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석사학위논문

우리 나라 제주도 근해의 유공충문에 관한 분류학적
연구

**Taxonomical study on the Phylum Foraminifera
from off Jeju Island, Korea**

김 상 진

한양대학교 대학원

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지도교수 이 원 철

이 논문을 이학 석사학위논문으로 제출합니다.

2013 년 8 월

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Abstract

Taxonomical study on the Phylum Foraminifera from off Jeju Island, Korea

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Phylum Foraminifera d'Orbigny, 1826 is one of the protozoan groups inhabiting either sea floor or water column. Benthic foraminiferans have a wide range of distribution, ranging from brackish to marine environment. Distribution of foraminifera is affected by various environmental factors, and they are useful indicators of modern and past environmental conditions. So far, Korean foraminiferal fauna has been poorly studied.

Foraminiferans were collected along the western south coast of Jeju Island with van Veen grab. In total, 20 species of foraminiferans were collected from the study area. Fifteen species were reported previously in ecological studies without taxonomical descriptions. Other five species are reported for the first time in Korea. The aim of this study is to taxonomically describe these five species. I have also recorded the highest diversity (16 species) at the St. 4, where foraminiferans were collected from muddy sediments.

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I. Introduction

Foraminifera d'Orbigny, 1826 are testate protozoans that live either on the sea floor or in the water column. The distribution of benthic foraminifera is very wide, ranging from brackish to marine environments. Most of the estimated 10,000 living species of forams live in the world's oceans. Of these, 40 - 50 species are planktonic, that is they float in the water. The remaining species live on the bottom of the ocean, on shells, rock and seaweeds or in the sand and mud of the bottom. In places, foraminifera are so abundant that the sediment on the bottom is mostly made up of their shells (Gupta 2002; Lana 2001).

Foraminiferans are found in all marine environments, from the intertidal to the deepest ocean trenches, and from the tropics to the poles, but species of foraminifera can be very particular about the environment where they live. Some are abundant only in the deep ocean, others are found only in brackish estuaries or salt marshes along the shore, and most live at certain depths and water temperatures in between (Gupta 1983).

Phylum foraminifera belongs to Kingdom Protist, form and composition of the test is the primary means by which forams are identified and classified (Adl *et al.* 2005). Foraminiferan shells, or tests, are built of hollow chambers separated by partitions, with small openings called foramina that connect the chambers (they get their name from these foramina). The final chamber (the last one added) has an opening or openings to the exterior, called the aperture. The living organism fills all the chambers in its shell except for one or two of the most recently constructed chambers. Most species build shells with multiple chambers (multilocular) but some species build shells with only a single

chamber (unilocular). Each of the major groups of foraminifera uses different materials to build their shells (Haynes 1981). The basic types of wall structures are:

Agglutinated - test made of particles cemented together. Some species use whatever particles are available, while other species may select only sponge spicules or mica flakes or a certain size particle to build their test.

Calcareous hyaline - interlocking crystals of calcite about 1 micrometer in diameter.

Microgranular - equidimensional, subspherical particles of calcite closely packed together without cement.

Porcellaneous - wall made of apparently randomly arranged microscopic rods of calcite, with ordered inner and outer surface layers (University of California Museum of Paleontology 2013).

According to Gupta (2003), compared to other marine species, foraminifera are known for their large amount of fossil records. Other species tend to catch many taxonomists attention by their ample diversity or population size. In Modern Ocean, foraminifera are the most diverse group of shelled microorganism. In 1987, 878 modern genera were defined by Loblich and Tappan. And presently, living foraminifera are there present species almost 10,000 (Vickerman 1992). in the kingdom Protista, foraminiferans are 20% of the estimated number that is total of modern species (Hammond *et al.* 1995).

Foraminiferan fauna is remarkably different on different sediments. It reflects physical transport and ecological processes. The primary component which affects the distribution of living foraminiferans is environmental factors (i.e., temperature, salinity, pH, depth, light, dissolved oxygen and food source) (Phleger 1960; Murray 1973 and 1991; Boltovskoy and Wright 1976; Woo *et al.* 1998). The physical transport processes

secondarily control the distribution of foraminifers. The physical transport processes affecting foraminiferal distribution are wave, current, tide and grain size. Culver and Banner (1978) shown that the distribution of foraminifera can be related to grain-size because both distributions are affected by the waves, currents and tides.

They are also useful indicators of marine ecology for modern and ancient environmental conditions because the distribution of foraminifera is affected by a variety of interrelated ecological conditions. Recently, the ecological studies of foraminiferans have improved to their value as using indicators for paleoenvironmental studies (Phleger 1960; Murray 1973 and 1991; Boltovskoy and Wright 1976).

The living benthic foraminifera are largely classified depending on their composition and types of test wall into rotaliid, miliolid and textulariid. The Rotaliida group has the calcareous and perforate test wall and the Miliolida group has the calcareous, porcelaneous and imperforate wall in post-embryonic stage. The textulariida group shows the agglutinated test composed of foreign matter held by various cements (Gupta 2002).

Quantitative studies of foraminiferans from the west coast of Korea were conducted at Gyeonggi Bay (Chang and Lee 1982 and 1983), Asan Bay (Chang 1983 and 1984; Chang and Lee 1984) and Gomso Bay (Woo *et al.* 1995). These studies showed the correlations between foraminiferal distributions and ecological factors (or geological characters). The modern tidal flats of the west coast of Korea have different environmental conditions including sand flat, intertidal sand shore, tidal channel, mixed flat and muddy flat. The variety environments have different physical, geological, biological and chemical factors; these different factors may control and distinctively produce foraminiferal populations and assemblages.

According to Korea Ocean Research and Development Institute (2001), there are approximately 2,000 benthic species living around Jeju Island, however, this result includes only macrobenthos and algae. Up to day, studies of living animals of Jeju Island waters were mainly focused on macrobenthos, deeming it difficult to find studies of meiobenthos. Data on meiobenthos of Jeju Island is missing. Therefore, taxonomical studies of foraminifera of Jeju Island and Ieo Island is missing.

The study area of this thesis is waters off Jeju and Ieo Islands (Table 1, Figure 1). These two bodies of water are normally influenced by Tsushima warm currents. However, aside from Tsushima warm currents; there have been records of it being influenced by variety of different water masses such as Yellow sea cold water, coastal sea of Korea and Mainland China Coast. The multiple sources of influence possibly increase the amount of biodiversity. The sediment characters of the ocean floor are also very diverse, made up of mud, sand, muddy sand and rock. This creates condition for living to meiobenthos and create ecosystem rich in biodiversity (Korea Ocean Research and Development Institute 2001).

My study is the starting point for taxonomical studies of foraminifera in Korea.

II. Materials and methods

Sampling of foraminifera at Jeju Island and Ieo Island took place on August and November of 2011 and February of 2012 to each represent three seasons (Table 2). Sampling took place at total of 5 sites, and using the obtained sediment samples foraminiferal species was further extracted. Lastly, these samples were identified to species level.

Samples were taken from 5 sites using van Veen grab with internal area size of 0.1 m² on the coast of Jeju Island and Ieo Island. Sub-sampling took place using the samples collected from van Veen grab using acrylic corer with internal area of 10 cm². Later, these collected samples were fixed using 70% ethanol and mixed with Rose bengal solution for staining (Walton 1952).

Analysis of foraminifera was carried out firstly by taking the dyed samples of foraminifera and filtering by putting them through 63 μ m sieve and running water to completely remove mud from the sample. Soap-floated method (Howe 1941) was used to separate foraminifera and sand. Extracted samples were then dried in the oven at 45-60°C. Dried samples were analyzed using stereo microscope (Olympus SZX21). Using standard brush samples were picked. Picked samples were later collected in groups according to specific species to be further compared to be identified using references (Cheong 1991; Loeblich and Tappan 1987).

Some specimens were prepared for Scanning Electron Microscope (SEM) by conventional methods. Dried specimens were mounted on stub and coated with platinum, using a sputter coater to a thickness of 15-30nm. The coated specimens were examined and photographed with Hitachi S3400 and S4700 scanning electron microscope. I

measured foraminiferans body size (length, width, thickness and detail of aperture) using Axio Vision Rel 4.8 software. Foraminiferal body sizes were measured on the SEM images; length was measured maximum diameter in umbilical view; width was measured minimum diameter in umbilical view; thickness was measured width in side view; aperture diameter and aperture tooth place were measured in aperture view (Figure 2).

III. Results

In total, five orders, 14 families, 17 genera, and 20 species are described in this study. The list is as following:

Order Rotaliida (seven families, eight genera, ten species);

Ammonia compressiuscula Brady, 1884

Noion commune (Asano, 1938)

Cancris auriculus (Fichtel & Moll, 1798)

Cibicides refulgens de Montfort, 1808

Cibicides robustus Phleger & Parker, 1951

Elphidium advenum (Cushman, 1922)

Elphidium macellum (Fichtel & Moll, 1798)

Cibicidoides subhaidingerii (Parr, 1950)

Anomalinoides glabratus (Cushman, 1924)

Hanzawaia nipponica Asano, 1944

Order Legeniida (three families, five genera, five species);

Laevidentalina sidebottomi (Cushman, 1933)

Lenticulina calcar (Linnaeus, 1767)

Saracenaria italic Defrance, 1824

Amphicoryna scalaris (Batsch, 1791)

Lagena sulcata (Walker & Jacob, 1798)

Order Milioida (two families, two genera, two species);

Quinqueloculina lamarckiana d'Orbigny, 1839

Spiroloculina communis Cushman & Todd, 1944

Order Bulminida (two families, two genera, two species);

Bolivina robusta Brady, 1881

Cassidella bradyi (Cushman, 1922)

Order Textularida (one family, one genus, one species);

Textularia agglutinans d'Orbigny, 1839

Five new record species is described in results. Other 15 species were included in appendix.

During this study, the diversity of foraminiferan is the highest (16 species) at the St. 4 (Table. 2). At the St. 4, the foraminiferans were collected from muddy sediments (Table 2).

Phylum Foraminifera d'Orbigny, 1826

Class Polythalamea Gross, 2001

Order Rotaliida Delage & herouard, 1896

Family Rotaliidae Ehrenberg, 1839

Genus *Ammonia* Brönnich, 1772

Species *Ammonia compressiuscula* Brady, 1884

Rotalia papillosa var. *compressiuscula* Brady, 1884. p. 708, pl. 107, fig. 1.

Ammonia compressiuscula, Wang *et al.*, 1985. p. 346, pl. 14, figs. 11, 12.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2b, 2c, 3b, 3c, 4a, 4b, 4c, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Five specimens kept on the stub for SEM.

Description. Length: 893.91 μm (n = 2); Aperture length: 91.53 μm (n = 2); Last chamber length: 246.74 μm (n = 1); Test large and robust, lenticular, trochospiral, about 3 to 4 slowly enlarging whorls, 10 to 14 chambers in final whorls, spiral side slightly less convex, sutures oblique and curved back at periphery, slightly depressed, with elevated poreless rims that later fuse to appear as beaded sutures, inflational beads or pustules progressively larger toward umbo, sutures radial, strongly incised and feathered on umbilical side because of alternating series of beadlike pustules along each edge, umbilical filled with inflational pillars, perforate extensions of chamber wall over spiral and sutural fissures form spiral canal and radial canals, with large apertures leading directly into umbilical canal system as well as at umbilical end of sutural fissure,

periphery with imperforate keel interrupted by sutural incisions of outer margin, wall calcareous, thick, finely perforate but sutures, pustules,, pillars, and keel imperforate.

Remark. These specimens differ from *Ammonia papillosa* Brady 1884, but the form of the test is lenticular instead of nearly globular shape of the latter. And it has very convex ventral side and raised, thickened sutures on dorsal view. The periphery shows sharply angular.

Distribution. North Atlantic Ocean, Mediterranean Sea, Jeju Island in Korea

Family Nonionidae Schultze, 1854

Genus *Nonion* De Montfort, 1808

Species *Nonion commune* (d'Orbigny, 1846)

Nautilus scapha n. sp. Fichtel and Moll, 1798. p. 105, pl. 19, figs d-f.

Nonionina communis 1846. d'Orbigny, p. 106, pl. 5, figs 7-8.

Nonion boueanum Marks, 1951. P. 48, PL. 5, figs. 17A, B.

Nonion boueanus Voloshinova, 1952. p. 18, pl. 1, figs 1-5.

Nonion commune Dieci, 1959. p. 53, pl. 4, fig. 25.; Rogl and Hansen, 1984. p. 66, pl. 24, figs 1-2.; Papp and Schmid, 1985. p. 45, pl. 34, figs 1-5.; Zlinska, 1997. p. 291, pl. 1, fig. 3.; Oblak, 2007. pp. 302-303, pl. 3, fig 1.

Nonion scaphum Rogl, 1969. p. 102, pl. 5, fig. 19.

Florilus boueanus Didlowski and Satanovskaja, 1970. p. 102, pl. 65, fig. 3.

Material Examined. The specimens were collected from St. 1b, 1c, 2a, 2b, 2c, 3a, 3b, 3c, 4c, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 799.25 μm (n = 2); Thickness: 415.79 μm (n=1); Test lamellar, flat, very low trochospiral, spiral side evolute and umbilical side involute. Peripheral outline subelliptical and smooth; peripheral margin broadly rounded. Chambers short, radially very rapidly increasing in size as added, 10 - 12 in adult coil, septal face with nearly parallel sides. Sutures very slightly curved, depressed, particularly so toward umbilical ends of umbilical side, cameral aperture Interiomarginal, equatorial, narrow arch, flanked (also in ultimate chamber) by two small, backwards directed plate-like ridges attached to

adjacent coil and running towards intercameral foramen, ridges separate cameral aperture from foliar anterior aperture on umbilical side and from a supplementary aperture along spiral suture, anterior and posterior foliar apertures remain open at least in most chambers of last coil, intercameral foramen arch-shaped, larger than aperture due to partial resorption at base of septal face, large pustules and conical pseudospines cover base of septal face obscuring aperture and present along foliar apertures and supplementary spiral ones, heavy ornamentation at border of folia obscures narrow umbilicus, wall optically granular, perforated by small pores larger on inside than on outside.

Remarks. This species is identical with *Nautilus scapha* described by Fichtel and Moll (1798). I accept the opinion of Papp and Schmid (1985) that the type of test with wavy outline that was often assigned to “*Nonion boueanum*” based on d’Orbigny (1846), is the ecological variation of *N. commune*.

This species is very similar to original species description by d’Obigny (1846). In most specimens’s test are almost round and circular; the suture are curved and recessed, the chambers are slender and long; last chamber shape looks like a dew in side view.

This species differs from *Nonionella japonica* (Asano, 1938) in having a less granular umbo and lobulate periphery. And also, it is different in having a broad and embracing final chamber and a acute periphery.

Distribution. North Atlantic Ocean, Mediterranean Sea, Grand Bank (Part of NorthAtlantic Ocean), Gulf of Mexico, Gulf of St. Lawrence (Part of North Atlantic Ocean), St. Lawrence Estuary (Quebec, Canada), New Caledonia, Jeju Island in Korea

Family Bagginidae Cushman, 1927

Genus *Cancris* de Montfort, 1808

Species *Cancris auriculus* (Fichtel & Moll, 1798)

Nautilus auriculus Fichtel and Moll, 1798. p. 108, pl. 20, figs. a - c.

Pulvinulina auricular Brady, 1884. p. 688, pl. 106, fig. 4

Cancris auriculus, Le Roy, 1944. p. 36, pl. 3, figs. 4- 9.

Material Examined. The specimens were collected from St. 3a, 3b, 3c, 4a, 4c, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Two specimens kept on the stub for SEM.

Description. Length: 483.58 μm (n = 1); Width (and last chamber): 332.23 μm (n = 1); Last chamber length: 433.43 μm (n = 1); Test trochospiral, compressed biconvex, elongate and auriculate in shape, spiral side evolute, umbilical side involute and more strongly inflated than spiral side, periphery acute with narrow carina, chambers rapidly increasing in size as added, sutures curved, slightly limbate on spiral side, aperture extraumbilical-umbilical with imperforate broad folium, wall lamellar, finely perforate except for imperforate, semicircular region of septal face, above folium, test elongate ovate to auriculate in outline, lenticular in section, periphery, angled to carinate, chambers increasing rapidly in breadth as added in flaring trochospiral coil, sutures depressed, arched on spiral side, nearly radial around open umbilicus on opposite side; wall calcareous, optically radial, perforate, but with imperforate area above aperture continuing into imperforate umbilical apertural flap, surface smooth other than peripheral keel; aperture low interiomarginal opening on umbilical side, with broad apertural flap that begins at base of imperforate area extending across opening to project umbilicus.

Remarks. This species is identical with *Nautilus auriculus* described by Fichtel and Moll (1798). These specimens were similar to original species by Fichtel and Moll (1798). This species is calcareous and finely and densely perforate except for the umbilical region. The biconvex test is auriculate in outline and lenticular in section. Chamber shapes are trochospirally enrolled and strongly increasing in breadth as added. Especially, the aperture is a low interiomarginal opening on the umbilical side and provided with a broad apertural flap. The test surface is smooth.

Distribution. North Atlantic Ocean, Mediterranean Sea, Bazaruto Archipelago (Part of Inhambane, Mozambique), Cape Hatteras (Part of North Carolina), Gulf of Mexico, Gulf of Cadiz (Spain), Florida Keys, Fowey (U.K.), Guam, New Caledonia, Jeju Island in Korea

Family Cibicididae Cushman, 1927

Genus *Cibicides* de Montfort, 1808

Species *Cibicides refulgens* de Montfort, 1808

Cibicides refulgens de Montfort, 1808. p. 23, 122.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2b, 3a, 3c, 4a, 4b, 4c, 5b, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 867.05 μm (n = 2); Width: 666.78 μm (n = 1); Last chamber length: 433.43 μm (n = 1); Test lamellar, trochospiral, plano-convex to slightly concavoconvex, evolute and flattened on spiral side, involute and convex on umbilical one, peripheral outline weakly lobulate in last chambers, peripheral margin acute with carina, 6 – 8 chambers in adult coil, sutures depressed, radial to slightly curved on umbilical side; on spiral side curved, broadly limbate and in last chambers slightly depressed, test coarsely perforated on spiral side, more finely on umbilical one, aperture interiomarginal, extraumbilical-equatorial with thick rim, extending into a supplementary spiral aperture with rim remaining open in last few chambers.

Remarks. According to Bhalla and Gaur (1987), *Cibicides refulgens* is a well-known and widely reported species of Genus *Cibicides*. It is rare in our material but my specimens are similar to the forms reported by de Montfort (1808). Test is very trochospiral on umbilical side and flattened on spiral side. The numbers of chambers are 6 to 8 and aperture can be observed on spiral view. The test has many pores.

Distribution. Admiralty Bay (Waitata, New Zealand), Bazaruto Archipelago (Part of Inhambane, Mozambique), Beaufort (South Carolina, U.S.A.), Biscayne Bay (Florida, U.S.A.), Gulf of Mexico, Mediterranean Sea, New Caledonia, New Zealand Exclusive Economic Zone, Scotian Shelf (Nova Scotia, U.S.A.), St. Lawrence Estuary (Quebec, Canada), Jeju Island in Korea

Species *Cibicides robustus* Phleger & Parker, 1951

Cibicides robustus Phleger and Parker, 1951. p. 31, pl. 17, figs. 1.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2b, 3a, 3c, 4a, 4b, 4c, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 538.21 μm (n = 1); Width: 468.64 μm (n = 1); Thickness: 203.69 μm (n = 1); Aperture length: 92.35 μm (n = 1); Aperture width: 21.47 μm (n = 1); Test large, biconvex, with about three and one-half whorls in adult, inner whorls of adult on evolute side covered with clear shell material forming thick, protuberant plug, surrounded by deep channel; periphery rounded; chambers distinct, thirteen in last-formed whorl; sutures slightly curved, limbate, raised on evolute side, flush with surface meeting near center in area of clear shell material on involute side; wall thick, smooth except at sutures; rather coarsely perforate; aperture peripheral extending over onto evolute side.

Remarks. Most specimens are similar to original species description (Phleger and Parker, 1951), and they have a regular form. A flat, spiral surface is the evidence of an attached life style. Aperture is large and spanning. Test shape has almost oval form and it is highly conical. Genus *Cibicides* was described by de Montfort (1808). According to Loblich and Tappan (1987), the type species is *Cibicides refulgens*. This species is characterized by a high conical and limbate suture on the flat side. Pore is irregular on the ventral surface. *Cibicides robustus* is similar to this species but suture is unclear and more indistinct than in *Cibicides refulgens* on the ventral side.

Distribution. Rabbit Key Basin (Gulf of Maxico, Florida, USA), Jeju Island in Korea

Family Elphidiidae Galloway, 1933

Genus *Elphidium* De Montfort, 1808

Species *Elphidium advenum* (Cushman, 1922)

Polystomella advena Cushman, 1922 p. 56, pl. 9, figs. 11, 12.

Elphidium advenum (Cushman), Cushman, 1930. 2S. pl. 10, figs. 1, 2.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3c, 4a, 4b, 4c, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 404.39 μm (n = 2); Width: 329.14 μm (n = 2); Thickness: 158.52 μm (n = 1); Test lamellar, planispiral involute, biumbonate and lenticular in profile view, peripheral outline subcircular, smooth to very slightly lobulate in last chambers, peripheral margin angular with blunt carina, slightly inflated and gently curved backwards, with relatively long folia, 12 - 14 ponticuli containing retral processes per chamber, their length about 1/3 of that of the chamber, very thick keel, sutures depressed, forming intraseptal interocular spaces bridged by ponticuli, fossettes opening between ponticuli elliptical, very small parafofsettes observed occasionally in last chamber, cameral aperture multiple, row of interiomarginal, relatively large rounded openings, preserved as such converted into intercameral foramina, test finely perforated and ornamented by numerous small pustules around apertures, at margins of fossettes and at margin of prominent umbilical plug.

Remarks. This variety differs from the typical form in the umbilical and apertural region. The umbilical region of this species is depressed and has no definite boss, and the peripheral margin is more lobulate and sharper than origin species by Cushman (1930).

Distribution Beaufort (South Carolina, U.S.A.), Biscayne Bay (Florida, U.S.A.), Buttonwood Sound (Florida U.S.A.), Buzzards Bay (Bourne U.S.A.), Cape Hatteras (North Carolina, U.S.A.), Coupon Bight (Florida, U.S.A.), Florida Bay, Guam, Gulf of Mexico, Long Island Sound (New York, U.S.A.), Marthas Vineyard (Massachusetts, U.S.A.), Massachusetts Continental Shelf, Mediterranean Sea, Mid-Atlantic Bight, Moloasses Reef (Bahamas), Nantucket Sound (Massachusetts, U.S.A.), New Caledonia, Rabbit Key Basin (Gulf of Mexico, Florida, USA), Scotian Shelf, South Florida Keys, Southampton (U.S.A.), Southeast U.S. Continental Shelf, Jeju Island in Korea.

Species *Elphidium crispum* (Linnaeus, 1758)

Nautilus crispus Linnaeus, 1758 p. 709.

Elphidium crispum (Linne) Hatta & Ujiie, 1992 p. 203, pl. 49, fig. 5; Loeblich & Tappan, 1994 p. 167, pl. 378, figs 4 – 6; Parker, 2009. p. 575, figs 406 a – h.

Material Examined. The specimens were collected from St. 2a, 2b, 2c, 4a, 4b, using van Veen grab (Table 1 and 2). Two specimens kept on the stub for SEM.

Description. Length: 402.02 μm (n = 2); Width: 424.48 μm (n = 2); Test lamellar, planispiral, involute, thick lenticular, nearly circular in side view, peripheral outline smooth to very slightly lobulate in last chambers, peripheral margin acute, provided with imperforate, blunt carina. 22 - 35 chambers in adult coil, chambers slightly inflated, short, nearly straight to weakly backward curved, very short, slightly anteriorly directed folium present with anterior and posterior foliar apertures, open in 1 - 2 last chambers, intraseptal, interocular space present communicating with exterior through elliptical fossettes between 20 – 22, ponticuli containing retral processes, many specimens ponticuli bifurcate to produce small parafossettes, epoxy casts show that retral processes become gradually thinner during ontogeny, cameral apertures and intercameral foramina multiple, interiomarginal rounded openings bordered by weak peristomalrims, test very finely perforated and covered adjacent to apertures and fossettes by small and numerous pustules and pseudospines, latter also projecting into fossettes, ponticuli may produce, through secondary lamination, fused elongated ridges nearly parallel with periphery, large imperforate, canaliculate umbilical plug characteristic.

Remarks. My materials differ from *Elphidium crispum* as presently understood by comparison with the type-figure given by Linne (1788) by smaller size, less chambers per coil, fewer ponticuli and fossettes, as well as by greater test thickness.

Distribution. Florida Bay, Guam, Gulf of Mexico, Indo-Pacific, Maldives, Mediterranean Sea, Moloasses Reef (Bahamas), New Caledonia, New Zealand Exclusive Economic Zone, North East Atlantic, Wimereux (France), Jeju Island in Korea

Family Parrelloididae Hofker, 1956

Genus *Cibicidoides* Thalmann, 1939

Species *Cibicidoides subhaidingerii* (Parr, 1950)

Truncatulina haidingerii Brady, 1884. p. 663, pl. 95, fig. 7.

Cibicides subhaidingerii Parr, 1950. p. 364, pl. 15, fig. 7.

Cibicidoides yoitaensis Matsunaga, 1963. p. 117, pl. 52, figs 3a-c.

Cibicidoides subhaidingerii van Morkhoven *et al.*, 1986. p. 95, pl. 28; Jones, 1994. p. 99, pl. 94, fig. 7; Robertson, 1998. p. 208, pl. 81, fig. 4.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2b, 3a, 3c, 4a, 4b, 4c, 5a, 5c, using van Veen grab (Table 1 and 2). Four specimens kept on the stub for SEM.

Description. Length: 908.02 μm (n = 2); Width: 886.95 μm (n = 2); Thickness: 459.77 μm (n = 1); Aperture length: 165.41 μm (n = 1); Aperture width: 29.92 μm (n = 1); Test low trochospire, unequally biconvex, more convex on evolute spiral side than on involute umbilical side, umbilical area may be slightly depressed, with or without small knob, peripheral outline smooth, peripheral margin acute with carina, 7 - 13 chambers in adult coil, cameral sutures limbate on both sides, on umbilical side radial to slightly curved, on spiral side curved, and depressed in last chambers, spiral suture strongly limbate, coarsely and uniformly perforated on both sides, wall optically granular, built of very irregularly arranged calcite platelets, chamber walls calcareous, thick, and coarsely perforate on both sides of test; aperture interiomarginal, primary aperture narrow equatorial slit bordered by thin lip and extends onto spiral side, extraumbilical-equatorial with thick rim, extending along spiral suture and remaining open in last chamber only.

Remarks. *Cibicidoides subhaidingerii* Parr (1950) was belongs to Genus *Cibicides*. This Genus *Cibicidoides* is very similar to *Cibicides*. Chambers shapes are almost same morphology on umbilical side. But *Cibicidoides* is lenticular and unflatted on spiral side. This species differs from *Cibicides refulgens* in larger size of the test, bluntly rounded periphery, less convex ventral side and unflatted on spiral side.

Distribution. New Caledonia, New Zealand Exclusive Economic Zone, Sahul Shelf (Timor Sea, Australia), Jeju Island in Korea

Family Gavelinellidae Hofker, 1956

Genus *Anomalinoides* Brotzen, 1942

Species *Anomalinoides glabratus* (Cushman, 1924)

Anomalina glabrata Cushman, 1924. p. 39, pl. 12, figs 5-7.

Anomalina glabrata Graham and Militante, 1959. p. 115, pl. 19, fig. 8.

Anomalinulla glabrata Saidova, 1975. pl. 76, fig. 8.

Material Examined. The specimens were collected from St. 1a, 1c, 4a, 4b, 4c, 5a, using van Veen grab (Table 1 and 2). Two specimens kept on the stub for SEM.

Description. Length: 585.36 μm (n = 1); Width: 498.55 μm (n = 1); Test low trochospiral, circular, lobulate, periphery broadly rounded, especially in last part of the whorl, spiral side convex with slightly depressed central part, last whorl broad with 7-10 inflated chambers, enlarging rapidly as added, earlier whorls small and slightly visible in the middle of the depressed part, often covered with thickened shell material, sutures oblique, arcuate, opposite side involute, umbilicate, few last chambers strongly inflated, triangular, sutures radial, wall thin, transparent, smooth, densely perforated, especially on spiral side, umbilical side with earlier part more sparsely perforated or nearly devoid of pores, granular in structure, aperture peripheral, large, semicircular, with slightly thickened lip, extending onto spiral side, shape circular, lobulate, periphery rounded, central part of spiral side often depressed, chambers of last whorl enlarging rapidly as added, few last chambers inflated

Remarks. This species was originally described by Cushman (1924) from Samoa. It was

characterized by it was nearly planispiral coiling, evolute spiral on umbilical side and involute spiral with a deep, open umbilicus on spiral side. Also, finely punctate specimens with a rounded periphery and a small apertural lip on the involute side are very similar to this species.

Distribution. New Caledonia, New Zealand Exclusive Economic Zone, Jeju Island in Korea

Genus *Hanzawaia* Asano, 1944

Species *Hanzawaia nipponica* Asano, 1944

Hanzawaia nipponica Asano, 1944. p. 99, pl. 4, figs. 1 - 2b; Chiji & Lopez, 1968. p. 107, pl. 15, figs. 14 a, b; Matoba, 1970. p. 55, pl. 8, figs. 10 a - c.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3c, 4a, 4b, 4c, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Two specimens kept on the stub for SEM.

Description. Length: 667.05 μm (n = 3); Thickness: 167.39 μm (n = 2); Aperture width: 45.9 μm (n = 2); Test lamellar very low trochospiral, spiral side slightly convex, advolute, umbilical side involute and flat, peripheral margin subangular, imperforate; peripheral outline smooth to slightly lobulated in last chambers, chambers narrow, each provided with short folium, slowly increasing in size as added, about 12- 14 in adult coil, sutures curved on both sides, limbate and slightly raised except in last chambers depressed, cameral aperture and intercameral foramen low, interiomarginal, equatorial slit provided with rim continuing into an antero-umbilical foliar aperture, foliar apertures remain open in most of chambers of ultimate coil, coarsely and densely perforated, limbing of sutures on both sides leads to pores being covered in early chambers except along their anterior portion, wall optically granular, distinct, small umbilical knob mostly present, secondary lamination covering earlier coils on spiral side forms small, slightly protruding, imperforate central boss.

Remarks. This planoconvex species was first described by Asano (1944). The characters

of *Hanzawaia* are the strongly curved, limbate and raised septal sutures. The aperture of the present materials was shown a short slit at base of last chamber and a prominent apertural lip. These specimens are large and show a well developed supplementary lobes.

Distribution. West Pacific Ocean, Jeju Island in Korea

Order Miliolida Delage & herouard, 1896

Family Hauerinidae Schwager, 1876

Genus *Quinqueloculina* d'Orbigny, 1826

Species *Quinqueloculina lamarckiana* d'Orbigny, 1839

Quinqueloculina lamarckiana d'Orbigny, 1839. p. 189, pl. 11, figs. 14, 15; Todd and Bronnimann, 1957. p. 27. pl. 3. fig. 12; Wang *et al.*, 1988. p. 127. pl. 13. figs. 10 - 12.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2a, 2b, 2c, 3c, 4a, 4b, 4c, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Three spceimens kept on the stub for SEM.

Description. Length: 803.96 μm (n = 3); Aperture length: 122.05 μm (n = 2); Aperture width: 69.28 μm (n = 2); Apertural Tooth place: 67.45 μm (n = 2); Test porcelaneous, broadly lenticular in lateral view, lenticular in peripheral view and subtriangular in end view, chambers subtriangular in section, arranged in quinqueloculine manner. chamber periphery acute and provided with prominent, thin carina, strongly embracing, 5 chambers (sometimes only carina of earlier chambers in coil) visible from exterior, aperture terminal, rounded-oval, with slightly everted collarlike peristomal lip (but no neck) and provided with distally protruding bifid tooth with long base, Y -shaped tooth with short or long branches with peristomal margin, test surface covered with fine, longitudinal, anastomosing microstriae.

Distribution. *Quinqueloculina lamarckiana* is very widely distributed species, was originally described by d'Orbigny (1839) from the recent sediments of West Indies region,

Caribbean. This species has the test triangular and sharply angled in transverse section and the slightly extended aperture with a simple tooth. My specimens show very large and oval test being a little longer than broad.

Distribution. Beaufort (South Carolina, U.S.A.), Biscayne Bay (Florida, U.S.A.), Buttonwood Sound (Florida U.S.A.), Canaveral Bight (Florida, U.S.A.), Cape Hatteras (North Carolina, U.S.A.), Coupon Bight (Florida, U.S.A.), Florida Bay, Florida Keys, Guam, Gulf of Mexico, Long Island Sound (New York, U.S.A.), Mason Inlet (North Carolina, U.S.A.), Mediterranean Sea, Mid-Atlantic Bight, Moloasses Reef (Bahamas), Pamlico Sound (North Carolina, U.S.A.), Rabbit Key Basin (Florida, U.S.A.), South Florida Keys, Southeast U.S. Continental Shelf, Jeju Island in Korea

Family Spiroloculinidae Wiesner, 1920

Genus *Spiroloculina* d'Orbigny, 1826

Species *Spiroloculina communis* Cushman and Todd, 1944

Spiroloculina communis Cushman and Todd, 1944. p. 63, pl. 9, fig. 4, 5, 7, 8.

Material Examined. The specimens were collected from St. 2a, 2c, 3a, 3b, 3c, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 858.92 μm (n = 2); Width: 418.53 μm (n = 2); Aperture diameter: 58.17 μm (n = 1); Apertural Tooth place: 21.54 μm (n = 1); Test porcelaneous, biloculine, evolute with about 8 chambers in adult, initial parts clearly seen, test flat, fusiform in lateral view, subrectangular in end view, moderately biconvex, chambers subquadratic in transverse section, truncated peripheral wall nearly straight to very slightly concave, separated from lateral walls by acute and carinated shoulders, chamber width and thickness increasing gradually, chamber carinae visible at sutures, test surface smooth, aperture subcircular, situated at end of elongated, slender neck, bordered by peristomal lip connected to carinae, and provided with distinctly bifid, scoop-shaped tooth with very short base.

Remarks. *Spiroloculina communis* is first described by Cushman and Todd, 1944 and it is characterized by strongly concave central part and the projecting chambers at the basal end extending into a long neck at the apertural end. My specimens have a circular aperture with a slightly flaring lip. And the origin species have a T-shape tooth plate but

unfortunately some of these t-shaped figured were broken in the specimens which I observed.

Distribution. Beaufort (South Carolina, U.S.A.), Biscayne Bay (Florida, U.S.A.), Buttonwood Sound (Florida U.S.A.), Canaveral Bight (Florida, U.S.A.), Cape Hatteras (North Carolina, U.S.A.), Coupon Bight (Florida, U.S.A.), Florida Bay, Florida Keys, Guam, Gulf of Mexico, Long Island Sound (New York, U.S.A.), Mason Inlet (North Carolina, U.S.A.), Mediterranean Sea, Mid-Atlantic Bight, Moloasses Reef (Bahamas), Pamlico Sound (North Carolina, U.S.A.), Rabbit Key Basin (Florida, U.S.A.), South Florida Keys, Southeast U.S. Continental Shelf, Jeju Island in Korea

Order Lagenida Delage & Hérourard, 1896

Family Nodosariidae Ehrenberg, 1838

Genus *Laevidentalina* Loeblich & Tappan, 1986

Species *Laevidentalina sidebottomi* (Cushman, 1933)

Dentalina sidebottomi Cushman, 1933. p. 12, pl. 3, fig. 4.

Laevidentalina sidebottomi Loeblich and Tappan, 1994. p. 65, pl. 113, fig. 13 – 19.

Material Examined. The specimens were collected from St. 2b, 4a, 4b, 4c, using van Veen grab (Table 1 and 2). Five specimens kept on the stub for SEM.

Description. Length: 1032 μm (n = 1); Width: 164.44 μm (n = 1); Aperture height: 58.17 μm (n = 1); Test elongated, very slightly tapering, not compressed, slightly curved test; chambers distinct, somewhat inflated, increasing in length as added, diameter nearly uniform, throughout; sutures distinct, slightly oblique, limbate, subcylindrical in cross-section with very wide chambers (five or more), becoming slightly elongated and inflated; last chamber tapers towards terminal, dorsal aperture while first chamber markedly rounded; sutures oblique and slightly depressed; wall translucent, smooth, very finely perforate; aperture radiate, terminal, at peripheral angle.

Remarks. This species was described by Cushman (1933), and it is characterized by elongate, slender test and the distinct suture. The last chamber is inflated and has the radiate aperture at the peripheral angle. The present specimens have the smooth wall and 5 chambers. They are almost same to the original description, with exception that in some collected specimens the first chamber is round and circular in shape.

Distribution. New Caledonia, New Zealand Exclusive Economic Zone (New Zealand),
Jeju Island in Korea

Family Vaginulinidae Reuss, 1860

Genus *Lenticulina* Lamarck, 1804

Species *Lenticulina calcar* (Linnaeus, 1767)

Nautilus calcar Linne, 1758. p. 709. figs. 3, 4

Cristella calcar Brady, 1884. p. 551. pl. 70, figs. 9-12.

Robulus calcar Asano, 1951. p. 2, fig. 5.

Lenticulina calcar Loeblich and Tappan, 1994. P. 68, pl. 5, figs 31-32.

Material Examined. The specimens were collected from St. 1b, 2b, 3a, 3c, 4a, 4c, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 873.74 μm (n = 2); Width: 771.11 μm (n = 2); Aperture height: 57.73 μm (n = 2); Test planispiral, enrolled, planispiral, symmetrical, involute, broadly lenticular, 7- 8 chambers gradually increasing in size, especially in radial 78 direction, in adult coil, sutures oblique, slightly curved backwards, large, but not protruding umbilical knobs present, small umbilical knobs and narrow, thick peripheral carina present, surface smooth, aperture terminal, radiate, composed of 8 bars meeting at elongated median ridge, accompanied by short slit bordered on either side by lip-like projections situated in subperipheral part of slightly concave distal face, border between latter and lateral wall subangular to rounded, radiate with small toothlike projections at its base accompanied by large Y-shaped opening apertural face, bordered by two large flaps.

Remarks. This species is characterized by the biconvex and umbonate test central, the distinct sutures, and the periphery with a narrow keel and a typically long spine

projecting from each chamber. Asano (1951) reported that this species occurs rarely in several samples.

Distribution. Cape Lookout (Ontario, Canada), East U.S. Continental Shelf, Georgia Shelf, Gulf of Mexico, Jacksonville Beach (Florida, U.S.A.), Massachusetts Continental Shelf, Mediterranean Sea, New Caledonia, New Zealand Exclusive Economic Zone, Rabbit Key Basin (Gulf of Mexico, Florida, USA), Southeast U.S. Continental Shelf, Jeju Island in Korea

Genus Saracenaria DeFrance, 1824

Species ***Saracenaria italica*** DeFrance, 1824

Material Examined. The specimens were collected from St. 2a, 2b, 3a, 4c, 5a, 5b, using van Veen grab (Table 1 and 2). One specimens kept on the stub for SEM.

Description. Length: 1002.42 μm (n = 1); Width: 325.91 μm (n = 1); Test elongate, small, trihedral, planospiral segments few, early portion close-coiled, later becoming uncoiled; periphery acute, keeled, chambers numerous, succeeding chambers five or six, arranged, in nearly straight superimposed series; dorsal margin sharp, noncarinate; transverse section triangular in cross sections, segments short, slightly oblique, inclined anteriorly toward initial end; sutures narrow, gently curved, not depressed; wall smooth; aperture slit at peripheral angle.

Remarks. The original description is based on *Saracenaria italica* is based on fossil species from Italy. The first extant specimens were described by Brady (1884) from 383 m off Fiji, Pacific Ocean. This species is in its shape and the relation between the test parts close to *Saracenaria pravoslavlevi* Fursenko and Polenova, differing from it by lacking a sharp transparent keel on the dorsal side and ventral margin of the test sides, by a somewhat thicker test wall and by the shape of the ventral surface. The absence of a keel and the shape of the test's transverse section bring this species close to *Saracenaria prolata* Kuznetsova 1962, from the Recent, but differences lie in the smaller test dimensions and larger number of coiled chambers in our species.

Distribution. Cape Lookout (Ontario, Canada), Gulf of Mexico, Jacksonville Beach (Florida, USA), Mediterranean Sea, Mid-Atlantic Bight, New Zealand Exclusive Economic Zone, Jeju Island in Korea

Genus *Amphicoryna* Schlumbergers, 1881

Species *Amphicoryna scalaris* (Batsch, 1791)

Nautilus (Orthoceras) scalaris Batsch, 1791. p. 1 – 4, pl. 2, fig. 4 a – b.

Nodosaria scalaris (Batsch) Brady, 1884. p. 510, pl. 63, fig. 28 – 31; Cushman, 1921. p. 199, pl. 35, fig. 6.

Amphicoryna scalaris (Batsch) Hatta & Ujiie, 1992. p. 166, pl. 21, fig. 8.

Material Examined. The specimens were collected from St. 4a, 4b, 4c, using van Veen grab (Table 1 and 2). Two specimens kept on the stub for SEM.

Description. Length: 718.95 μm (n = 2); Width: 260.51 μm (n = 2); Neck height: 151.3 μm (n = 2); Aperture diameter: 61.25 μm (n = 2); Aperture inner diameter: 20.03 μm (n = 2); Apertural Tooth place: 19.54 μm (n = 2); Test elongate, at base with apiculate spines, in megalospheric specimens proloculus followed by series of rectilinearly arranged, uniserial globular chambers, whereas in microspheric generation at first chambers arranged in astacolite coil; adult chambers of microspheric specimens arranged like in megalospheric specimens, shell shape of juvenile microspheric specimens triangular in section and have sharp angles (oblique sutures), all other chambers globular with numerous longitudinal costae and have straight depressed sutures, aperture terminal, radiate and produced on long neck, 3 - 5 ringlike concentric ridges present on neck.

Remarks. According to Batsch (1791), this species show that the surface of the chamber is smooth and the typical longitudinal costae are found all chambers. And it shows the

aperture having a distinct neck and lip with transvers costae instead of longitudinal ones.

Also, this species is rare in this study area.

Distribution. Guam, Gulf of Mexico, Mediterranean Sea, New Caledonia, New Zealand Exclusive Economic Zone, Rabbit Key Basin (Gulf of Mexico, Florida, USA), Jeju Island in Korea

Family Lagenidae Reuss, 1862

Genus *Lagena* Walker & Boys, 1784

Species ***Lagena sulcata*** (Walker & Jacob, 1798)

Serpula (Lagena) sulcata Walker and Jacob, 1798. p. 634.

Lagena sulcata Sliter, 1980. pl. 8, figs. 8-10.

Material Examined. The specimens were collected from St. 2a, 2c, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 507.68 μm (n = 1); Width: 259.44 μm (n = 1); Neck Length: 221.14 μm (n = 1); Chamber length: 286.25 μm (n = 1); Aperture diameter: 34.02 μm (n = 1); Aperture inner diameter: 21.39 μm (n = 1); Test unilocular, ovoid in shape, with elongated neck and aboral, hollow spinose projection, aperture round, at end of neck, surrounded by thick phialine lip from which several conical thickenings inward, test covered with fine longitudinal, sometimes anastomosing striae, which may extend with spiral twist over aboral hollow spinose projection and which may be connected to spirally arranged pseudospinose costae around apertural neck, wall distinctly perforated.

Remarks. My specimens were very similar to describing by Sliter (1980). This species have the basal end drawn out into a stout spine and the apertural end with a tapering cylindrical neck with a lip. And it has the distinct neck ornamented with ring-like costae.

Distribution. Buzzards Bay (Bourne U.S.A.), Canso Strait (Nova Scotia, Canada), Cape Lookout (Ontario, Canada), East U.S. Continental Shelf, Grand Banks, Gulf of Mexico,

Gulf of St. Lawrence (Part of North Atlantic Ocean), Mediterranean Sea, New Zealand
Exclusive Economic Zone, North East Atlantic, Northeast U.S. Continental Shelf, St.
Lawrence Estuary (Quebec, Canada), Jeju Island in Korea

Order Textulariida Delage & Hérourard, 1896

Family Textulariidae Ehrenberg, 1838

Genus *Textularia* Defrance, 1824

Species *Textularia agglutinans* d'Orbigny, 1839

Textularia agglutinans d'Orbigny, 1839. p. 144, pl. 1, figs. 17, 18, 32 – 34; Brady, 1884. pl. 43, fig. 1, 2; Said, 1949. p. 5, pl. 1, fig. 3; Le Calvez, 1977. p. 13 - 14, fig. 1; Banner and Pereira, 1981. p. 93, pl. 1. fig. 6 – 7.

Material Examined. The specimens were collected from St. 1a, 1b, 1c, 2a, 2c, 3a, 3c, 4b, 5a, 5b, 5c, using van Veen grab (Table 1 and 2). Three specimens kept on the stub for SEM.

Description. Length: 739.33 μm (n = 2); Width: 468.78 μm (n = 2); Test agglutinated, large, elongated, narrowly triangular in lateral and peripheral views, slightly compressed in earlier stages, periphery broadly rounded in adult; suboval to subcircular, often with peripherally compressed margins; about 20 chambers in adult, arranged biserially throughout (megalospheric specimens), more rapidly increasing in breadth in earlier stages and less so in later ones, thus leading to margins becoming nearly parallel as seen in lateral view; sutures distinct and depressed, nearly perpendicular to axis and very slightly curved; distal chamber wall more or less convex with rounded edges; aperture basal slit, often in slight recess; many specimens in adult stages distal wall adjacent to apertural extremities strongly infolded; chamber shape may become irregular in late stages.

Remarks. This species first described by d'Orbigny (1839). The species is characterized by the lateral fistulous projections on the early chambers and the projecting peripheral border on the later chambers. Some of specimens do not observed the projection due to the bad preservation.

Distribution. Bazaruto Archipelago, Cape Hatteras, Cape Lookout (Ontario, Canada), East U.S. Continental Shelf, Florida Keys, Fowey, Guam, Gulf of Mexico, Gulf of St. Lawrence (Part of North Atlantic Ocean), Mediterranean Sea, Moloasses Reef, New Caledonia, New Zealand Exclusive Economic Zone, Rabbit Key Basin, Southeast U.S. Continental Shelf, Jeju Island in Korea

Order Buliminida Calkins, 1909

Family Bolivinidae Glaessner, 1937

Genus *Bolivina* d'Orbigny, 1843

Species ***Bolivina robusta*** Brady, 1881

Bolivina robusta Brady, 1881. p. 57; Cushman, 1937. p. 131, pl. 17, fig. 1 – 3; Loeblich & Tappan, 1994. p. 111, pl. 215, figs. 17 – 18.

Material Examined. The specimens were collected from St. 3b, 4a, 4b, 4c, 5b, using van Veen grab (Table 1 and 2). Two specimens kept on the stub for SEM.

Description. Length: 414.95 μm (n = 2); Width: 240.8 μm (n = 2); Aperture length: 34.79 μm (n = 2); Aperture width: 18.48 μm (n = 2); Apertural Tooth place: 21.42 μm (n = 2); Test lamellar, biserial, compressed with rounded periphery, oval in end view, wedge-shaped in lateral view; rapidly increasing in width in early stages, with nearly parallel peripheral margins in adult, chambers gradually increasing in size, about 12 chambers in adult, provided with 3 - 4 basal lobes per chamber, sutures slightly curved, obscured by ornamentation, latter composed of prominent ribs and blade-like ridges forming reticulate pattern pores large, distinct in last chambers only, situated in depressions surrounded by polygonal ridges, aperture elliptical, extending from base of chamber with thick rim, toothplate with two serrated unequal tongues present, producing wide adaperatural depression bordered by distinct ridge-like margin.

Remarks. According to Belford (1966), two forms of this species were known, one with a distinct basal spine and the other without spine. Both forms are same in chamber shape,

outline, top view, type of toothplate, and the characteristic lobate appearance of the suture in external side. In my study, I observed just one form, without spine.

Distribution. East U.S. Continental Shelf, Guam, New Caledonia, New Zealand Exclusive Economic Zone, Jeju Island in Korea

Family Fursenkoinidae Loeblich & Tappan, 1961

Genus *Cassidella* Hofker, 1951

Species *Cassidella bradyi* (Cushman, 1922)

Virgulina bradyi Cushman, 1922. p. 104, pt. 3, p. 115, pl. 24, fig. 1.

Cassidella bradyi Jones, 1994. pl. 52, fig. 9.

Material Examined. The specimens were collected from St. 1a, 1b, 4a, 4b, 4c, using van Veen grab (Table 1 and 2). Two specimens kept on the stub for SEM.

Description. Length: 890.48 μm (n = 1); Width: 183.64 μm (n = 1); Aperture length: 86.95 μm (n = 1); Aperture width: 14.51 μm (n = 1); Test small, elongate, tapering on both ends, laterally compressed, elliptical in cross section, periphery broadly rounded, very faintly lobulated, chambers elongate, arranged biserially throughout but twisted around axis of coiling in early stages, about 4 pairs visible in adult, sutures very slightly depressed, strongly oblique and slightly curved, wall lamellar, optically granular, aperture elongate, slit to comma shaped, normal to basal suture and touching latter in early stages but separated from it in adult, simple, folded toothplate is present.

Remarks. My material is similar to the original description by Cushman (1922), the latter in having distinct tooth plate and more rounded early portion of the test. Also chambers size is almost the same on the entire body, but in the original description chambers get bigger and bigger. But It isn't important taxonomic key for species identification.

Distribution. East U.S. Continental Shelf (North Carolina, USA), New Zealand Exclusive Economic Zone, Jeju Island in Korea

IV. Discussion

Kang (2003) reported 159 benthic foraminiferal species from Korea. They were identified from off Seogwipo, a port in Jeju and 183 benthic foraminiferal species were identified from the Southern Yellow sea by Cheong (1991). However, the evidences supporting the description of taxonomical work are lacking. So, the taxonomical study is critically needed to revise 183 foraminiferal species reported by Cheong (1991). Few images provided by Cheong (1991) lack many important characters, such as aperture, keel (rim) or shape of surface. During my study, I found 20 species. Among them, 15 species were mentioned by Cheong (1991, 1992, 1994, and 1996) and Kang (2003), but these records are doubtful due to lack of descriptions. For example, *Elphidium advenum* and *Elphidium crispum* are characterized by thick keel. But Kang (2003) does not clearly mention thickness. And 5 species; *Nonion commune*, *Cibicides robustus*, *Laevidentalina sidebottomi*, *Saracenaria italic* and *Cassidella bradyi* are rarely reported species.

Ammonia compressiuscula Brady, 1884 was shown significant difference of body size. This results need to more study about seasonal variation and food web. The fall and winter seasons (November 2011, February 2012) specimens are larger than summer season (August 2011) specimens.

The species reported during this study are remarkable in regard of the sediment type. Station 4 had muddy sediments and showed the highest biodiversity. Foraminifera within the cores are correlated with sedimentary facies. Particle size and sorting of the sediment probably alter the depth of oxygen saturation, nutrient availability and chemical parameters of the sediments sampled. The lower energy facies (those dominated by silt and clay) exhibited very high numbers of live Foraminifera within the uppermost

centimeter which declined sharply with depth; this is in agreement with numerous other studies (Gooday 1986; Jorissen *et al.* 1994; Castignetti 1996). The gradual decline of living Foraminifera down the cores of sandy sediments may be associated with the greater availability of oxygen throughout these sediments due to increased permeabilities, although burial of Foraminifera in these relatively more dynamic environments may have occurred (Castignetti and Manley 1998).

Molecular works are also needed to complement the taxonomical results. It will definitely provide more precise conclusions. The study of genetic diversity (i.e.; genus *Ammonia*) shows that analysis of rDNA sequences was combined with morphological, ecological and biogeographical data delineates species boundaries and requires revision of morpho-taxonomic characters used for species identification. Similar studies of other cosmopolitan genera will contribute to a better understanding of the species concept in foraminifera and will help in the interpretation of their morphologic variability (Pawlowsky 2000).

In conclusion, there needs to be more taxonomical studies of foraminiferans, not only from Jeju Island, but around the world, in order to clarify taxonomic characters we use today, along with molecular data which could be of a great aid.

V. References

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Table 1. Sample locations.

Site No.	Latitude	Longitude	Date of Sampling	Depth (m)	Sediment type	Sediment Temp. (C°)	Collector
St. 1a	126.24	33.43	22 Aug. 2011	44	mud	18.4	Yoo, Hyunsu
St. 1b	126.24	33.43	26 Nov. 2011	41	mud	19.5	Kim, Gwangsu
St. 1c	126.24	33.43	11 Feb. 2012	70	mud	14.2	Kim, Sangjin
St. 2a	126.89	33.57	25 Aug. 2011	51	sand	16.2	Yoo, Hyunsu
St. 2b	126.89	33.57	22 Nov. 2011	58	sand	19.5	Kim, Gwangsu
St. 2c	126.89	33.57	9 Feb. 2012	55	sand	13.1	Kim, Sangjin
St. 3a	126.58	33.21	23 Aug. 2011	92	mud	20.3	Yoo, Hyunsu
St. 3b	126.58	33.21	25 Nov. 2011	93	mud	18.1	Kim, Gwangsu
St. 3c	126.58	33.21	8 Feb. 2012	65	mud	15.7	Kim, Sangjin
St. 4a	125.91	32.75	24 Aug. 2011	100	mud	11.8	Yoo, Hyunsu
St. 4b	125.91	32.75	25 Nov. 2011	99	mud	18.2	Kim, Gwangsu
St. 4c	125.91	32.75	11 Feb. 2012	118	mud	14.9	Kim, Sangjin
St. 5a	125.25	32.24	25 Aug. 2011	57	mud	13.6	Yoo, Hyunsu
St. 5b	125.25	32.24	25 Nov. 2011	57	mud	19.3	Kim, Gwangsu
St. 5c	125.25	32.24	6 Feb. 2012	60	mud	11.3	Kim, Sangjin

Table 2. New records of Foraminifera in study area.

	St. 1			St. 2			St. 3			St. 4			St. 5		
	St. 1a	St. 1b	St. 1c	St. 2a	St. 2b	St. 2c	St. 3a	St. 3b	St. 3c	St. 4a	St. 4b	St. 4c	St. 5a	St. 5b	St. 5c
<i>Ammonia compressuscula</i>	+	+	+		+	+		+	+	+	+	+	+	+	+
<i>Nonion commune</i>		+	+	+	+	+	+	+	+			+		+	+
<i>Canceris auriculus</i>							+	+	+	+		+	+	+	+
<i>Cibicides refulgens</i>	+	+	+		+		+		+	+	+	+		+	
<i>Cibicides robustus</i>	+	+	+		+		+		+	+	+	+	+	+	+
<i>Elphidium advenum</i>	+	+	+	+	+	+	+		+	+	+	+	+	+	+
<i>Elphidium macellum</i>				+	+	+				+	+				
<i>Cibicides subhaidergerii</i>	+	+	+		+		+		+	+	+	+	+		+
<i>Anomalinoides glabratus</i>	+		+						+	+	+	+	+		
<i>Hanzawaia nipponica</i>	+	+	+	+	+	+	+		+	+	+	+	+	+	+
<i>Quinqueloculina lamarekiana</i>	+	+	+	+	+	+			+	+		+			
<i>Spiroloculina communis</i>				+		+	+	+	+						
<i>Laevidentulina sidebottomi</i>					+					+	+	+			
<i>Lenticulina calcar</i>		+			+		+		+	+		+			
<i>Saracenaria italica</i>				+	+		+					+	+	+	
<i>Amphicoryna scalaris</i>										+	+	+			
<i>Lagena sulcata</i>				+		+					+				
<i>Textularia agglutinans</i>	+	+	+	+		+	+		+		+		+	+	+
<i>Bolivina robusta</i>								+		+	+	+		+	
<i>Cassidella bradyi</i>	+	+								+	+	+			
Number of species	10	11	10	9	12	9	11	5	12	15	13	16	9	10	8

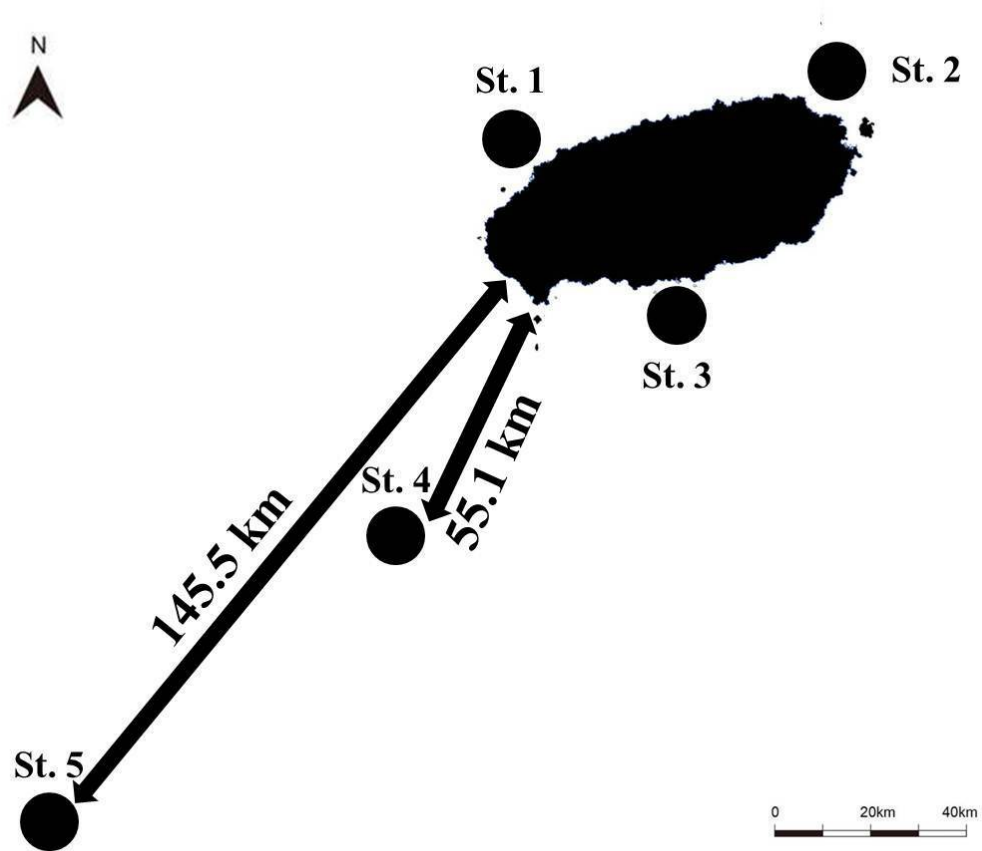


Figure 1. Sample location from Jeju Island.

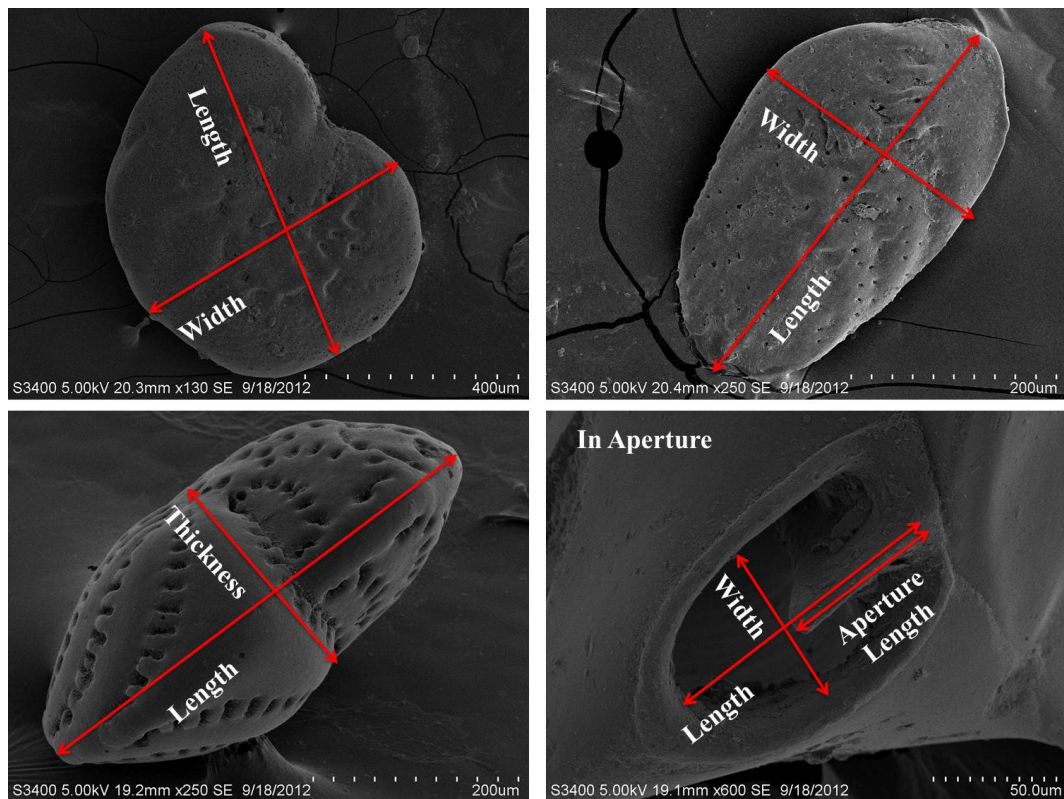


Figure 2. Standard measurments of foraminiferan body size.



Figure 3. *Ammonia compressiuscula* (A) umbilical view; (B), (C), (D) apertural view; (E) spiral view.

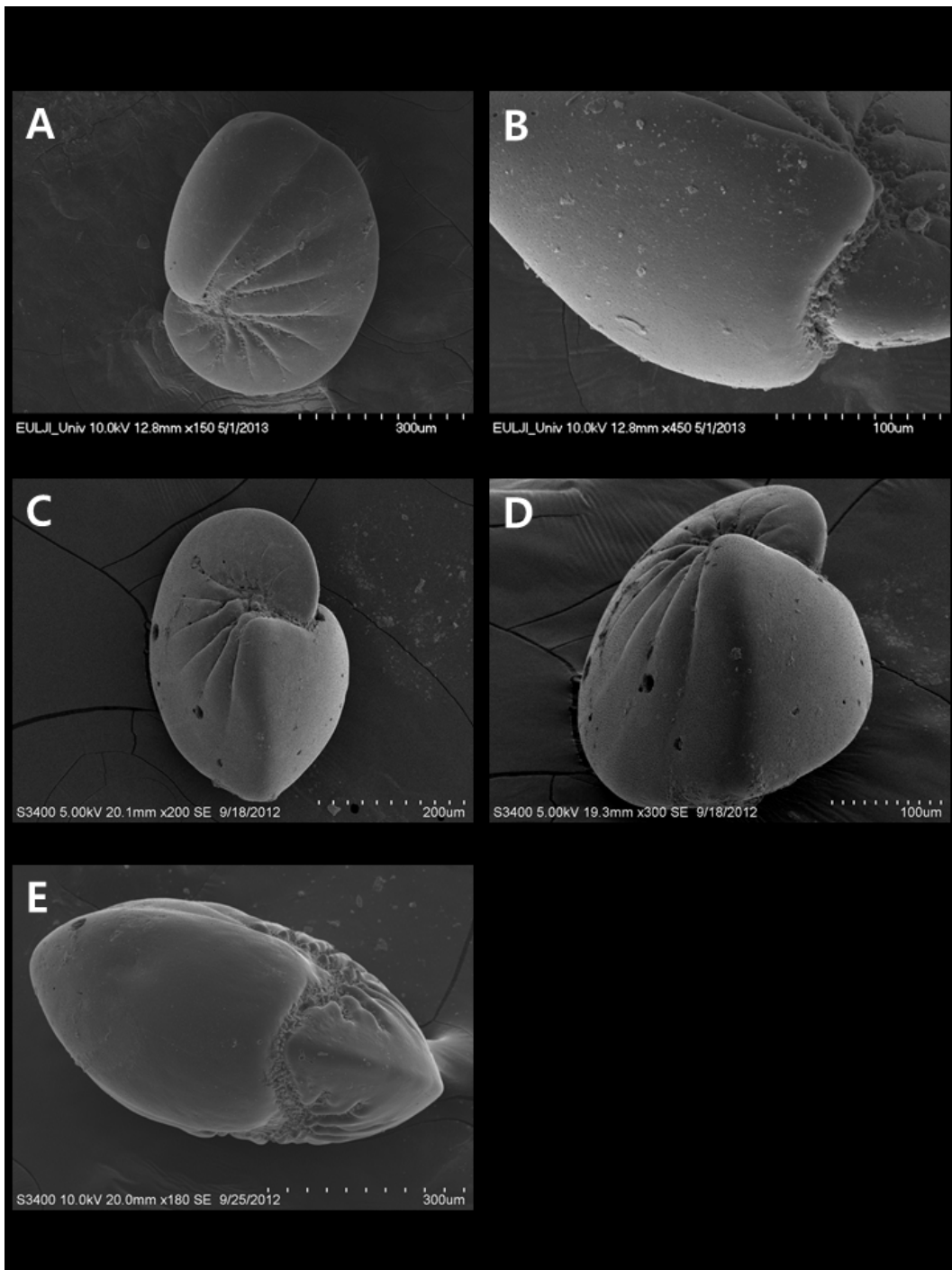


Figure 4. *Nonion commune* (A) umbilical view; (B), (E) apertural view; (C) spiral view; (D) Side view.

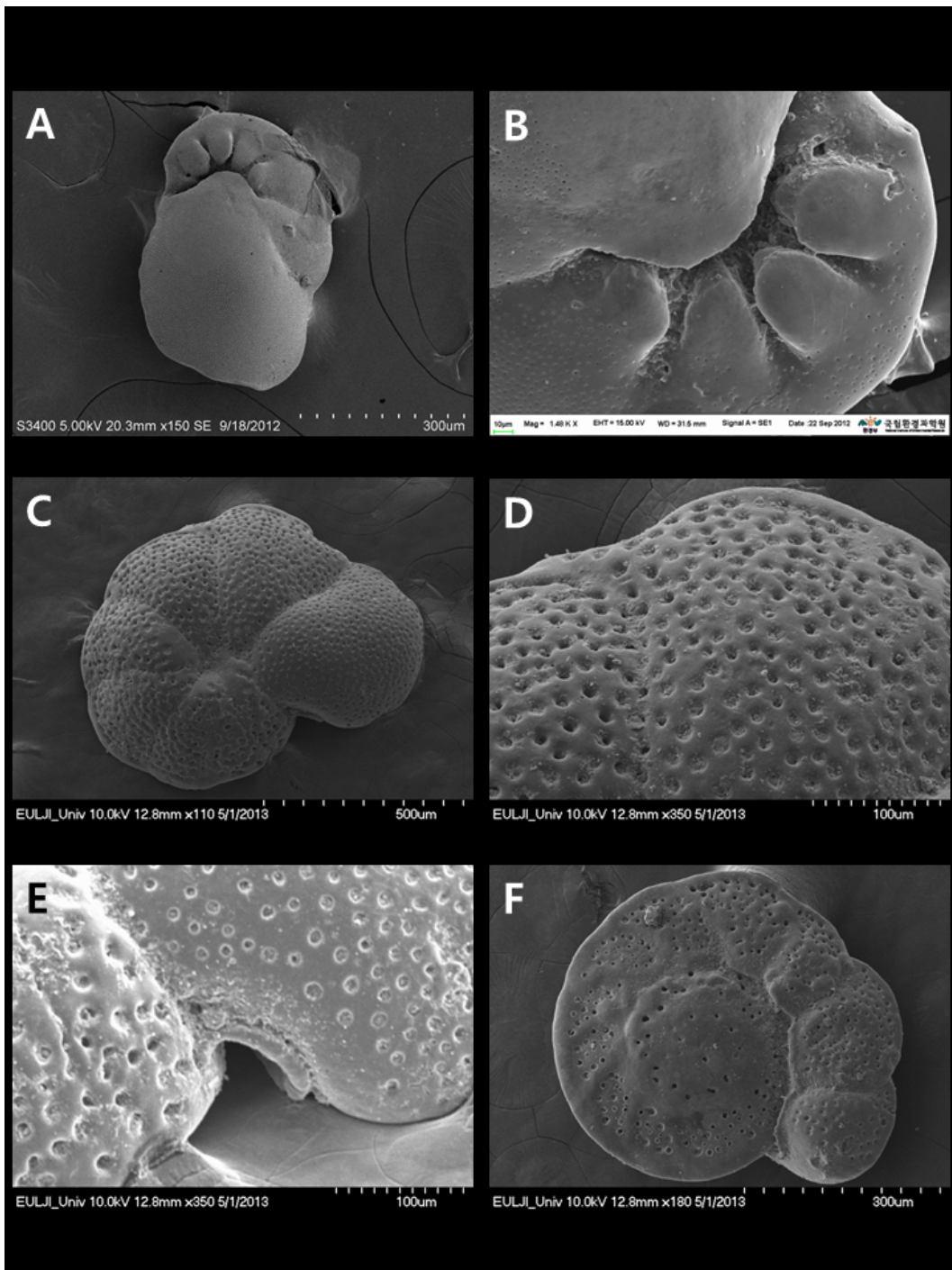


Figure 5. (A), (B): *Cancris auriculus* (A) umbilical view; (B) apertural view; (C), (D), (E), (F): *Cibicides refulgens* (C) umbilical view; (D) detail of surface; (E) apertural view; (F) spiral view.

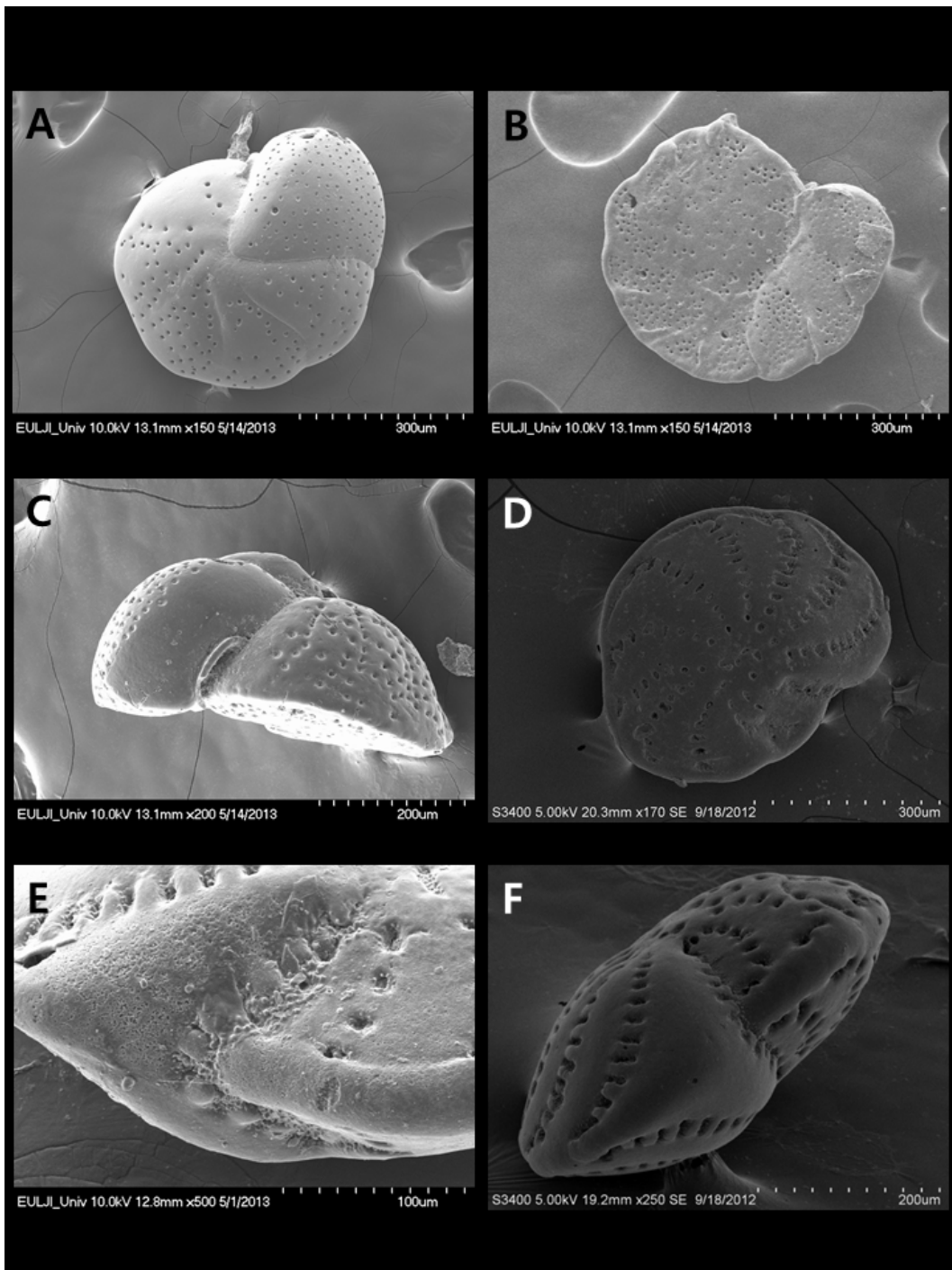


Figure 6. (A), (B) (C): *Cibicides robustus* (A) umbilical view; (B) spiral view; (D), (E), (F): *Elphidium advenum* (D) umbilical view; (E), (F) apertural view.

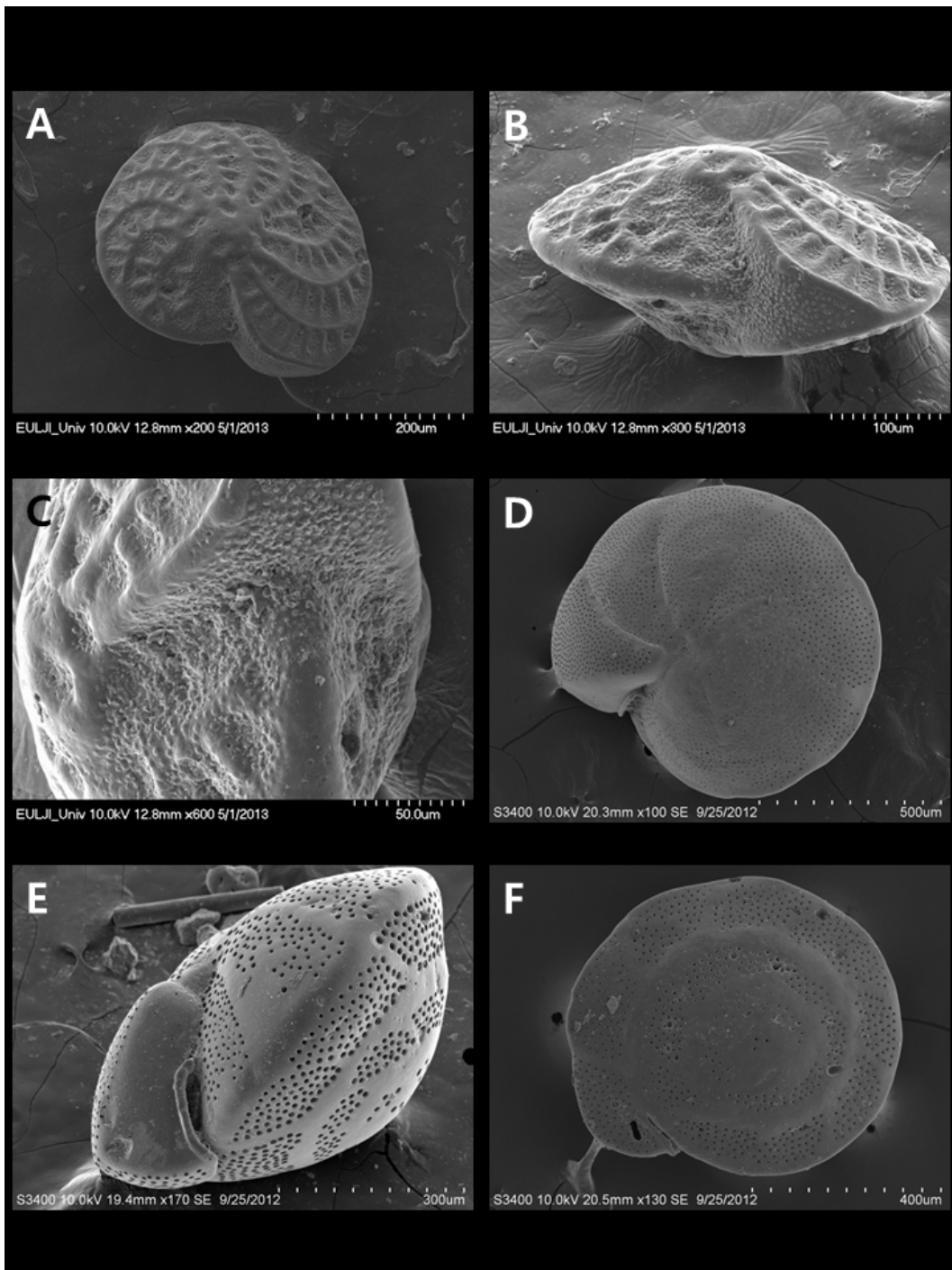


Figure 7. (A), (B), (C): *Elphidium crispum* (A) umbilical view; (B), (C) apertural view; (D), (E), (F): *Cibicidoides subhaidingerii* (D) umbilical view; (E) apertural view; (F) spiral view.

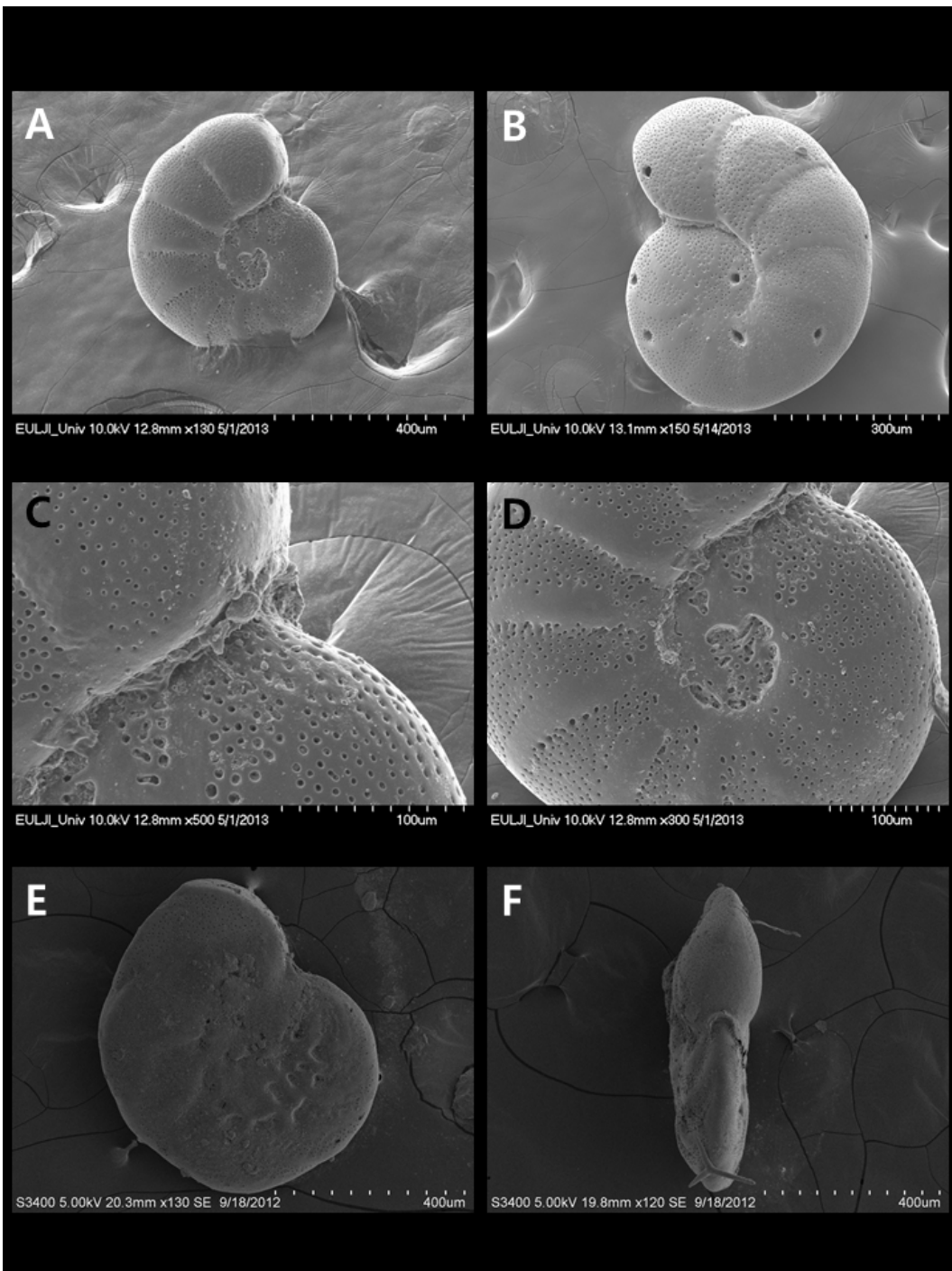


Figure 8. (A), (B), (C), (D): *Anomalinoides glabratus* (A) umbilical view; (B) spiral view; (C) apertural view; (D) detail of surface (E), (F): *Hanzawaia nipponica* (E) umbilical view; (E) apertural view; (F) apertural view.

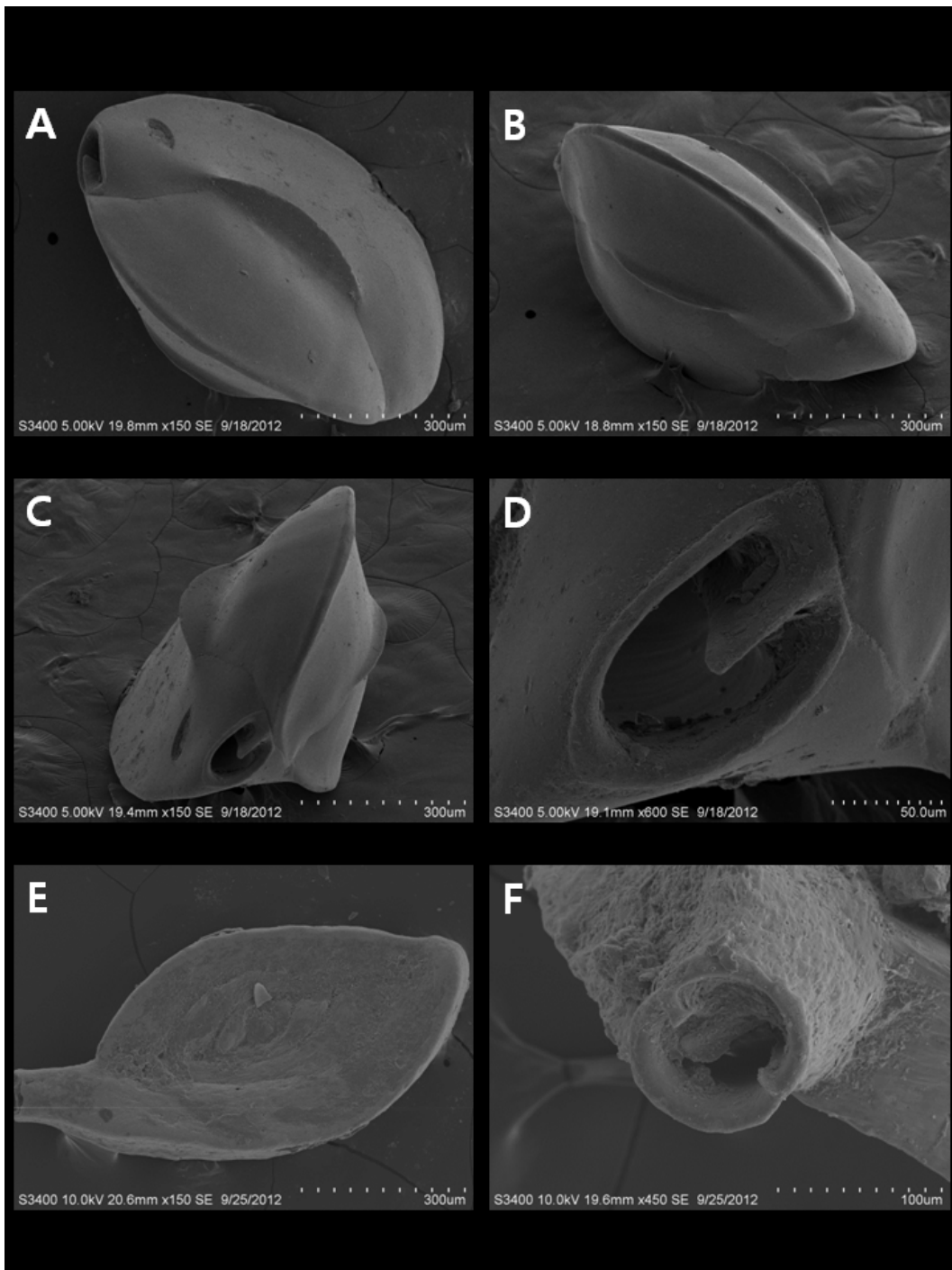


Figure 9. (A), (B), (C), (D): *Quinqueloculina lamarckiana* (A) opposite view; (B) side view; (C) apertural view; (D) detail of aperture (E), (F): *Spiroloculina communis* (E) side view; (F) detail of aperture.

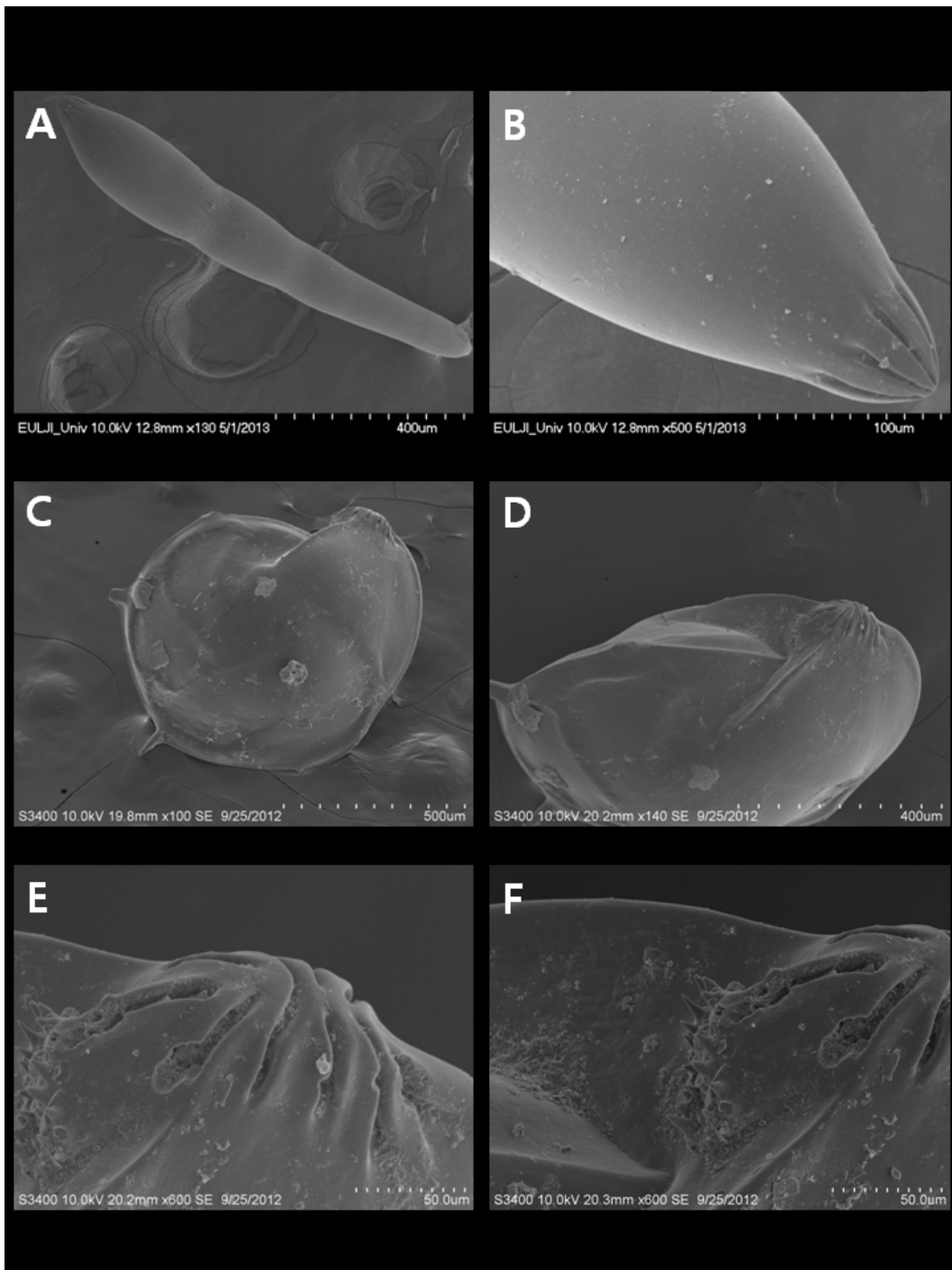


Figure 10. (A), (B), (C): *Laevidentalina sidebottomi* (A) side view; (B) apertural view; (C), (D), (E), (F): *Lenticulina calcar* (C) umbilical view; (D) apertural view; (E), (F) detail of aperture.

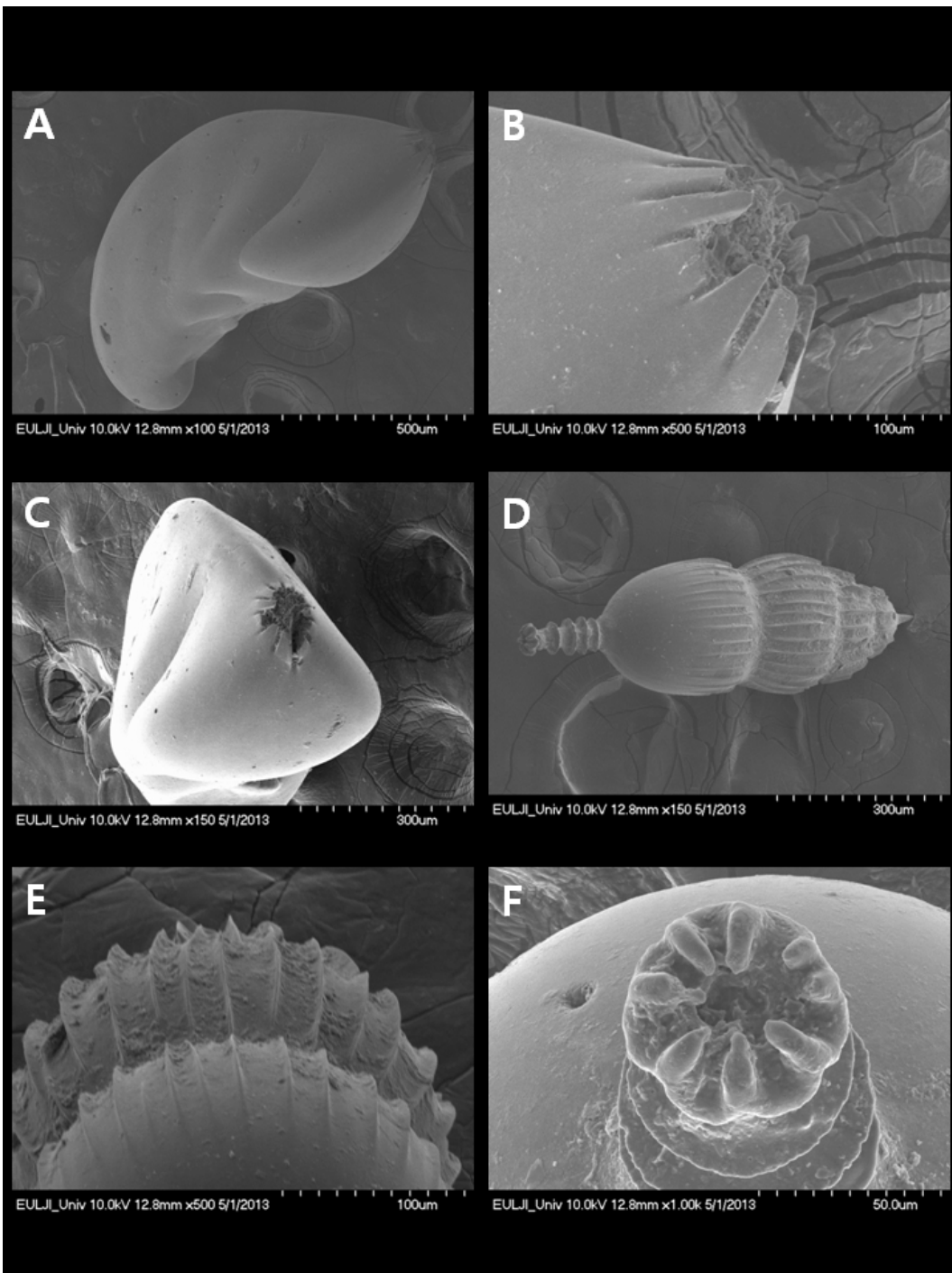


Figure 11. (A), (B), (C): *Saraceneria italica* (A) side view; (B) detail of aperture; (C) apertural view; (D), (E), (F): *Amphicoryna scalaris* (D) side view; (E) detail of surface; (F) detail of aperture.

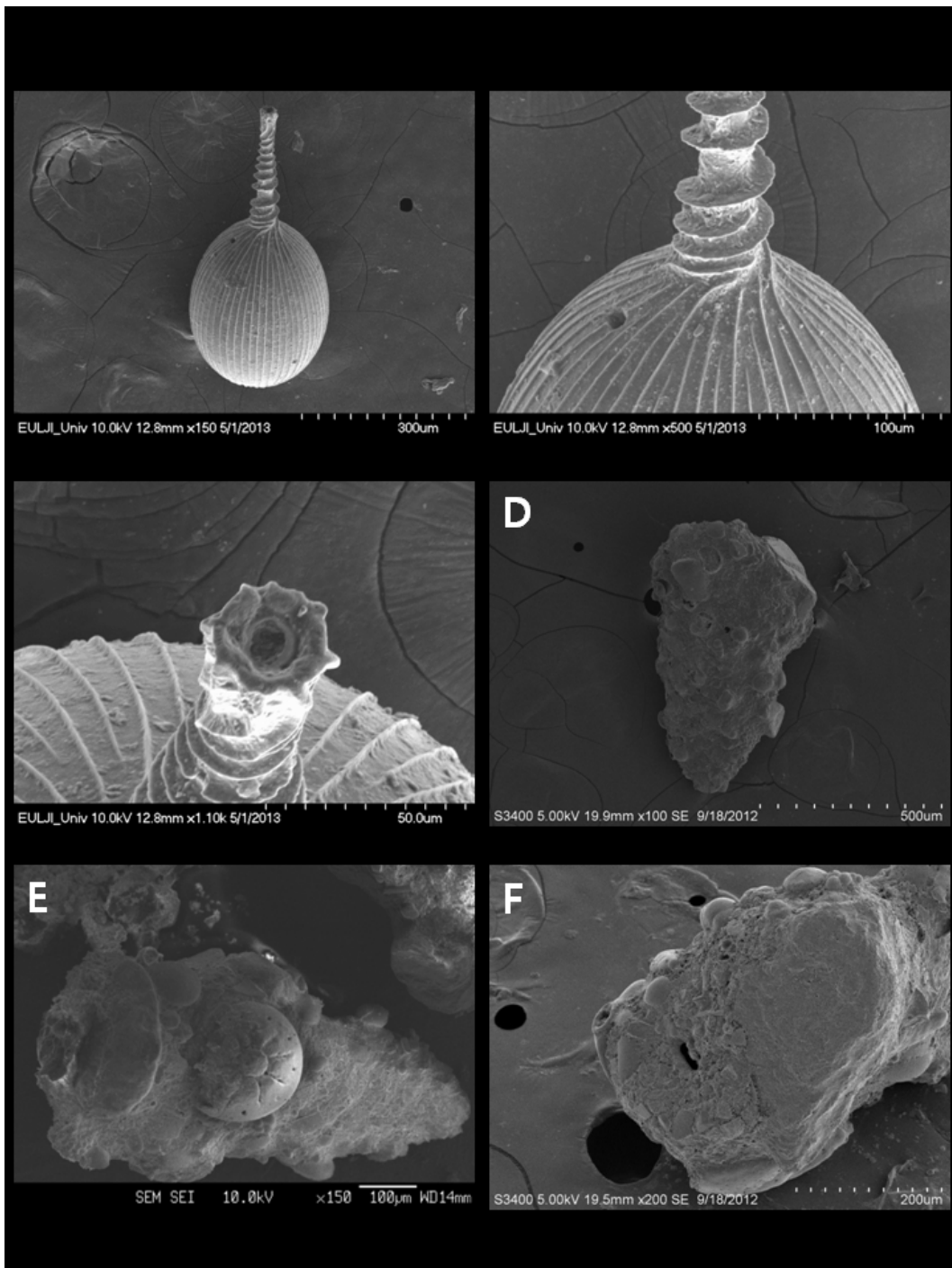


Figure 12. (A), (B), (C): *Legena sulcata* (A), (B) side view; (C) detail of surface; (D), (E), (F): *Textularia agglutinans* (D), (E) side view; (F) apertural view.

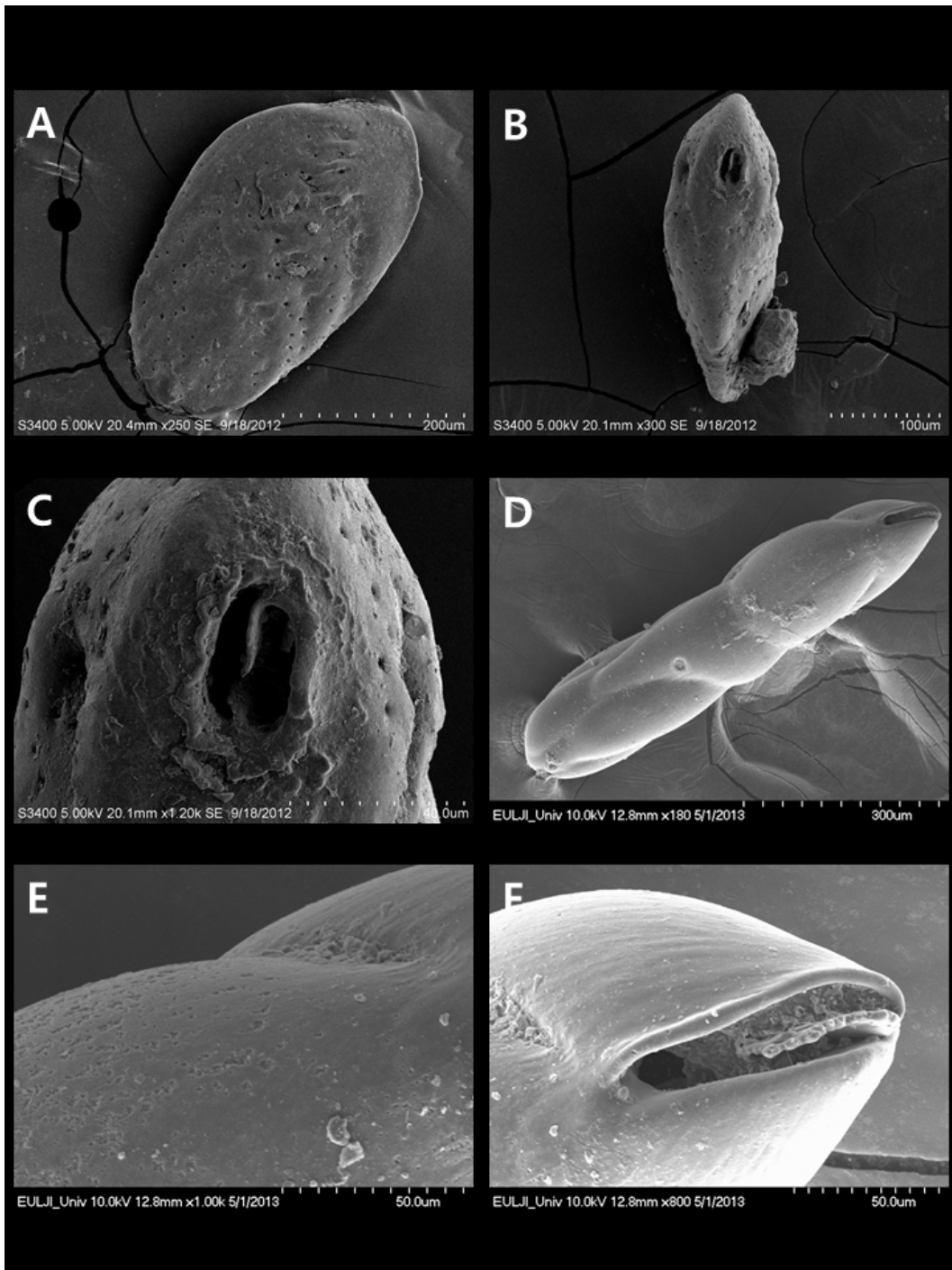


Figure 13. (A), (B), (C): *Bolivica robusta* (A) side view; (B) apertural view; (C) detail of aperture; (D), (E), (F): *Cassidella bradyi* (D) side view; (E) detail of surface (F) detail of aperture.

국문요지

우리나라의 제주도 및 이어도 해역에서 수행한 중형저서동물 채집결과 총 20 종의 미기록종을 발굴하였다. 그 중 5 개의 종; *Noion commune* (Asano, 1938), *Cibicides robustus* Phleger & Parker, 1951, *Laevidentalina sidebottomi* (Cushman, 1933), *Saracenaria italic* Defrance, 1824, *Cassidella bradyi* (Cushman, 1922) 은 이번 연구를 통해 처음 보고되는 종이며 나머지 15 개의 종; *Ammonia compressiuscula* Brady, 1884, *Cancris auriculus* (Fichtel & Moll, 1798), *Cibicides refulgens* de Montfort, 1808, *Elphidium advenum* (Cushman, 1922), *Elphidium macellum* (Fichtel & Moll, 1798), *Cibicidoides subhaidingerii* (Parr, 1950), *Anomalinoidea glabratus* (Cushman, 1924), *Hanzawaia nipponica* Asano, 1944, *Lenticulina calcar* (Linnaeus, 1767), *Amphicoryna scalaris* (Batsch, 1791), *Lagena sulcata* (Walker & Jacob, 1798), *Quinqueloculina lamarckiana* d'Orbigny, 1839, *Spiroloculina communis* Cushman & Todd, 1944, *Bolivina robusta* Brady, 1881, *Textularia agglutinans* d'Orbigny, 1839 또한 이번 연구에서 처음으로 분류학적 기재를 하였다. 위 15 개의 종은 이미 국내 유공충류 연구에서 보고되었으나 각 종에 대한 분류학적인 기재가 없고, 분류학적 기재가 있다 하더라도 자세한 묘사와 설명이 불명확하였다. 이번 연구에서는 한국산 유공충류의 분류학적 연구에 중점을 두었고 종 다양성을 파악하는데 그 목표를 두었다.

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제일 먼저 부족하고 모자란 저를 바른 길로 인도해 주시고 많은 지도와 조언을 해주신 이원철 교수님께 깊은 감사의 말씀을 전합니다. 또한 바쁘신 중에도 심사위원으로서 논문지도에 고생하신 Ivana Karanovic 교수님, Robert J. Blakemore 박사님께도 감사드립니다. 그리고 제 논문 지도를 위해 멀리 이탈리아에서 한국까지 오신 Fabrizio Frontalini 박사님께도 감사의 마음을 전합니다.

제가 석사과정에 진학한지 2 년여 시간이 흐르고 이제 졸업을 앞둔 시점에서 참 많은 일들이 떠오릅니다. 때론 힘들고 지칠때도 있었지만, 연구실 선배님들의 진심어린 조언과 격려 덕분에 여기까지 올 수 있었다고 생각합니다. 주변에서 지켜보며 따뜻한 조언 아끼지 않으셨던 박은옥 박사님, 항상 저를 놀리시지만 한편으로는 저에게 진심어린 말씀을 많이 해주셨던 이강현 박사님, 노량진에서 앞으로의 진로에 대해 많은 조언 해주셨던 방현우 박사님, 연구에 매진할 수 있도록 서류작업에 큰 도움주셨던 여원선생님, 이탈리아와 북극 다산기지에 많은 얘기 해주셨던 규희누나, 제가 흔들릴 때마다 빠있는 말로 저를 정신차리게 해주셨던 진욱이형, 졸업 논문 쓸때 속 깊은 얘기 많이 해주신 영희누나, 은정누나, 명절때마다 항상 집까지 데려다 주시기도하고 항상 제 마음을 이해해주시고 많은 도움주셨던 현기형, 다산기지에서 후배보다 무거운 짐 드시고 후배보다 더 고생하시고도 돌아오는 비행기 안에서는 앞으로 더 열심히 할 수있다고 잘해보자고 고언해주셨던

기춘이형, 진욱이형보다 더 빠있는 농담으로 저를 따끔하게 지적해주셨지만 속마음은 굉장히 따뜻한 승한이형, 제 장난을 켈 잘 받아주시고 잘 웃어주시고 항상 밝아서 좋은 홍정호형, 먼저 졸업해서 바쁘와중에도 중간중간 연락해서 응원해주시는 소영누나, 은경누나, 말 벗이자 아직은 친한 형 동생사이인 광수형, 항상 깊은 생각으로 저를 깨우쳐주시는 동구형, 싸가지 없는 동생을 잘 이해해주고 잘 챙겨주는 좋은 림메 형근이형, 같이 연구실 들어와서 같이 개고생하며 많은 얘기 나눴던 현수형, 어리고 못된 선배가 맨날 놀려도 다 받아주고 속도 깊은 김정호형, 막내 벗어나게 해준 이천 출신 캐나다인 래혁이, 이제 곧 고생길 뒤흔 은지, 꿈을 포기하지 않고 최선을 다하며 지금도 고생하고 있는 내게 귀감을 줬던 지은이, 똥바 좋아하는 현주씨에게도 감사의 말을 전합니다.

바쁘다는 핑계로 서울까지 와서도 소주한잔 못해준 고등학교 친구들 현수, 상형이, 석사과정 막 시작해서 고생중인 중환이, 군대에서 고생하고 있을 상원이 에게도 미안하다는 말과 함께 고맙다는 말을 전합니다. 각자 힘든 와중에도 힘이 되어주고 함께 울고 웃어주었던 내 대학동기들 세홍, 재홍, 재형, 준혁, 성훈, 권형, 상민, 상현이형, 병후, 나래, 지예, 유선이 에게도 감사하고 앞으로도 잘부탁드리는 말을 전합니다.

해양생태계 채집 때에 만나 저에게 좋은 말씀 해주셨던 국립수산과학원 윤석현 박사님, KOEM 유정규 박사님, 헤민누나, 종호형, 희경이, KICE 찬수형, 완희형, 해양연구원 도현이형, 연호형, 군산대 진이형, 부경대 수정이형에게도 감사의 말씀을 전해드립니다.

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Curriculum Vitae

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Representative Oral Presentations

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Kim, S., & W. Lee. The first record and redescription of two species of Foraminifera from the south western coast of Jeju Island, Korea. The Korean Society of Oceanography. 2012.

연구윤리 서약서

본인은 한양대학교 대학원생으로서 이 학위논문 작성 과정에서 다음과 같이 연구윤리의 기본원칙을 준수하였음을 서약합니다.

첫째, 지도교수의 지도를 받아 정직하고 엄정한 연구를 수행하여 학위논문을 작성한다.

둘째, 논문작성시 위조, 변조, 표절 등 학문적 진실성을 훼손하는 어떤 연구부정행위도 하지 않는다.

2013 년 7 월 1 일

학 위 명: 이학석사

학 과: 환경과학과

지도교수: 이 원 철

성 명: 김 상 진



(서명)

한양대학교 대학원장 귀하

Declaration of Ethical Conduct in Research

I, as a graduate student of Hanyang University, hereby declare that I have abided by the following Code of Research Ethics while writing this dissertation thesis, during my degree program.

"First, I have strived to be honest in my conduct, to produce valid and reliable research conforming with the guidance of my thesis supervisor, and I affirm that my thesis contains honest, fair and reasonable conclusions based on my own careful research under the guidance of my thesis supervisor.

Second, I have not committed any acts that may discredit or damage the credibility of my research. These include, but are not limited to: falsification, distortion of research findings or plagiarism."

____2013.07.01____

Date

Degree : Master of Science

Department : Department of Environment Science

Thesis Supervisor : Professor Lee, Wonchoel

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(Signature)

