as indicators of methane-rich environments: A study of modern methane seeps in Santa Barbara Channel, California. *Marine Micropaleontology* 49: 123-138.

Javaux, E.J. & D.B. Scott (2003). Illustration of modern benthic foraminifera from Bermuda and remarks on the distribution in other subtropical/tropical areas. Palaeontologia electronica, 6:29pp electronic version: http://palaeo-electronica.org/2003_1/benthic/benthic.pdf

Kathal, P.K. & S.N. Bhalla (1998). Recent foraminiferal thanatocoenoses from the Gulf of Mannar, India. *Neus Jaharbuch Geologie und Paleontologie* 207: 419-431.

Kathal, P.K., S.N. Bhalla & R. Nigam (2000). Foramgeographical affinities of the west and east coasts of India: An approach through cluster analysis and comparison of taxonomical, environmental and ecological parameters of Recent foraminiferal thanatotopes. *Bulletin, Oil and Natural Gas Corporation of India* 37: 65-75.

Khare, N., S.K. Chaturvedi & A. Mazumder (2007). An overview of foraminiferal studies in near shore regions off eastern coast of India and Andaman and Nicobar Islands. *Indian Journal of Marine Sciences* 36: 288-300.

Loeblich, A.R. Jr. & H. Tappan (1987). *Foraminiferal genera and their classification.* Von Nostrand Rinhold, New York, 970pp.

Narappa, K.V., M.S. Rao & M.P. Rao (1981). Living foraminiferida from the estuarine complex of the Gautami and Nilareva distributaries of River Godavari Part 1. *Living populations in relation to ecological factors. Proceedings of the IX Colloquium on Micropalaeontology and Stratigraphy*: 49-68.

Nee, S. (2004). More than meets the eye: Earth's real biodiversity is invisible. *Nature* 429: 804-805.

Nigam, R. (2005). Addressing environmental issues through foraminifera – Case studies from the Arabian Sea. *Journal of Paleontological Society* 50: 25-36.

Nigam, R. & P.J. Henriques (1992). Planktonic percentage of foraminiferal fauna in surface sediments of the Arabian Sea (Indian Ocean) and a regional model for paleodepth determination. *Palaeogeography, Palaeoclimatology and Palaeoecology* 91: 89-98.

Orr J.C, J.F. Victoria, A. Oliver, B. Laurent, C.D. Scott, A.F. Richard,

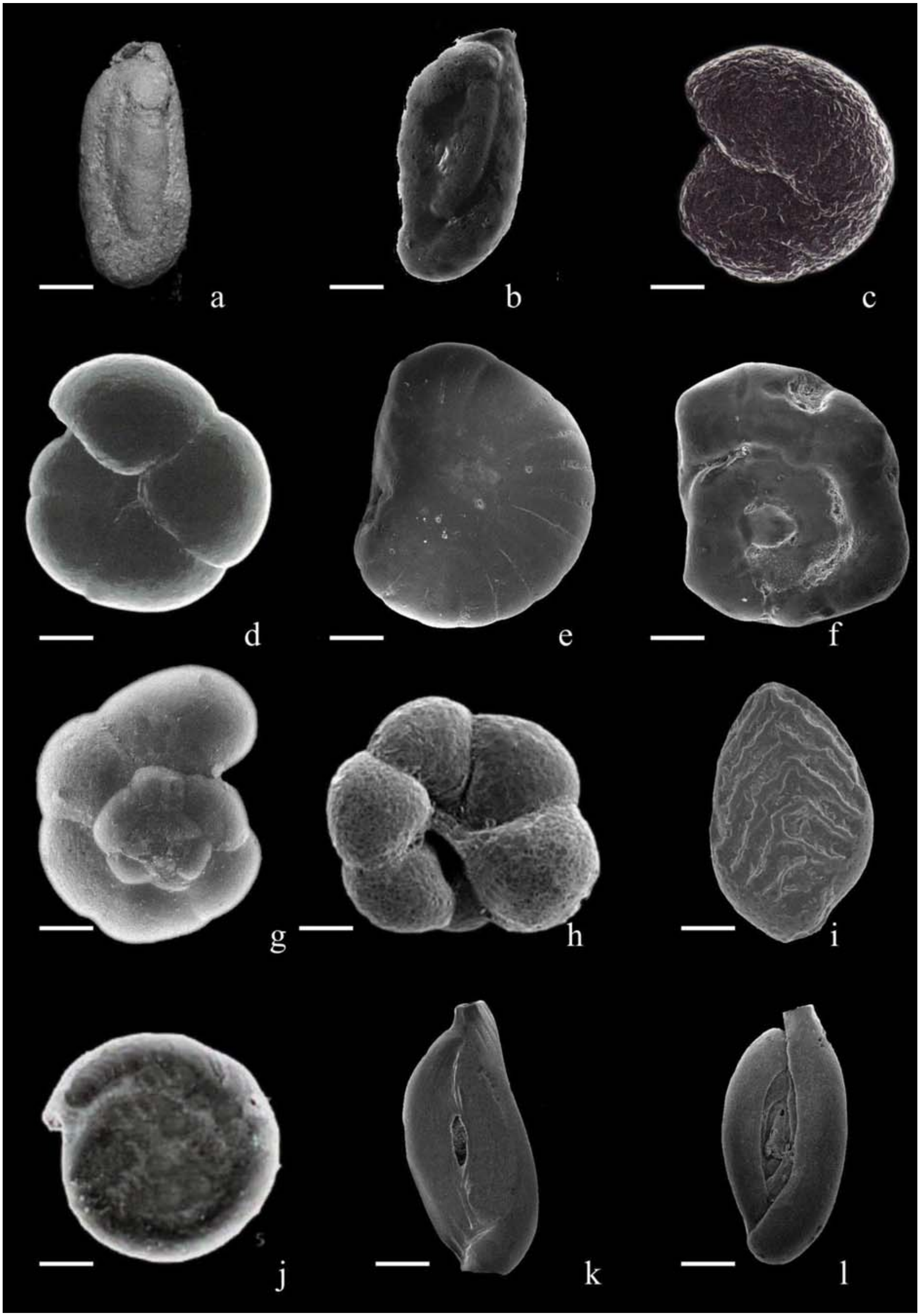

Image 1. a – *Miliammina fusca* (E1); b – *Miliammina* sp. (W11); c – *Cribrostomoides* sp (E1).; d – *Haplophragmoides canariensis* (E1); e – *Cyclammina cancellata* (W3); f – *Trochamminoides proteus* (W11); g – *Trochammina inflata* (E2); h – *Siphotrochammina lobata* (W11); i - *Siphotrochammina flintii* (W7); j – *Cornuspira involvens* (W9); k – *Edentostomina cultrata* (W2); l – *Spiroloculina aequa* (W3). Scale 100µm

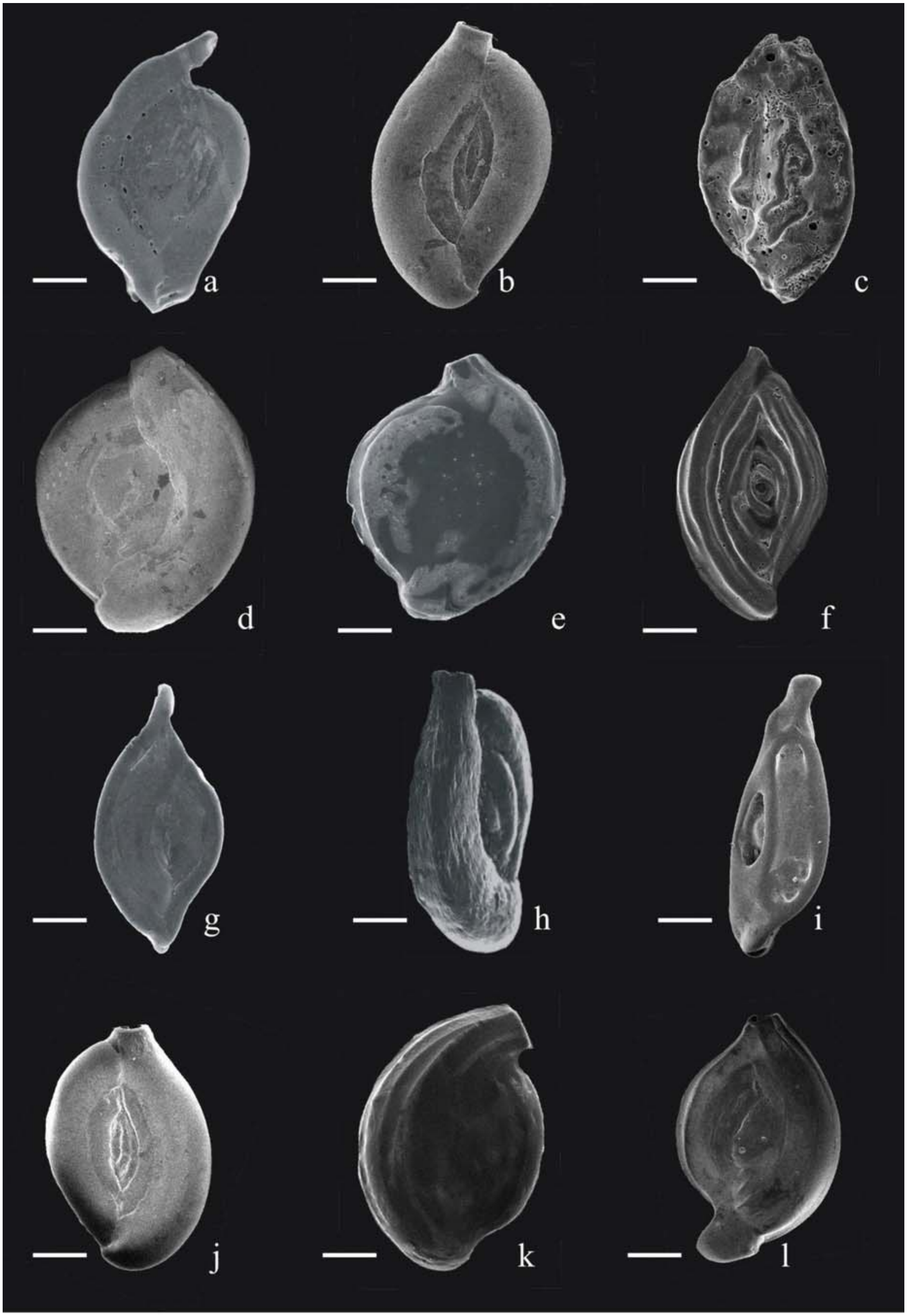

Image 2. a - *Spiroloculina antilarium* (W3); b - *Spirolouculina communis* (W3); c - *Spiroloculina corrugata* (W6); d - *Spiroluculina depressa* (W1); e - *Spiroluculina excavata* (W3); f - *Spiroluculina exima* (W3); g - *Spiroloculuna indica* (W4); h - *Spiroloculina lucida* (W11); i - *Spiroloculina nobilis* (E7); j - *Spiroloculina orbis* (W11); k - *Spiroloculina tricarinata* (W5); l - *Spiroloculuna* sp.1 (W5). Scale 100µm.

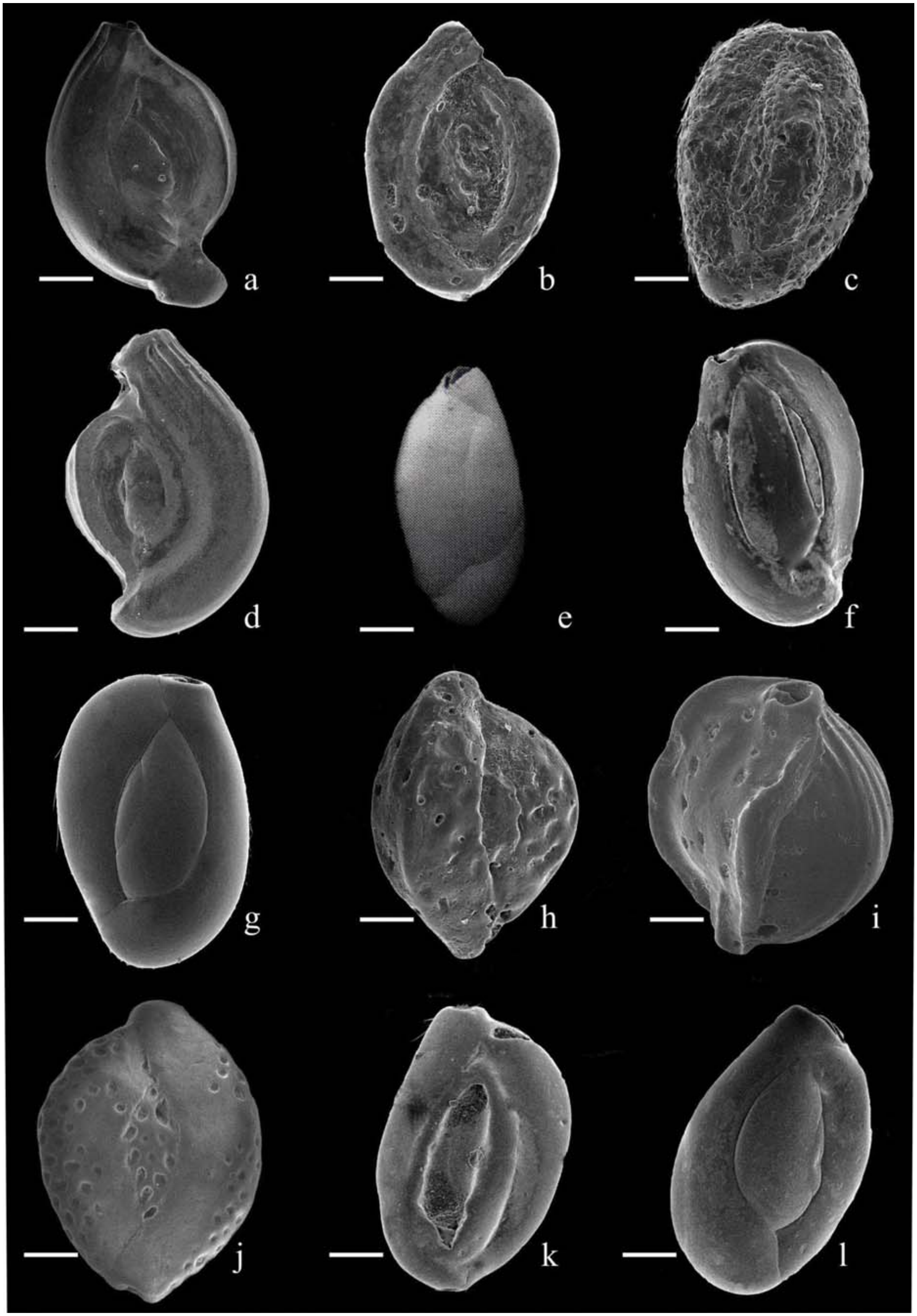

Image 3. a - *Spiroloculina* sp.2 (E9); b - *Spirolouculina* sp.3 (W12); c - *Quinqueloculina agglutinans* (W11); d - *Quinqueloculina intricata* (W3); e - *Quinqueloculina laevigata* (W1); f - *Quinqueloculina lamarkiana* (W3); g - *Quinqueloculina ludwigi* (W3); h - *Quinqueloculina parkeri* - 3 chambers view (W9); i - *Quinqueloculina parkeri* - apertural view (W9); j - *Quinqueloculina pseudoreticulata* (E9); k - *Quinqueloculina schlumbergeri* (W3); l - *Quinqueloculina seminulumum* (W2). Scale 100µm.

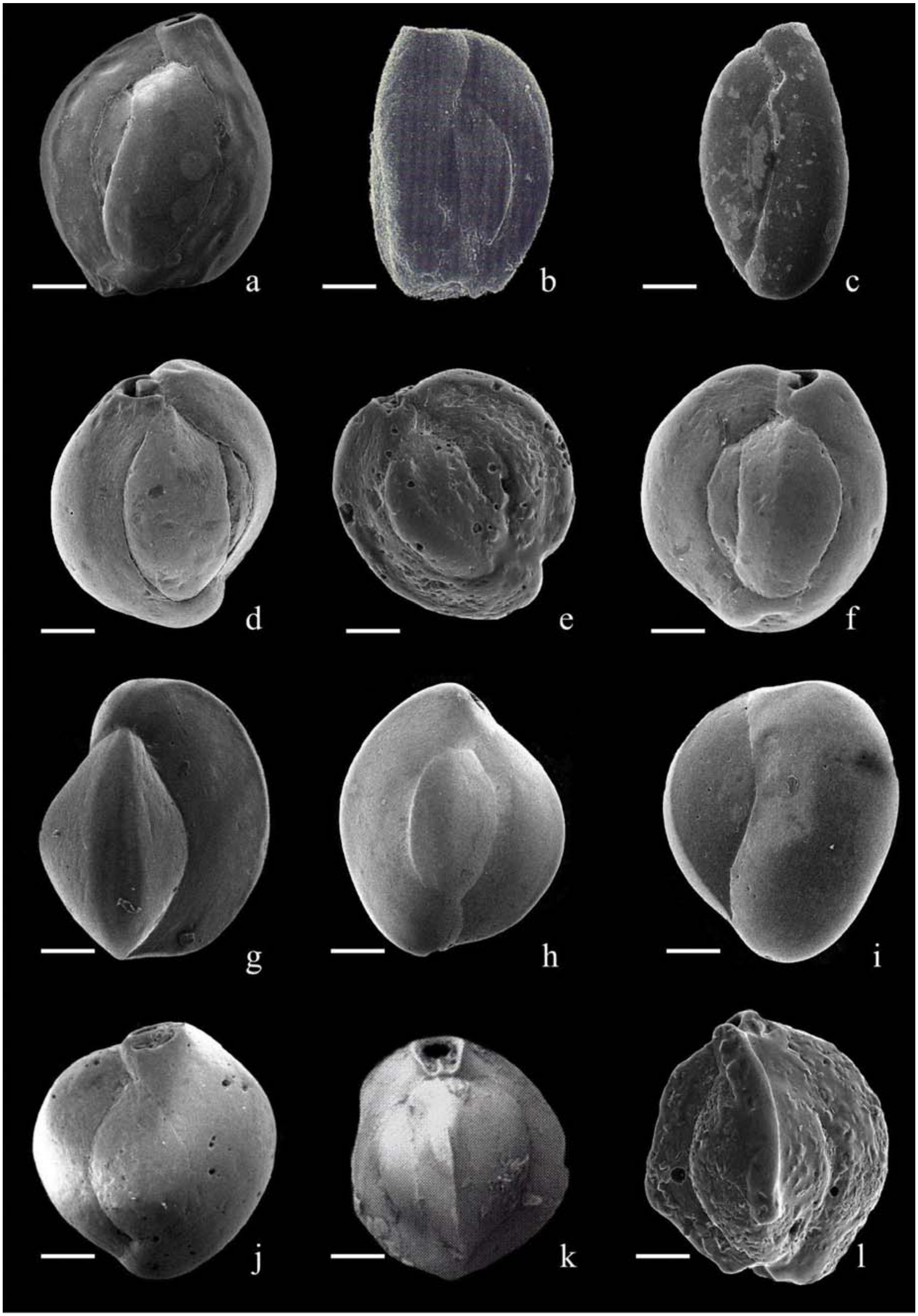

Image 4. a - *Quinqueloculina strigillata* (E7); b - *Quinqueloculina tropicalis* (W3); c - *Quinqueloculina venusta* (E9); d - *Quinqueloculina vulgaris* (E9); e - *Quinqueloculina* sp.1 (E9); f - *Quinqueloculina* sp.2 (E9); g - *Cruciloculina triangularis* (E9); h - *Triloculina insignis* - 3 chambers view (W1); i - *Triloculina* insignis - 2 chambers view (W1); j - *Triloculina* rotunda (W7); k - *Triloculina trigonula* (W1); l - *Triloculina* tricarinata (W2). Scale 100µm.

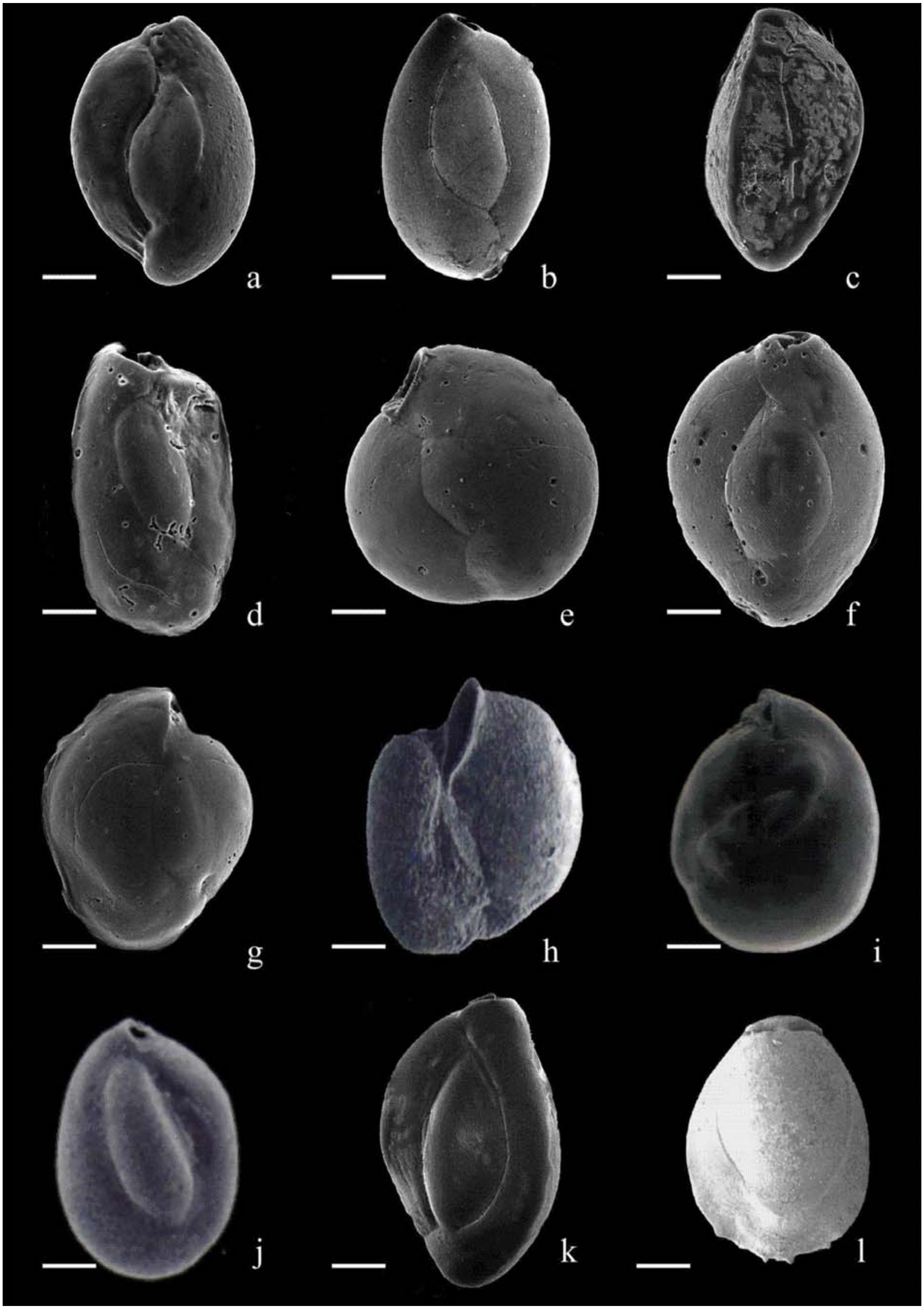

Image 5. a - *Triloculina oblonga* (W2); b - *Triloculina schreiberiana* (W10); c - *Triloculina terquemiana* (W3); d - *Triloculina* sp.1 (W12); e - *Triloculina* sp.2 (E9); f - *Triloculina* sp.3 (E10); g - *Miliolinella australis* (W3); h - *Miliolinella labiosa* (W3); i - *Miliolinella subrotunda* (E4); j - *Miliolinella* sp.1(W1); k - *Miliolinella* sp.2 (E4); l - *Pyrgo denticulata* (E9). Scale 100µm.

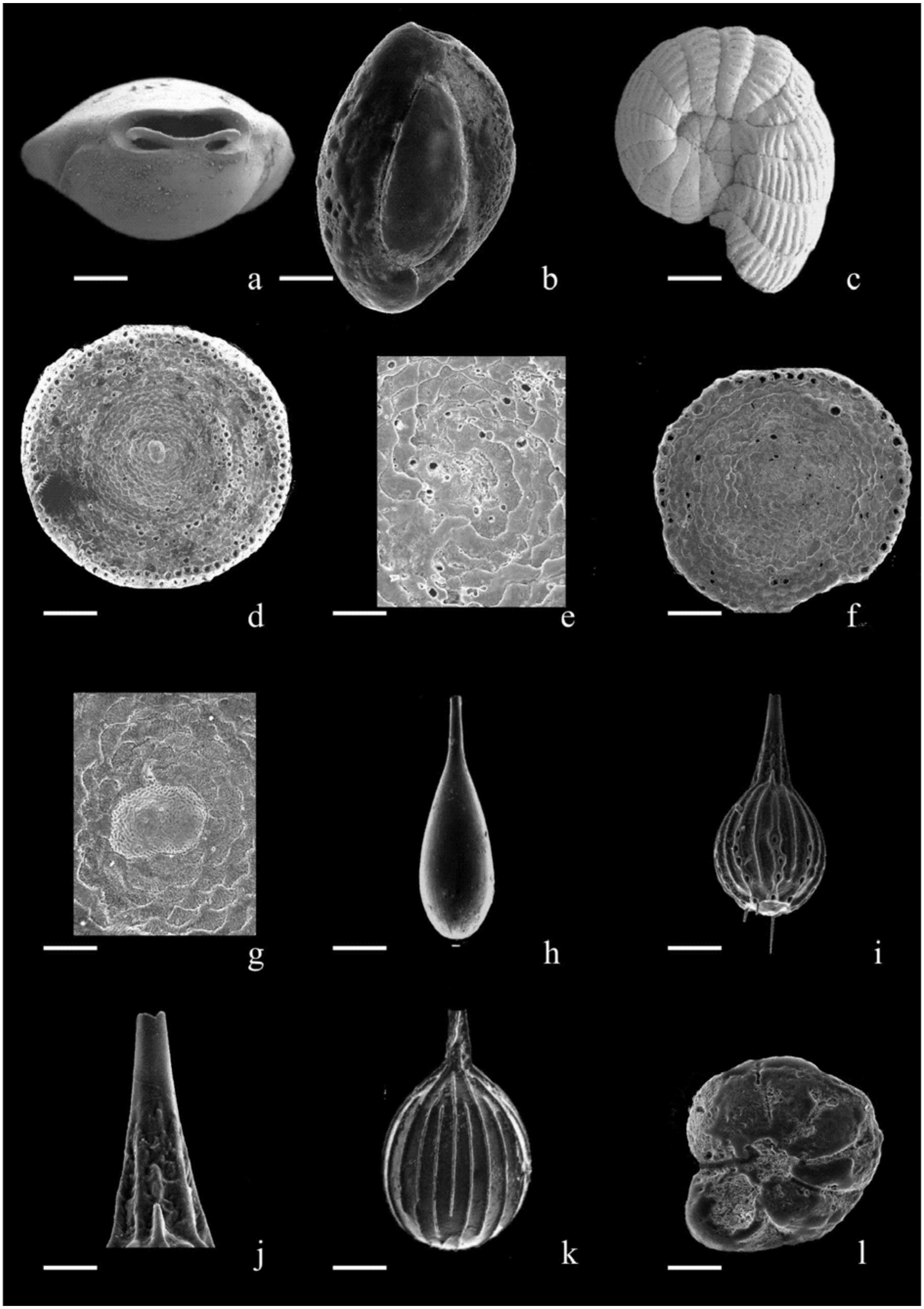

Image 6. a - *Pyrgo denticulata* - apertual view (E9); b - *Rupertianella rupertiana* (E10); c - *Peneroplis pertusus* (W9); d - *Amphisorus hemiprichii* - lateral view (W9); e - *Amphisorus hemiprichii* - cyclic arrangement of chambers (W9); f - *Marginopora vertebralis* - lateral view (W9); g - *Marginopora vertebralis - Proloculus with cyclic arrangement of chambers* (W9); h - *Lagena leavis* (W4); i - *Lagenastriata* (W1); j - *Lagena straita* - enlarged neck (E2); k - *Lagena sulcatus* (E2); l - *Conorboideadvena* (W8). Scale 100µm

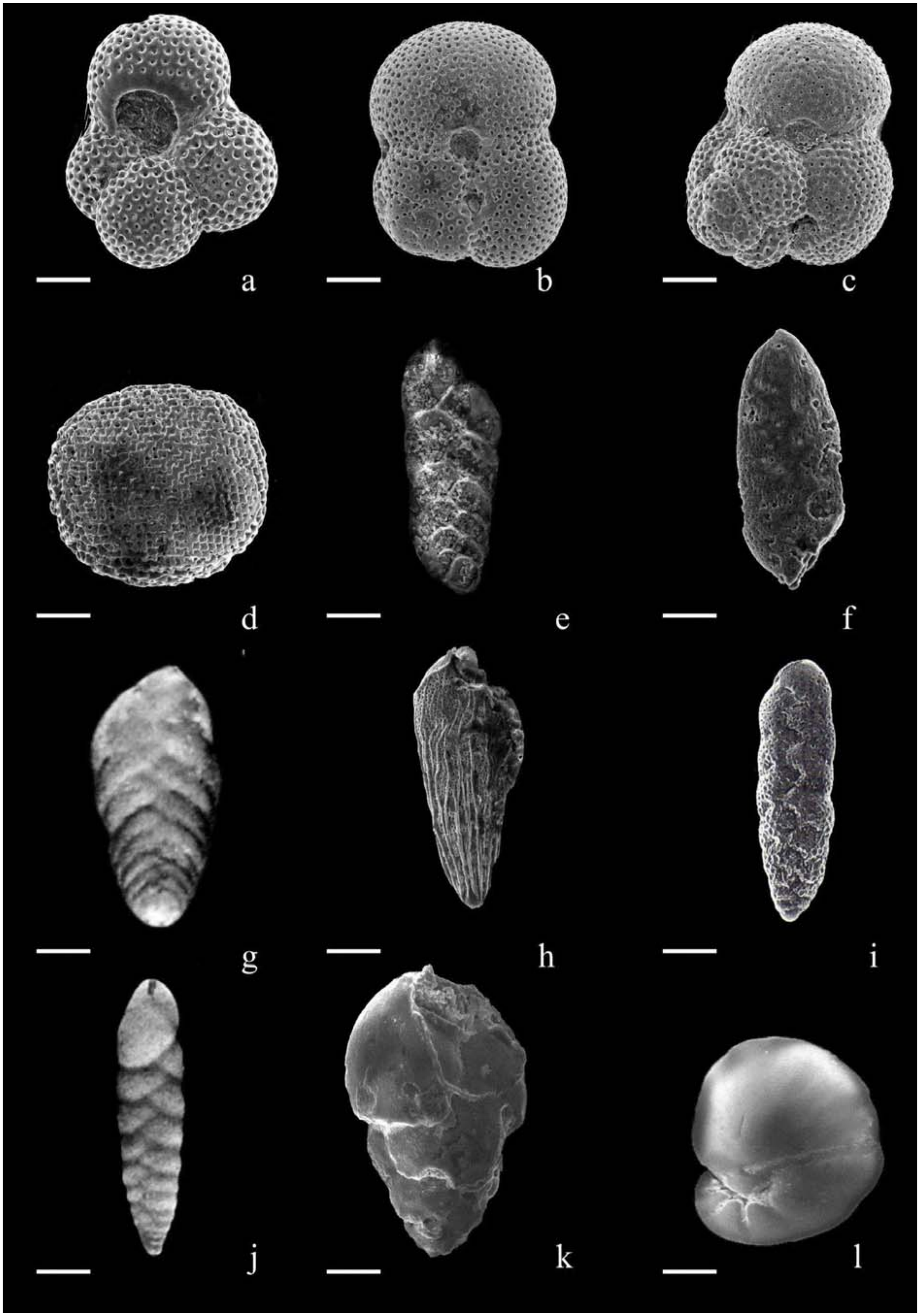

Image 7. a – *Globigerina bulloides* (W1); b – *Globigerinoides rubber* (W1); c – *Globigerinoides sacculifer* (W7); d – *Orbulina universa* (W7); e – *Bolivina limbata* (W1); f – *Bolivina ordinaria* (W1); g – *Bolivina kuriani* (W4); h – *Bolivina striatula* (W1); i - *Bolivina variabilis* (W1); j – *Loxostomum limbatum* (W1); k – *Bulumina marginata* (W1); l – *Cancris auriculus* (W4). Scale 100µm.

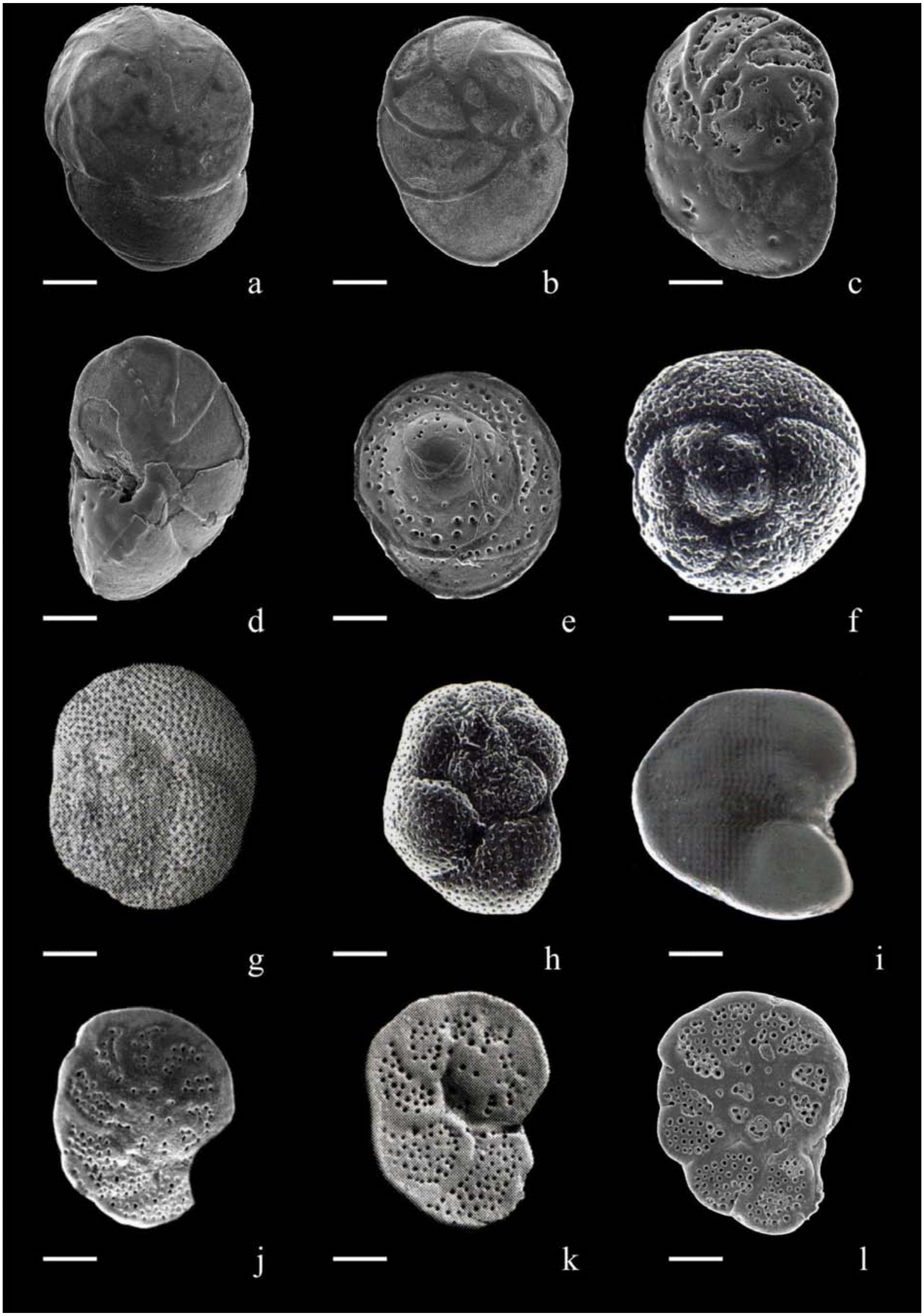

Image 8: a - *Cancris indicus* (W1); b - *Eponides respandus* (W1); c - *Poroeponides lateralisdorsa* view (W3); d - *Poroeponides lateralis* – apertural view (W3); e - *Discorbis* sp. (E10); f. *Neoconorbis* sp. (E9); g - *Rosalina brady* (W5); h - *Rosalina* sp. (E6); i - *Hyalinea balthica* (E7); j - *Planulina* sp. (W12); K - *Cibicides refulgens* (W3); l - *Cibicides lobatulus* (W3). Scale 100µm.

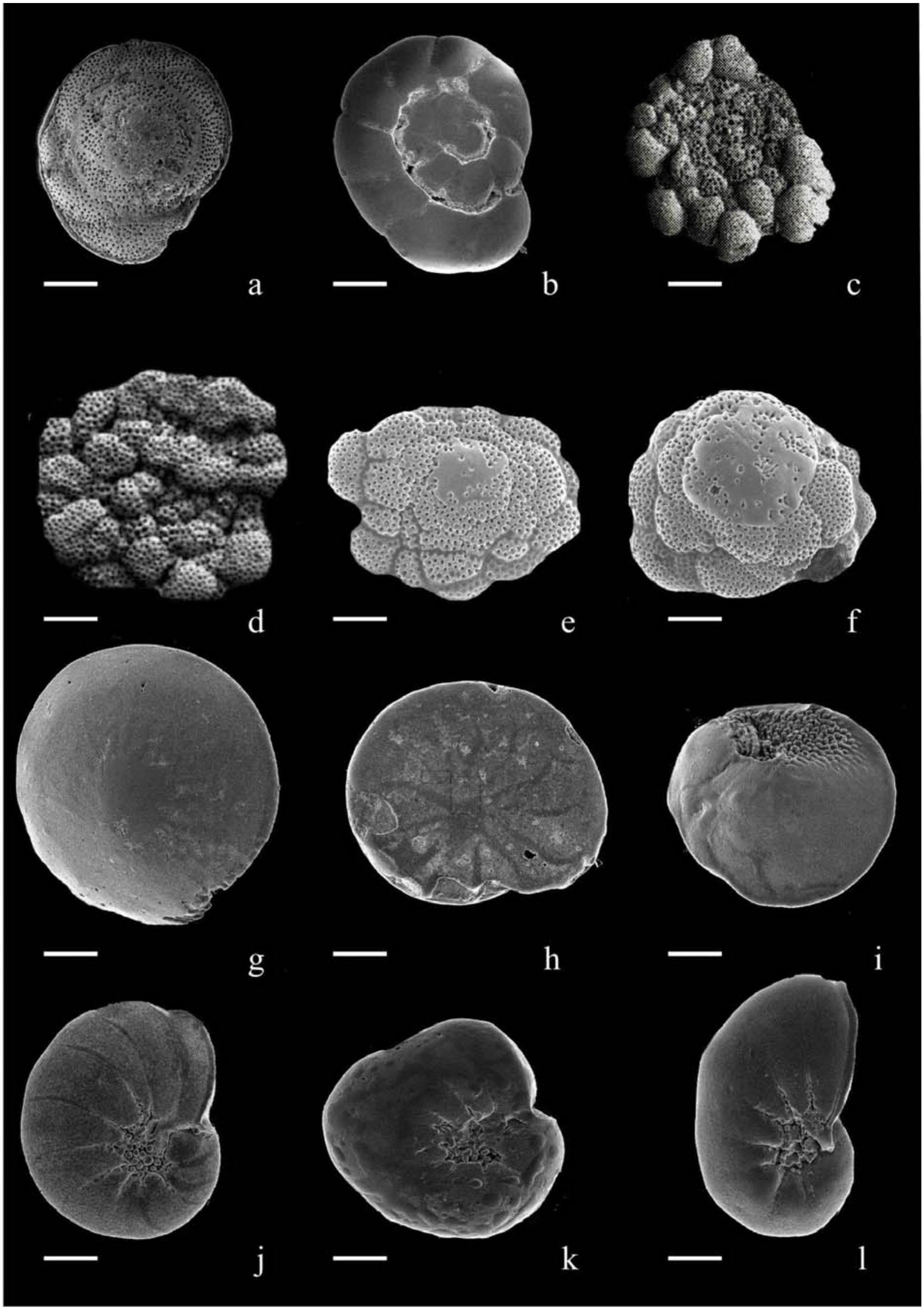

Image 9. a - *Cibicides* sp. (W12); b - *caribeanella polystoma* (W11); c - *Cymbaloporetta* bradyi (W9); d - *Cymabaloporetta squamosa* (W9); e - *Amphistegina madagascariensis* (W9); f - *Amphistegina radiate* (W2); g - *Amphistegina lesson* (W9); h - *Nonion scaphum* (W1); i - *Nonionella stella* 2 (W2); j - *Nonion asterizens* (W3); K - *Nonion boueanum* (W1); l - *Nonion elongatum* (W1). Scale 100µm

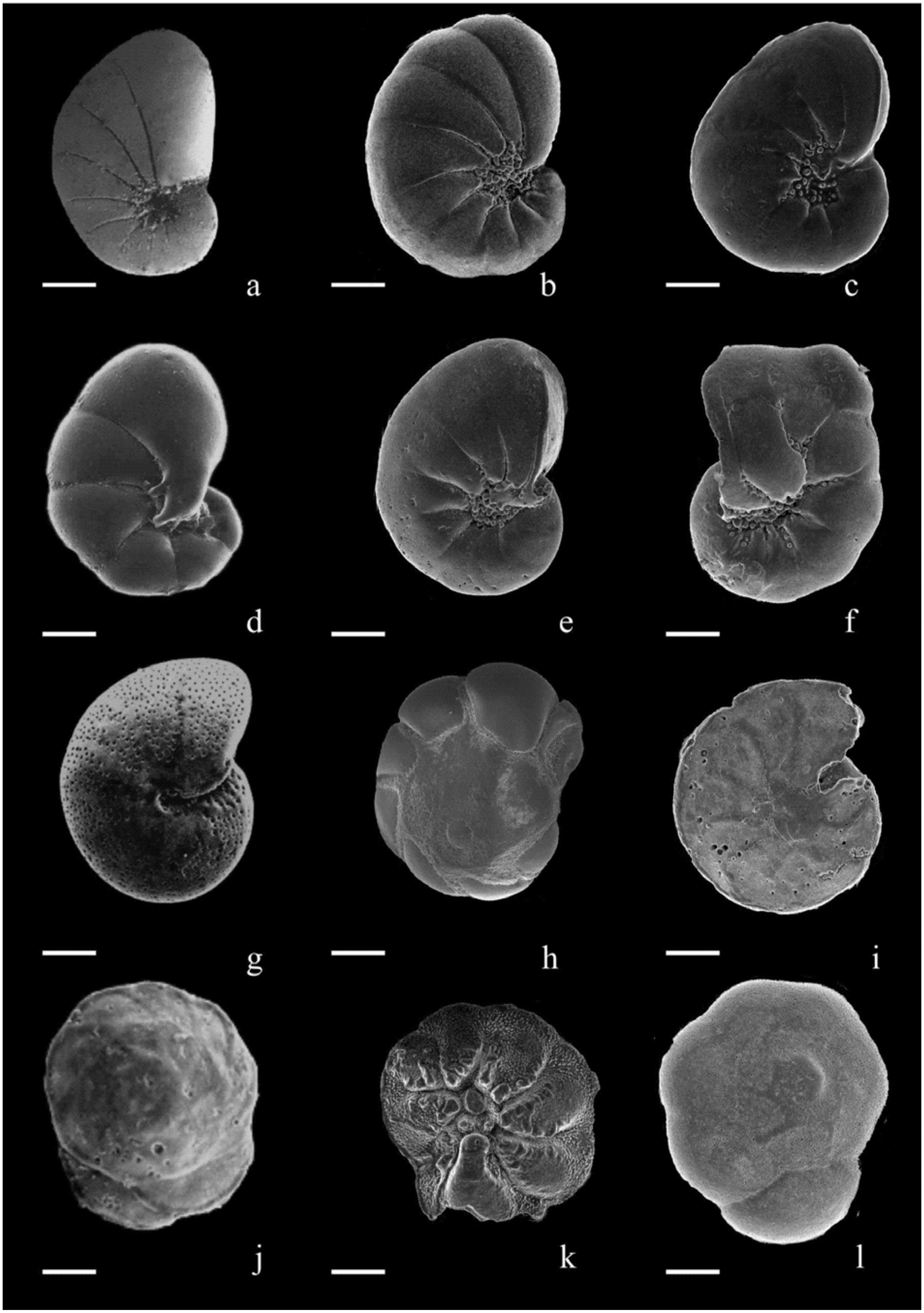

Image 10. a - *Nonion grateloupi*(W6); b. *Nonion incisum* (W7); c. *Nonionella monicana* (W7); d. *Nonionella opima* (W5); e. *Nonion scaphum* (W1); f. *Nonoella stella* (W2); g. *Melonis* sp. (E4); h. *Gyroidina neosoldani* (W11); i. *Hanzawaia concentric* (W10); j. *Bucella hannai* – dorsal (W8); k. *Bucella hannai* - ventral (W8); l. *Ammonia beccarii* (W1). Scale 100µm.

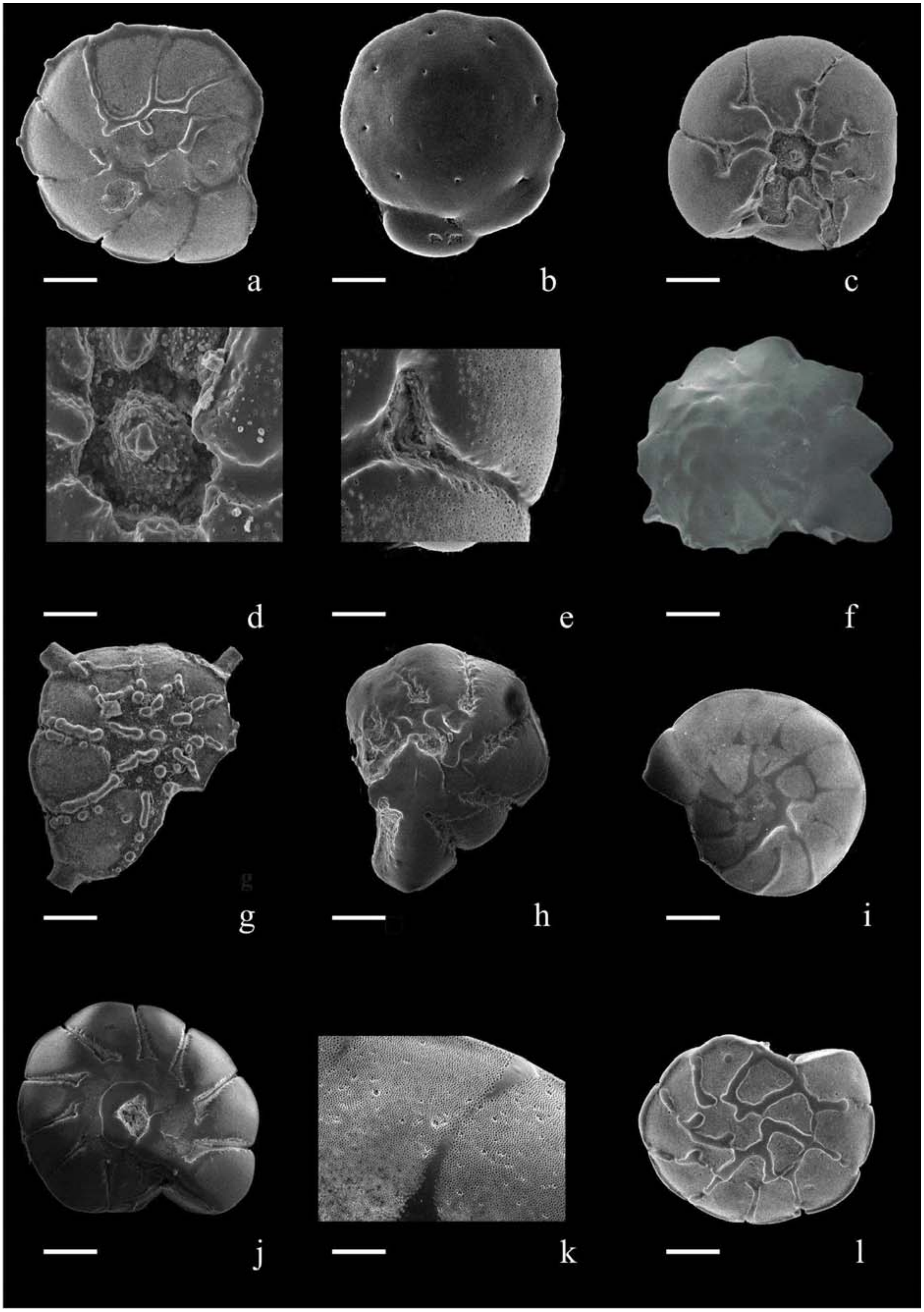

Image 11. a - *Ammonia dentate* (W1); b. *Ammonia tepida* – dorsal (W1); c. *Ammonia tepida* – ventral (W1); d. *Ammonia tepida* – umbilical plug (W1); e. *Ammonia tepida* – test with canal (W1); f. *Pararotalia calcar* (W3); g. *Aesterorotalia trispinos*-dorsal (E1); h. *Aesterorotalia trispinosa*-ventral (E1); i. *Rotalidium annectans* – dorsal (W1); j. *Rotalidium annectans* – ventral (W1); k. *Rotalidium annecatans* – enlarged tests with pores (W1); l. *Rotaidinoidespapillosus* – dorsal (W2). Scale 100µm.

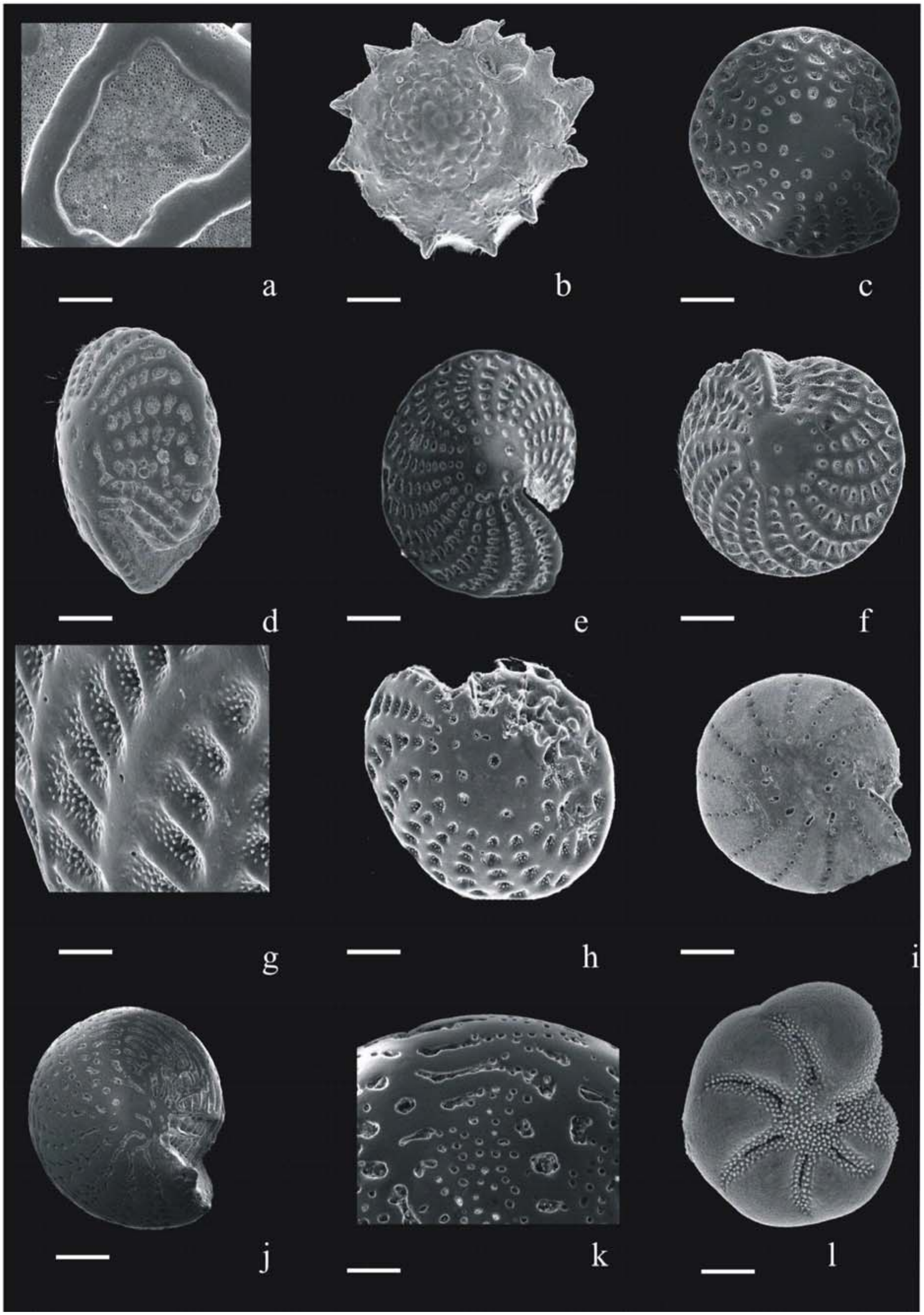

Image 12. a - *Rotalinoides papillosus* – enlarged test (W2); b - *Calcarina calcar* (W9); C - *Elphdium advenum*-dorsal (W2); D - *Elphdium advenum* – apertural view (W2); e - *Elphidium craticulatim* (W3); f - *Elphidium crispum*- dorsal (W1); g - *Elphidium crispum*-canal system (W1); h - *Elphidium discoidale* (W1); i - *Elphidium discoidale multiloculaturm* (E9); j - *Elphidium hispidulum* – dorsal (W1); k - *Elphidium hispidulum* – test with canals and pores (W1); l - *Elphidium incertum* (W12). Scale 100µm.

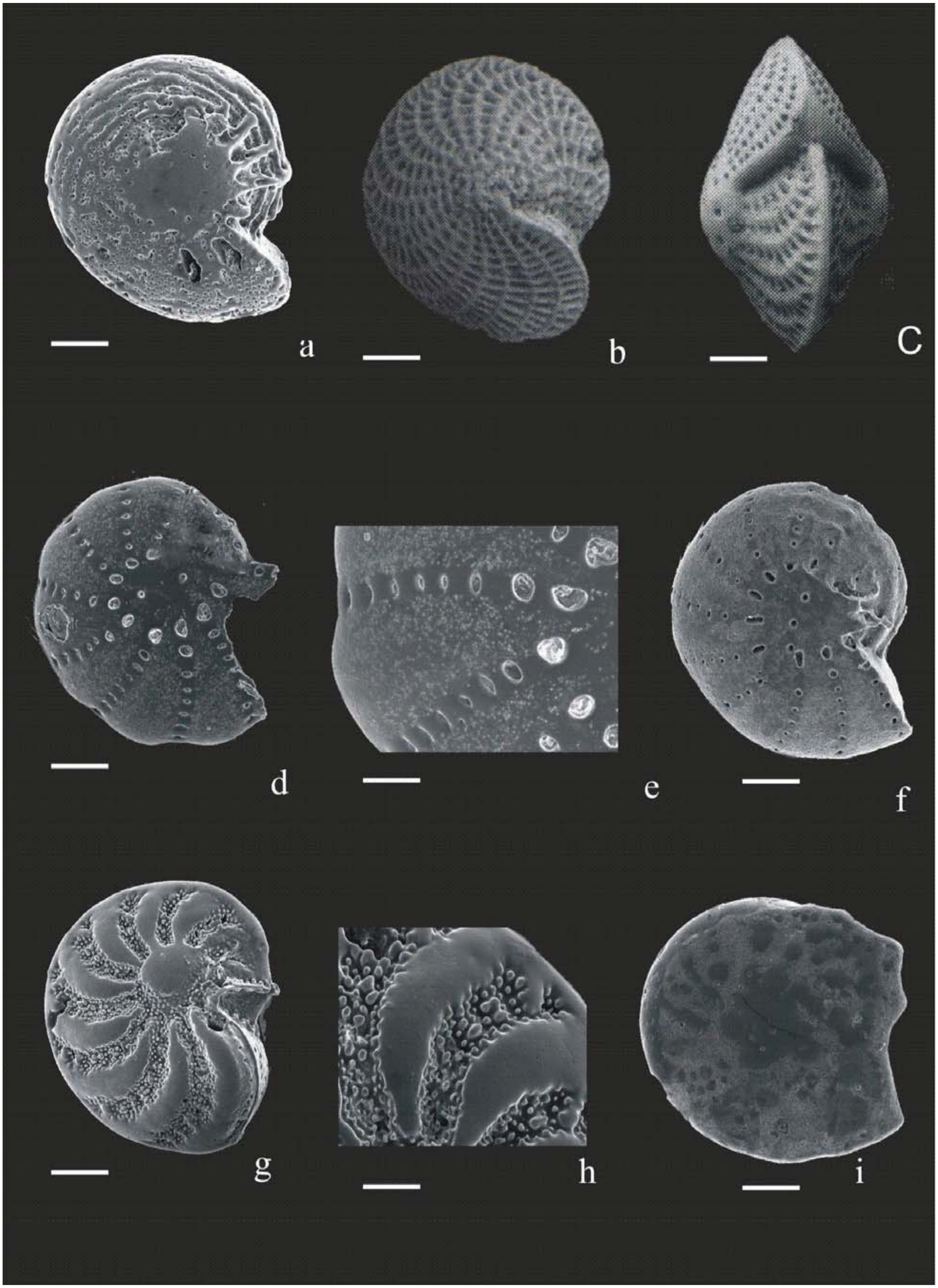

Image 13. a - *Elphidium jenseni* (W3); b - *Elphidium macellum* – dorsal view (W3); c - *Elphidium macellum* – apertural view (W3); d - *Elphidium indicum* (W2); e - *Elphidium indicum* – test with pores (W2); f - *Elphidium simplex* (W3); g - *Ozawaia* sp. – Apertural view (W6); h - *Ozawaia* sp. – Test with calcareous granules (W6); i - *Operculina ammonoides* (W5). Scale 100µm.

G. Anand, G. Nicolas, I. Akio, J. Fortunat, M.K. Robert, L. Keith, M.R. Ernst, M. Richard, M. Patric, M. Anne, G.N. Raymond, K.P. Gian, B.R. Keith, L.S. Christopher, L.S. Jorge, S. Reiner, D.S. Richard, J.T. Ian, F.W. Marie, Y. Yasuhiro & Y. Andrew (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437: 681-685.

Raj, R. & L.S. Chamyal (1998). Microfauna from a middle Holocene terrace lower Mahi Valley, western India. *Journal of Paleontological Society* 43: 59-71.

Rao, K.K., P. Sivadas, B. Narayanan, K.V. Jayalakshmy & M.K. Kutty (1987). Distribution of foraminifera in the lagoons of certain island of the Lakshadweep Archipelago, Arabian Sea. *Indian Journal of Marine* Science 16: 61-178.

Satyanarayana K., A.N. Reddy, B.C. Jaiprakash, L. Chidambaram, S. Srivastava & D.K. Bhattacharya (2007). A note on foraminifera, grain size clay mineralogy of Tsunami sediments from Karaikal-Nagore-Nagapatnam beaches, southeast coast of India. *Journal of Geological Society, India* 69: 70-74.

Saraswati, P.K. (2007). Symbiont-bearing benthic foraminifera of Lakshadweep. *Indian Journal of Marine Science* 36: 351-354.

Scott, D.B., F.S. Medioli & C.T. Schafer (2001). *Monitoring of Coastal Environments Using Foraminifera and Thecamoebian Indicators.* Cambridge University Press, 176pp.

Shareef, N.A. & V. Venkatachalapathy (1988). Foraminifera from shore sands of Bhatkal and Devgad Islands, west coast of India. *Journal of Geological Society of India* 31: 432-441.

Talib, A. & K.N. Gaur (2008). Foraminiferal composition and age of the Chari Formation, Jumara Dome, Kutch. *Current Science* 95: 367 - 373.

Todo, Y., H. Kitazato, J. Hashimoto & A.J. Gooday (2005). Simple foraminifera flourish at the ocean's deepest point. *Science* 307: 689.

Vickerman, K. (1992). The diversity and ecological significance of Protozoa. *Biodiversity and Conservation* 1: 334-341.

Walton, W.R. (1952). Techniques for recognition of living foraminifera. Contributions from the Cushman Foundation for Foraminiferal Research, 3: 56-60.

Weldeab, S., D.W. Lea, R.R. Schneider & N. Anderson (2007). 155000 years of West African monsoon and ocean thermal evolution. *Science* 316: 1303-1307.

Zachos, J.C., U. Rohl, S.A. Schellenberger, A. Sluijs, D.A. Hodell, D.C. Kelly, E. Thomas, M. Nicolo, I. Raffi, L.J. Lourens, H. McCarren & D. Kroon (2005). Rapid acidificaition of the ocean during the palaeocene-Eocene thermal maximum. *Science* 3008: 1611-1615.