

Three new records of recent benthic Foraminifera from Korea

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Foraminifera are protists that inhabit diverse marine environments and show high abundance and diversity. However, previous studies on foraminifera in Korea mostly focused on geological and paleoecological fields and were conducted in a limited area. Therefore, there is a high possibility for discovering new and unrecorded species. Here we describe three newly recorded foraminiferal species from the southwestern part of Jeju Island during a survey on the meiofaunal community, which belongs to three different genera (*Ammobaculites*, *Cylindroclavulina*, *Saracenaria*), three families (Lituolidae, Vaginulinidae, Valvulinidae), and three orders (Lituolida, Textulariida, Vaginulinida): *Ammobaculites formosensis* Nakamura, 1937, *Cylindroclavulina bradyi* (Cushman, 1911), and *Saracenaria hannoverana* (Franke, 1936). These species have been reported from Chinese region in the East China Sea, however this is the first report from Korean waters. Particularly, *Cylindroclavulina bradyi* is the first report of the genus *Cylindroclavulina* in Korean waters. The present study supports the diversity of foraminiferal species in Korea, and the necessity of further surveys in Korean waters.

Keywords: East China Sea, extant species, Globothalamea, modern foraminifera

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INTRODUCTION

Foraminifera are single-celled amoeboid protists, which inhabit a wide range of marine environments, and show high abundance and species diversity (Sen Gupta, 1999; Sabbatini *et al.*, 2014). They can mineralize a shell (test) that can be fossilized (Murray, 2006; Yahya *et al.*, 2014). The fossil records of foraminifera exist from the Cambrian to present (Kaminski *et al.*, 2010; Debenay, 2012), and about 39,000 fossil and 8,900 recent valid species have been recorded worldwide (Hayward *et al.*, 2019). In Korea, a total of 1,196 foraminiferal species has been recorded in the national species list of Korea 2018 (NIBR, 2019). Since the number 1,196 includes fossil species, extant species, synonyms, and unaccepted species names, it is necessary to reorganize the list in order to grasp the current status of the actual species diversity of modern foraminifera. Therefore the actual number of modern foraminiferal species is estimated to be much smaller.

Previous studies on foraminifera in Korea mostly focused on geological and paleoecological aspects, and the study areas were mostly limited to coastal regions around southeastern and northwestern parts of Korean Peninsula (Chang and Lee, 1984; Chang, 1986; Cheong, 1989; Jung *et al.*, 1997; Kim *et al.*, 1997; Woo *et al.*, 1997; Woo *et*

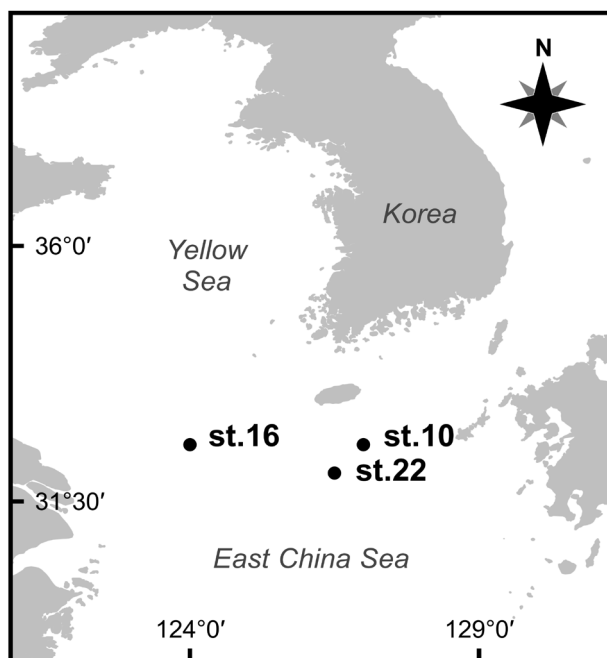
al., 2000; Woo and Choi, 2006; Woo and Lee, 2006; Woo, 2007; Choi *et al.*, 2010; Jeong *et al.*, 2016). Therefore, a high possibility of discovering new and unrecorded species is expected, particularly from uninvestigated regions such as the northeastern coast and open ocean regions. Indeed, 180 unrecorded species from around Jeju Island (Kim *et al.*, 2016) and 30 unrecorded species from the western and northeastern coasts (Lee *et al.*, 2017) were reported, as well as one new species from the northeastern coast (Lee *et al.*, 2019). Herein, we discovered and described three newly recorded recent benthic foraminiferal species from the East China Sea region.

MATERIALS AND METHODS

Sediment samples were collected from the southwestern part of Jeju Island in August 2019 by using Smith-McIntyre grab sampler on board (Table 1, Fig. 1). Surface sediment of the uppermost layer (0–1 cm) was directly sieved through a 125 µm mesh screen with sea water collected from each sampling site. To maintain live specimens, sieved sediments from each site were stored in 250 mL bottles with natural sea water filtered through a 38 µm sieve. Samples were kept in a cool-box and periodically

Table 1. Information on the sampling stations.

Station	Latitude (N)	Longitude (E)	Depth (m)
10	32°30'	127°00'	118
16	32°30'	124°00'	35
22	32°00'	126°30'	94

**Fig. 1.** Map of three sampling stations in the southwestern part of Jeju Island (East China Sea). This map is made with Natural Earth free vector and raster map data and QGIS software v.2.18.18.

aerated during transportation to the laboratory.

In the laboratory, benthic foraminiferal specimens were picked under Olympus SZ40 dissecting microscope using a fine brush, and dried on a micropaleontology slide at room temperature. Dried individuals were taxonomically identified, and selected specimens were photographed using an Olympus PEN Lite E-PL3 camera attached to an Olympus SZX12 dissecting microscope. The digital images were Z-stacked using Helicon Focus 7.5.8 software (Helicon Soft Ltd.). Selected specimens were mounted on a stub, coated with Au under 5 mA, 200 s in a COXEM Ion Coater SPT-20, and examined in a COXEM EM-30 scanning electron microscope (SEM). Taxonomic identification, systematic classification, and distributional survey were carried out based on following references: Cushman (1911), Ellis and Messina (1940), Loeblich and Tappan (1987), Jones (1994), Debenay (2012), Hayward *et al.* (2019). Specimens examined in this study were deposited in the Marine Biodiversity Institute of Korea (MABIK) and National Institute of Biological Resources (NIBR).

RESULTS AND DISCUSSION

Three newly recorded benthic foraminiferal species were identified from the southwestern part of Jeju Island (East China Sea), belonging to three different genera (*Ammobaculites*, *Cylindroclavulina*, *Saracenaria*), three families (Lituolidae, Vaginulinidae, Valvulinidae) and three orders (Lituolida, Textulariida, Vaginulinida). In particular, the genus *Cylindroclavulina* is recorded for the first time in Korea. These results support the diversity of foraminiferal species in Korea, and the necessity of further surveys in Korean waters.

SYSTEMATICS

Phylum Foraminifera d'Orbigny 1826

Class Globothalamea Pawlowski, Holzmann & Tyszk, 2013

Order Lituolida Lankester, 1885

Family Lituolidae Blainville, 1827

Genus *Ammobaculites* Cushman, 1910

1. *Ammobaculites formosensis* Nakamura, 1937

(Plate 1. 1a–d)

Ammobaculites formosensis Nakamura, 1937, p. 133, pl. 10, figs. 1a–b (cited from Ellis and Messina, 1940); Scott *et al.*, 2000, p. 5–6, figs. 1. 1–2; Debenay and Luan, 2006, p. 77, pl. 1, fig. 12; Garrett, 2010, p. 128, pl. 1, fig. 1; Wang *et al.*, 2016, p. 4, pl. 2, fig. 20.

Material examined. 1 individual, Korea, East China Sea, station 16 (32°30'N, 124°00'E), 6 August 2019, by Smith-McIntyre grab, collected by Somin Lee and Nayeon Park, MABIK ID: MABIK PR00043230.

Diagnosis. Test is free, elongated, and rounded shape in cross section. In early stage, chambers are closely, planispirally coiled, and compressed. Later stage is composed of five cylindrical chambers uniserially arranged. Chamber width and height gradually increase as added in later cylindrical stage. Sutures are indistinct in early coiled stage, and coiling axis slightly depressed. Wall is agglutinated with fine to coarse sediment particles. Aperture is at the terminal and rounded shape. Test length is about 550 μ m.

Remarks. This species resembles *Ammobaculites agglutinans* in general shape but differs from it in the smaller size of early coiled portion. The width of coiled portion in *A. formosensis* is almost the same or smaller than that of the final chamber. While the width of the coiled portion in *A. agglutinans* is larger than that of the final chamber. Additionally, the chamber width in the later stage of *A. formosensis* tends to increase as added, whereas it is con-

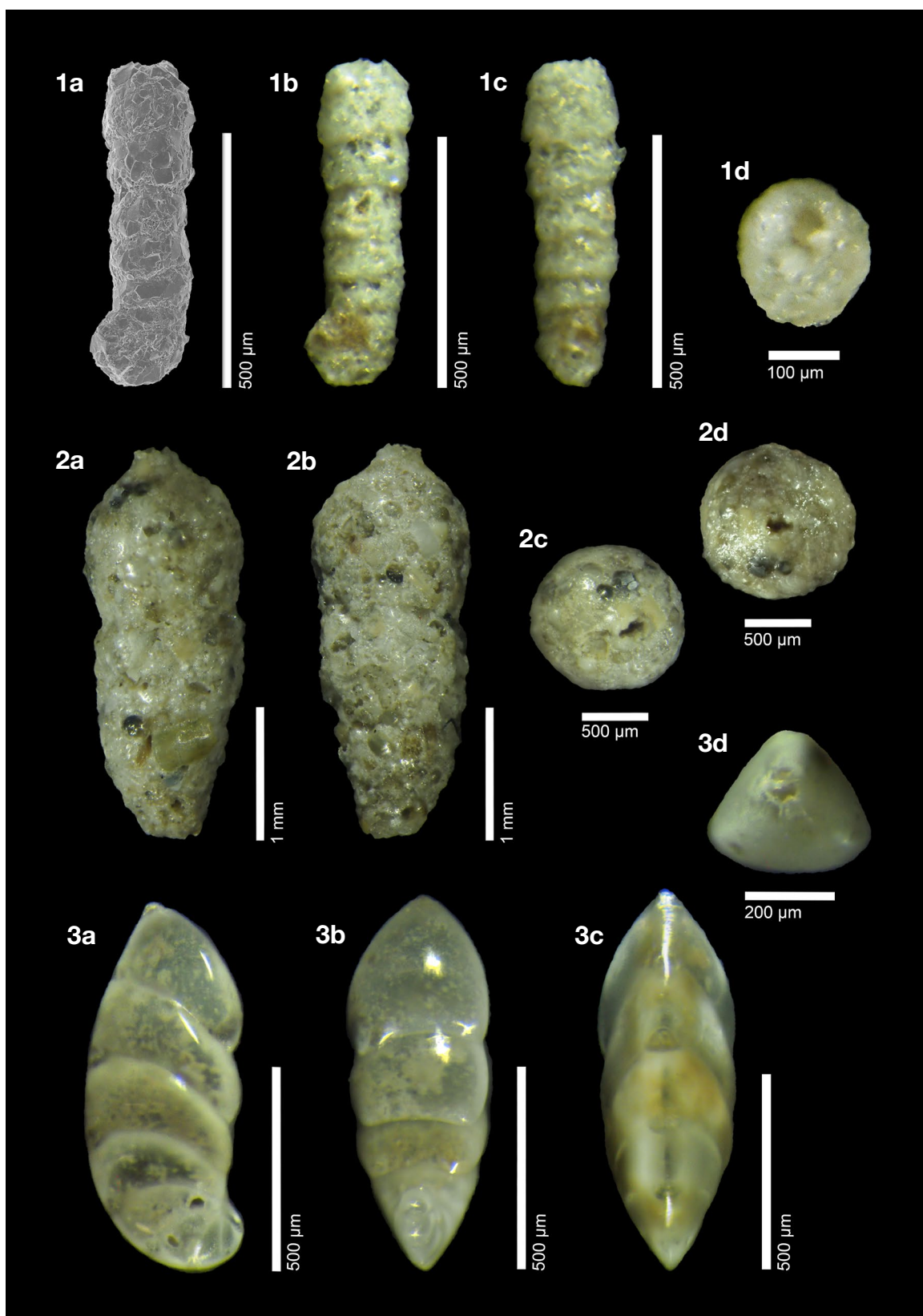


Plate 1. 1. (a–d) *Ammobaculites formosensis* Nakamura, 1937; 1a. SEM image, side view; 1b. Digital camera image, side view; 1c. Frontal view; 1d. Apertural side view. 2. (a–d) *Cyndroclavulina bradyi* (Cushman, 1911); 2a–b. Side view; 2c–d. Apertural side view. 3. (a–d) *Sarcenaria hannoverana* (Franke, 1936); 3a. Side view; 3b. Ventral view; 3c. Dorsal view; 3d. Apertural side view.

stant in *A. agglutinans*.

A total of 44 modern species belonging to the genus *Ammobaculites* have been recorded worldwide, and seven species have been recorded in Korea (Hayward *et al.*, 2018a; NIBR, 2019). *Ammobaculites formosensis* is originally reported from northern Taiwan (Ellis and Messina, 1940) in the East China Sea and has been documented in the Bohai Sea (Wang *et al.*, 2016) and South China Sea: Mekong Delta (Debenay and Luan, 2006) and Pearl River (Garrett, 2010). This is the first report of *A. formosensis* from Korean waters.

Distribution. Korea and China.

Order Textulariida Mikhalevich, 1980

Family Valvulinidae Berthelin, 1880

Genus *Cylindroclavulina* Bermúdez & Key, 1952

2. *Cylindroclavulina bradyi* (Cushman, 1911)

(Plate 1. 2a–d)

Clavulina bradyi Cushman, 1911, p. 73–74, figs. 118–119.
Cylindroclavulina bradyi: Bermúdez and Keys, 1952, p. 76; Loeblich and Tappan, 1987, p. 182, pl. 201, figs. 7–13; Jones, 1994, p. 53, pl. 48, figs. 32–38; Debenay, 2012, p. 79.

Material examined. 1 individual, Korea, East China Sea, station 10 (32°30'N, 127°00'E), 8 August 2019, by Smith-McIntyre grab, collected by Somin Lee and Nayeon Park, MABIK ID: MABIK PR00043231.

Diagnosis. Test is free, stout, elongated, and slightly tapering toward the rounded initial end. Chambers are not distinctly marked externally. Early triserial stage is not clearly observed in exterior, and the later portion is uniserial with slightly depressed sutures. Wall is composed of fine to coarse heterometric sediment grains and the test surface is greyish in color. Aperture is terminal, rounded, and somewhat flaring at the end of a short neck. Test length is about 2.95 mm.

Remarks. This species is originally classified as *Clavulina bradyi* by Cushman (1911), and later accepted to *Cylindroclavulina bradyi* as a type species of the genus *Cylindroclavulina* by Bermúdez and Keys (1952). There are four modern species belonging to this genus (Hayward *et al.*, 2018b): *C. atlantica*, *C. bradyi*, *C. elongata* and *C. ovata*. *Cylindroclavulina bradyi* is morphologically most similar to *C. elongata*, but the latter has more narrowly elongate test, more distinct neck and teeth, and more loosely agglutinated test wall (Ellis and Messina, 1940). The present specimen is somewhat more elongated and slenderer than the type specimens described by Cushman (1911) and very similar to the specimens recorded by Jones (1994, plate 48, figure 32) and Debenay (2012).

Distribution. Korea, China, Japan, Micronesia, New Caledonia, and New Zealand.

Class Nodosariata Mikhalevich, 1992 emend. Rigaud *et al.*, 2015

Order Vaginulinida Mikhalevich, 1993

Family Vaginulinidae Reuss, 1860

Genus *Saracenaria* Defrance, 1824

3. *Saracenaria hannoverana* (Franke, 1936)

(Plate 1. 3a–d)

Cristellaria (Saracenaria) hannoverana Franke, 1936, p. 98, pl. 9, fig. 3.

Saracenaria hannoverana: Zheng and Fu, 2008.

Material examined. 1 individual, Korea, East China Sea, station 22 (32°00'N, 126°30'E), 7 August 2019, by Smith-McIntyre grab, collected by Somin Lee and Nayeon Park, NIBR ID: NIBRPR0000109979.

Diagnosis. Test is free, elongate, triangular in cross-section, and curved at the basal part. Early portion is planispirally coiled and the later portion is uniserial. Sutures are slightly depressed and gently curved in lateral view. Test is composed of nine chambers, and chamber size gradually increases as added. Aperture is terminal, slightly produced, and radiate. Wall is calcareous, hyaline, and the surface is smooth. Test length is about 950 µm.

Remarks. This species is originally classified as belonging to subgenus *Cristellaria (Saracenaria)*. According to Hayward *et al.* (2019), *Saracenaria* was upgraded to genus level by Zheng and Fu (2008) listing *Saracenaria hannoverana* as a valid species. This species has been reported from Chinese regions in the East China Sea (Hayward *et al.*, 2018c) and this is the first report from Korea. According to NIBR (2019), four species belonging to *Saracenaria* have been reported in Korea: *S. altifrons*, *S. angularis*, *S. italica*, and *S. latifrons*. *Saracenaria hannoverana* differs from *S. altifrons* in the shorter and less inflated apertural face. *Saracenaria hannoverana* differs from *S. angularis* by having a smooth periphery without a keel. The present species also differs from *S. italica* by having a narrower apertural face and constant chamber width. Additionally, *S. hannoverana* differs from *S. latifrons* by having a shorter apertural face and a gently acute dorsal margin without keel.

Distribution. Korea and China.

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