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New cytheracean ostracod fossils from the Plio-Pleistocene Seogwipo Formation of the Jeju Island, Korea

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ABSTRACT: A new genus and two new species of ostracods are described from the Plio-Pleistocene Seogwipo Formation of the Jeju Island, Korea. In this study, *Tamnacythere* is erected as a new genus, and *Tamnacythere seogwipoensis* and *Kotoracythere paiki* are erected as new species. These two new species are the extinct cryophilic ostracods occurring only from the late Pliocene and early Pleistocene strata which are distributed around the Seogwipo area of the Jeju Island, Korea as well as the coastal areas on the East Sea (Sea of Japan) side of central and northern Honshu and southern Hokkaido, Japan.

Key words: ostracods, cryophilic, Plio-Pleistocene, Seogwipo Formation, Jeju Island, Korea

1. INTRODUCTION

The Jeju Island located about 90 km south of the southwestern tip of Korean Peninsula is a shield volcano formed by late Cenozoic volcanism (Fig. 1). The elliptical shaped island is 73 km by 31 km in size and mainly composed of thick basaltic lava flows with minor intercalated pyroclastic and clastic sedimentary rocks (Won, 1975, 1976; Lee, 1982a, b). The Seogwipo Formation is exposed in a narrow belt along the southern coast of the island (Fig. 1). The formation is an uplifted outcrop of continental shelf deposits which provides an unusual opportunity to study the late Cenozoic marine fauna of the Far East region. Thus, the paleontological studies on these strata will help to understand the paleoceanographical history of the region during late Cenozoic, and to manifest the stratigraphic and geographical distribution of the East Asian fossil fauna.

The first paleontological study of the Seogwipo Formation was performed by Yokoyama (1923) who reported 27 species of molluscan fossils from the formation. Since then, various fossil fauna from the outcrops of the Seogwipo Formation have been studied by many paleontologists: mollusks (Haraguchi, 1931; Yoon, 1988; Kang, 1995; Woo et al., 1995; Kim et al., 1999; Khim et al., 2000), foraminifers (Kim, 1972; Nomura, 1984; Kang et al., 1999; Kang, 2003), ostracods (Paik and Lee, 1984, 1986, 1988; Park et al., 1986; Lee, 1990; Lee and Paik, 1992), brachiopods (Kim, 1984), nannofossils (You et al., 1987; Yi et al., 1998) and trace fossils (Kim, 1991; Kim and Heo, 1995).

The Seogwipo fauna and flora reported to date are composed of mixtures of warm- and cold-water elements, indicating that the formation was deposited in shallow sea under the influence of both cold and warm currents (You et al., 1987; Yoon, 1988; Lee, 1990; Lee and Paik, 1992; Kang, 1995; Yi et al., 1998; Kang et al., 1999; Kang, 2003). Yoon (1988) and Kang (1995) investigated the Seogwipo molluscan fauna and reported that the Seogwipo Formation contains elements of both cold-water Omma-Manganji and warm-water Kakegawa faunas of the Japanese Islands. Yoon (1988) postulated that the Seogwipo molluscan fauna flourished in sublittoral shallow water under the intermingling influence of warm and cold waters. Kang (1995) defined the Seogwipo molluscan fauna as a relatively warm water fauna with temporarily adding cold water species. According to the studies of ostracods, the ostracod assemblage in the lower part of the formation is dominated by cold-water elements, while the upper part of the formation is characterized by a decrease in the cold-water elements and the occurrence of several warm-water elements (Lee, 1990; Lee and Paik, 1992). In these studies, the cold-water elements denote the circumpolar and cryophilic species which belong to genera that inhabit the shallow seas of higher latitudes than the East Sea (Sea of Japan) today. The warm-water elements are presently distributed in the South China Sea, southern part of the Yellow Sea and Korean South Sea influenced by the warm Kuroshio Current. Studies of other microfossils such as calcareous nannoplankton (Yi et al., 1998) and foraminifers (Kang et al., 1999; Kang, 2003) also revealed similar patterns; cold-water species are dominant in the lower part and warm-water species in the upper part of the formation. According to Yi et al. (1998), the paleoceanographic condition of the Seogwipo area changed from a cooling to a warm phase during deposition of the Seogwipo Formation, and the position of an oceanographic boundary between warmer and cooler water masses appeared to have oscillated north-south over the Korea Strait and Jeju Island in response to glacial and interglacial cycles. Therefore, it is generally considered that the lower part of the formation was deposited during the cold event that oceanographic changes caused the expansion of cold water mass and the southward

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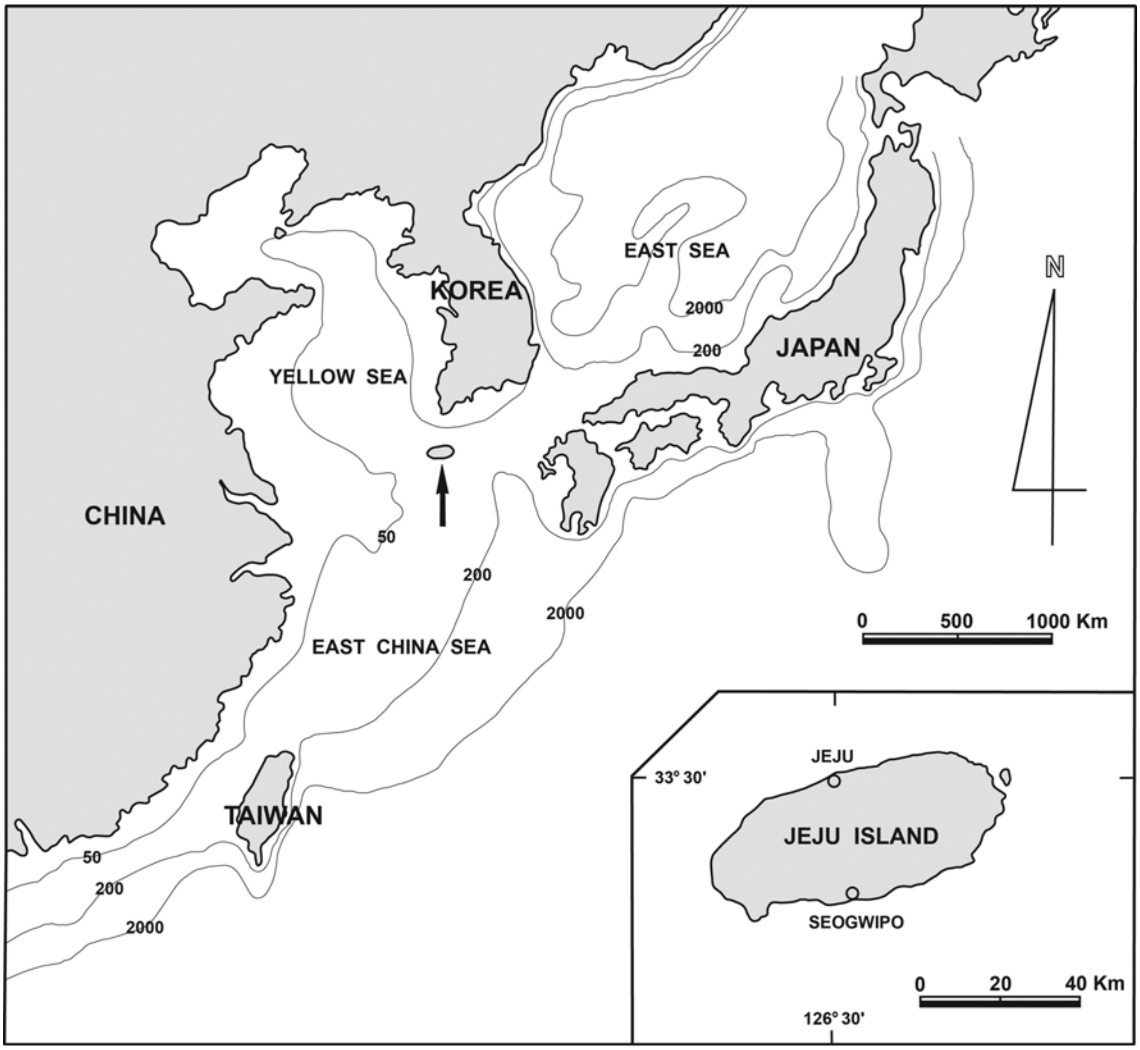

Fig. 1. Location map of the Jeju Island.

migration of the arctic-subarctic species to the Seogwipo area of the Jeju Island.

Until recently the studies on the Seogwipo ostracods have been focused on the paleoenvironmental investigation of the formation. The taxonomic study of the Seogwipo ostracod fauna will contribute to a better understanding on the paleogeographic distribution of East Asian ostracod fauna and the paleoceanographical history of this region during late Cenozoic time. In his doctoral dissertation, Lee (1990) identified 150 species belonging to 65 genera and described 20 new species from the Seogwipo Formation which has yet to be published. As part of the taxonomic studies of the Seogwipo ostracod fauna, this study aims to describe and illustrate a new genus and two new species of ostracods which occur abundantly from the lower part of the Seo- gwipo Formation: *Tamnacythere* as a new genus, and *Tamnacythere seogwipoensis* and *Kotoracythere paiki* as new species. These two new species are known as the extinct cryophilic ostracod species occurring only from the late Pliocene and early Pleistocene strata distributed around the Seogwipo area of the Jeju Island, Korea and the coastal areas on the East Sea (Sea of Japan) side of central and northern Honshu and southern Hokkaido, Japan. These are so called cold-water or cold-current species which belong to genera that inhabit higher latitudes than the East Sea (Sea of Japan) today (Ozawa et al., 2004).

2. GEOLOGIC SETTING OF THE SEOGWIPO FORMATION

The Seogwipo Formation is exposed in a sea-cliff west of the Seogwipo harbor with N10°W strike and dips 8° to the west. The extent of the formation is restricted to a narrow 1-km long belt along the coast, from the west of the Cheonji Bridge to the southern sea-cliff of Namseong-ri, Seogwipo City. The subsurface equivalent of the formation is known to occur throughout the Jeju Island below thick basaltic lava piles based on findings of thick marine sedimentary strata

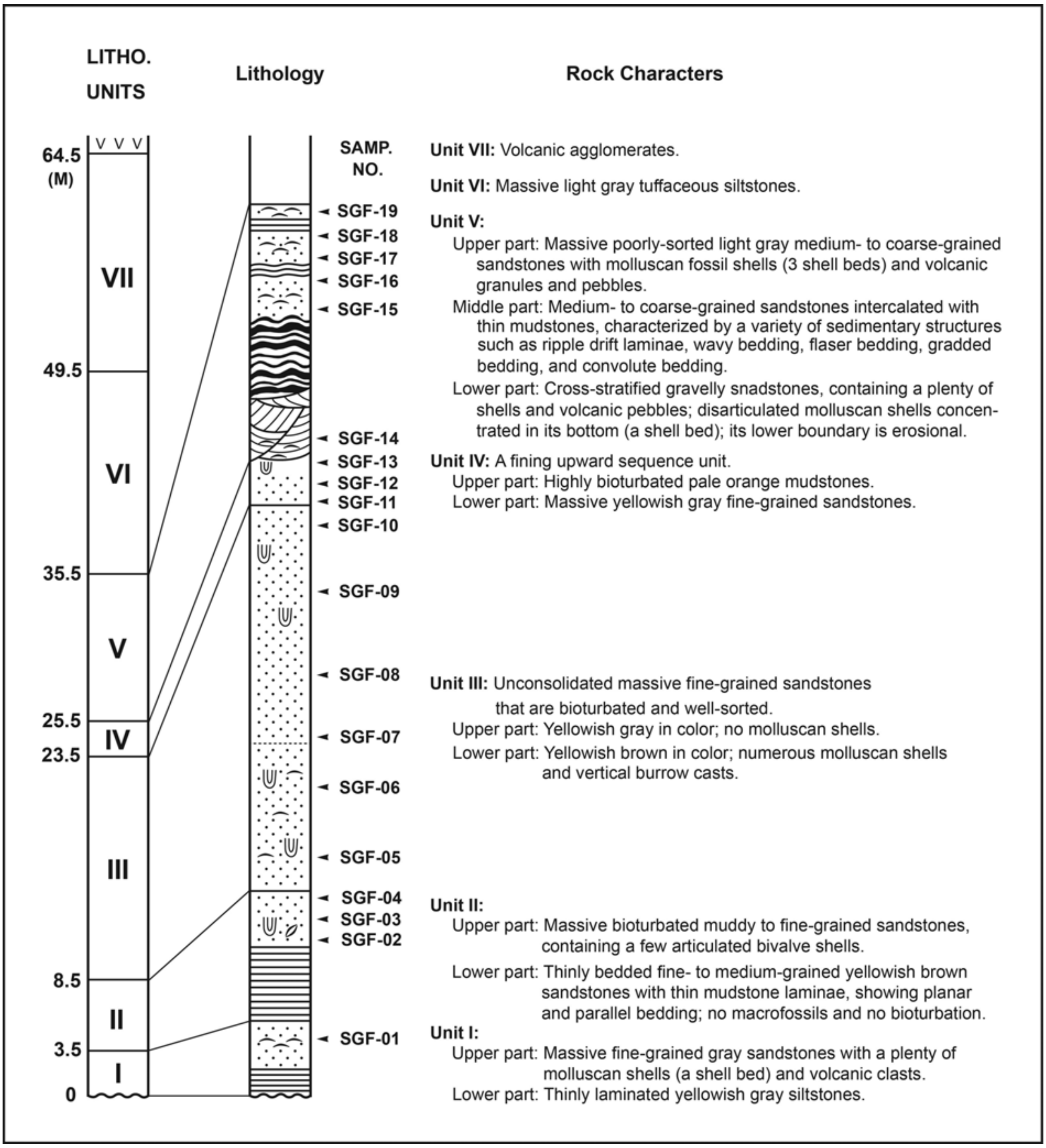

Fig. 2. Columnar section of the Seogwipo Formation illustrating the lithologic characters of each unit and sample horizons.

with molluscan shell fragments and microfossils from drill cores of Korea Agricultural Promotion Corporation (KAPC) (Jung et al., 1997; Lee and Paik, 1997; Kang et al., 2002; Kang, 2003; Yoon et al., 2004). The greatest exposure of the formation is found along the southern sea-cliff of Namseong-ri, Seogwipo City, and the lower part of the formation gradually submerges under the sea toward west because of west dipping of the strata. The lowermost part of the formation is not exposed in the study area and thus the author only observed about 65 m-thick section from sea level to the top of the sedimentary beds (Fig. 2). The formation is overlain by a thick Quaternary basalt flow of the Seogwipo Hawaiite.

Previously there was no consensus on the geologic age of the Seogwipo Formation which has been interpreted as Late Pliocene (Yokoyama, 1923; Kim, 1972; Kim, 1984; Yoon, 1988), as Pleistocene (Haraguchi, 1931; Lee, 1990; Lee and Paik, 1992; Kang, 1995), and as Pliocene to Pleistocene (Paik and Lee, 1984, 1986, 1988; You et al., 1987). A recent paleontological study based on the marker species of calcareous nannoplankton provided the most reliable data on the age of the formation to date, assigning the Seogwipo Formation to the *Pseudoemiliania lacunosa* Zone (NN19) of the latest Pliocene and Early Pleistocene, and suggested that the lower boundary of the formation is older than 1.72 Ma, while the upper one is slightly younger than 0.85 Ma (Yi et al., 1998).

The Seogwipo Formation has been correlated with the Plio-Pleistocene Omma-Manganji deposits, which are distributed along the East Sea (Sea of Japan) borderland of Japan, by its geologic age and faunal composition (Yoon, 1988; Lee, 1990; Lee and Paik, 1992; Kang, 1995; Yi et al., 1998; Kang et al., 1999; Kang, 2003). Yoon (1988) studied the Seogwipo molluscan fauna, and correlated the formation with the Omma Formation and its correlatives in the Japanese Islands. Kang (2003) correlated the benthic foraminiferal fauna in the lower and middle parts of the formation yielding cold water elements with the Omma-Manganji Fauna, whereas that in the upper part of the formation yielding warm water elements with Younger Omma Fauna of Japan.

The formation consists mainly of fine to coarse sandstones and mudstones, and sedimentary structures such as cross stratification, ripple marks, flaser and wavy beddings, graded bedding, boring shells, worm burrows and other bioturbation structures indicating shallow water conditions are observed. The formation contains five shell beds which consist mainly of molluscan fossil shells, such as *Mizuhopecten* and *Glycymeris* (Yoon, 1988). On the basis of clastic rock textures and sedimentary structures, the formation at the study area is informally divided into seven lithologic units. The lithologic characteristics of each unit are illustrated and summarized in the columnar section of Figure 2.

3. MATERIALS AND LABORATORY METHODS

A total of 31 samples were collected from the type section of the Seogwipo Formation cropping out at the southern coast of the Seogwipo City, among which 19 samples containing abundant ostracods were selected for the present study. The sampled horizons are marked in the columnar section (Fig. 2).

In laboratory, each sample was dried and 100 g of dry samples were processed to extract ostracods. Two different methods were employed according to the lithology of samples in order to disintegrate the lithified sediments: sandstones were processed by sodium sulphate (Na_2SO_4) and mudstones by solvent naphtha method, respectively. Once disintegrated, the aggregates were washed and a 230-mesh (63 μm opening) screen was used to sort the detritus. Ostracod specimens were picked from the dried residues.

4. SYSTEMATIC PALEONTOLOGY

All types and illustrated specimens of the new taxa investigated in the present study are deposited in the collections of the Paleontological Laboratory, Department of Earth and Environmental Sciences (formerly Department of Geology), Korea University (PLKU), designated under PLKU-O-numbers.

The following abbreviations are employed in the descriptions: C = Carapace, LV = Left valve, RV = Right valve, A-1 = Instar of adult minus one stage, L = Length (mm), H = Height (mm), W = Width (mm), Sp = Specimen measured, Me = Measurements, N = Number of specimens measured, X = Arithmetic mean (mm), Sd = Standard deviation (mm), OR = Observed range (mm).

The abundance of each species is expressed by three different terms as follows: Abundant = more than 10%, Common = less than 10% and more than 1%, and Rare = less than 1% of total individuals in a sample, respectively.

Subclass OSTRACODA Latreille, 1806
Order PODOCOPIDA Sars, 1866
Suborder PODOCOPINA Sars, 1866
Superfamily CYTHERACEA Baird, 1850
Family HEMICYTHERIDAE Puri, 1953
Subfamily HEMICYTHERINAE Puri, 1953
Tribe HEMICYTHERINI Puri, 1953
Genus *TAMNACYTHERE* gen. nov.

Type species: *Tamnacythere seogwipoensis* gen. et sp. nov.

Etymology: Named after Tamna, the ancient name of the Jeju Island, referring to the first occurrence of this genus from the island.

Diagnosis: A genus of tribe Hemicytherini characterized by the following characters. Carapace elongate oblong in lateral outline, oval to oblong in dorsal view. Surface pitted or reticulated. Surface ornamentation tends to be much stronger toward the posterior. Inner margin and line of concrescence separated anteriorly and posteroventrally. Holamphidont hingement, consisting of an anterior stepped tooth, an anteromedian socket, a posteromedian crenulate groove and a posterior reniform tooth, in the right valve. Merodont hingement in the penultimate instars. Muscle scars consisting of two frontal scars and a vertical row of four adductor muscle scars of which dorsomedian scar is divided.

Remarks: In his article on classification and distribution of the Recent Hemicytheridae and Trachyleberididae (Ostracoda) of northeastern North America, Hazel (1967) states that muscle scars are extremely useful criteria for placing genera within subfamilies and relating subfamilies within families, and the divided frontal muscle scar is of generally great taxonomic importance. Although it is known that the number of frontal scars is variable within the same species in some hemicytherine ostracods (Doruk, 1974a, b, c; Schornikov, 1974; Athersuch and Ruggieri, 1975; Irizuki, 1993), the dominant pattern for a species is very consistent. So it is dangerous to judge the pattern for a species from that seen on some individuals. Each of most hemicytherine genera is known to have a unique number of frontal scars.

Tamnacythere is easily distinguished from the allied genera *Normanicythere* Neale, 1959, *Yezocythere* Hanai and Ikeya, 1991 and *Urocythereis* Ruggieri, 1950 by its two frontal scars instead of three. *Normanicythere* is similar to this new genus in lateral outline and hinge structure, but differs in having a smooth or pitted surface, three frontal scars, different pattern of adductor muscle scars, and fewer marginal pore canals. This new genus is closely related to *Yezocythere* in lateral outline, marginal area, and the general arrangement of fossae in the posterior half of the carapace, but a variably ornamented surface with pits and reticulation, an inconspicuous subcentral tubercle, a weak eye tubercle, a stepped anterior hinge element, two frontal scars and an elongate, undivided ventromedian adductor scar easily differentiate this new genus from the latter. Besides, the younger instars of *Tamnacythere* are lacking in the posteroventral and posterodorsal swellings which are conspicuously present in those of *Yezocythere*. The general muscle scar pattern of this new genus is very close to that of *Hemicythere* Sars, 1925, but this new genus is quite different from the latter in the lateral outline, the surface ornamentation, and the detail of posterior hinge element.

Stratigraphic range: Late Pliocene to Early Pleistocene.

Tamnacythere seogwipoensis gen. et sp. nov.
Pl. 1, figs. 1–11; Figure 3.

1986 *Urocythereis* sp.; Paik and Lee, pl. 2, fig. 8.
1987 *Normanicythere* sp. A; Cronin and Ikeya, p. 80, pl. 1, fig. 8.
1988 *Urocythereis* sp.; Paik and Lee, pl. 2, fig. 8.
1992 *Normanicythere* sp.; Lee and Paik, pl. 3, fig. 1.
1993 *Normanicythere?* sp.; Ishizaki et al., fig. 7(A).
1996 *Normanicythere?* sp.; Kamiya et al., pl. 1, figs. 8–10.
1996 *Yezocythere?* sp.; Ozawa, pl. 9, fig. 10.
2001 *Normanicythere* sp.; Chun et al., fig. 6(B).
2003 *Yezocythere?* sp. 3; Ozawa, fig. 2(2).
2004 *Normanicythere* sp.; Lee & Huh, pl. 3, fig. 5.
2010 *Yezocythere* sp.; Ozawa and Domitsu, fig. 5(24).
2010 *Yezocythere* sp.; Ozawa, fig. 7(20).

Etymology: Named after the Seogwipo Formation which yielded the type specimen of this species.

Holotype: LV, female, PLKU-O-693 (Pl. 1, figs. 2a, b; L, 0.87; H, 0.47).

Type locality: Sample horizon SGF-10 from the type section of Seogwipo Formation which crops out in sea cliffs along the southern coast of Namseongri village, Seogwipo City, Jeju Island, Korea (Lat. 33E14′10″N, Long. 126E33′26″E).

Illustrated specimen: Holotype, LV, female, PLKU-O-693 (Pl. 1, figs. 2a, b), sample SGF-10; paratype, RV, female, PLKU-O-694 (Pl. 1, fig. 1; L, 0.88; H, 0.47), sample SGF-10; paratype, LV, female, PLKU-O-695 (Pl. 1, figs. 3, 6; L, 0.88; H, 0.49), sample SGF-05; paratype, RV, female, PLKU-O-696 (Pl. 1, figs. 4a, b, 11; L, 0.92; H, 0.48), sample SGF-05; paratype, RV, male, PLKU-O-697 (Pl. 1, fig. 5; L, 0.96; H, 0.44), sample SGF-05; paratype, LV, female, PLKU-O-700 (Pl. 1, fig. 8; Fig. 3a; L, 0.86; H, 0.48), sample SGF-17; paratype, RV, female, PLKU-O-701 (Pl. 1, fig. 7; Fig. 3b; L, 0.88; H, 0.47), sample SGF-17; paratype, C, dorsal side, female, PLKU-O-698 (Pl. 1, fig. 9; L, 0.85; W, 0.42), sample SGF-02; paratype, C, dorsal side, male, PLKU-O-699 (Pl. 1, fig. 10; L, 0.94; W, 0.39), sample SGF-03.

Diagnosis: A species of *Tamnacythere* distinguished by variably ornamented surface grading from coarse and regular reticulation into pitted or weaker reticulation anteriorly. Surface coarsely reticulated in the posterior half, but rather pitted with small round fossae in the central area of anterior half. Holamphidont hingement. Two frontal scars and four adductor muscle scars of which dorsomedian one is divided.

Description: Carapace elongate oblong in lateral view, highest at anterocardinal angle. Anterior end broadly rounded.

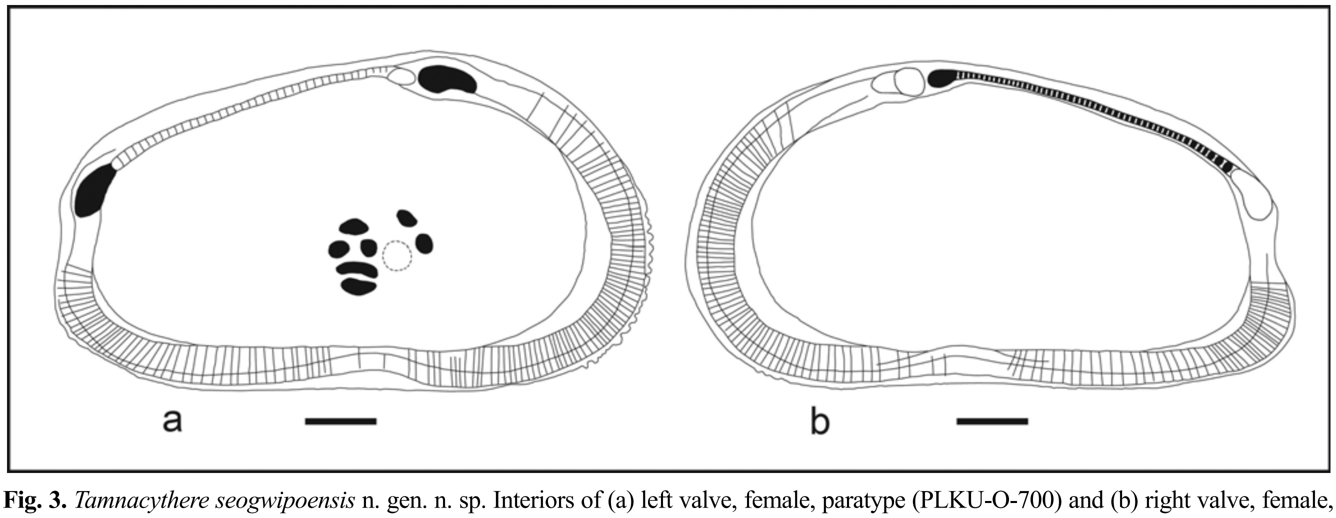

Fig. 3. *Tamnacythere seogwipoensis* n. gen. n. sp. Interiors of (a) left valve, female, paratype (PLKU-O-700) and (b) right valve, female, paratype (PLKU-O-701). Bar scales: 100 μm.

Dorsal margin nearly straight to slightly arched, parallel to the ventral margin in the male, somewhat sloping posteriorly in the female. Ventral margin almost straight or slightly concave. Posterior end concave dorsally and convex ventrally. Left valve slightly larger and overlapping the right valve in the region of the anterior tooth. Dorsal hinge line straight, obscured posteriorly by the slight rising of dorsal margin, which forms a shallow trough-like depression in the dorsal contact area. In dorsal view, carapace elongate oval in females and elongate oblong in males, showing slight concavity just behind the faint subcentral tubercles; anterior more acutely rounded than posterior; widest posteriorly in the female carapace; sides parallel in the male carapace. Sexual dimorphism pronounced, the males longer and less high than the females.

Surface variably ornamented with pits and reticulation; surface coarsely reticulated except at the central area of the anterior half, where the reticulation is obscured by the enlargement of muri to form a pitted surface with small round fossae. Fossae tend to be increase in size towards posterior region and arranged subhorizontally or subradially in the posterior half. Shallow marginal depression formed by the connection of the fossae developing along the anterior to posteroventral margins. Subcentral tubercle inconspicuous, but clearly expressed as a smooth and unornamented area in front of middle. Eye tubercle indistinct, but ocular sinus clearly present internally.

Marginal infold moderately wide. Vestibule crescent shape, moderate anteriorly, narrow at posteroventral angle. The line of concrescence and inner margin coincide ventrally. Radial pore canals simple, straight, numerous in anterior and posteroventral regions, sparse in oral region. Normal pore canals numerous, large, and scattered over the surface, giving the appearance of slight crater-like elevations within the fossae. Selvage distinct.

Muscle scars situated in a shallow subcentral interior depression, consisting of two rounded frontal scars in an oblique row and a vertical row of four adductor muscle scars of which dorsomedian one is divided and ventromedian one is very elongated and undivided. Hinge holamphidont in the adult; anterior tooth large and stepped, postjacent socket small and oval, median groove long, straight and crenulate, posterior tooth large, smooth and elongate reniform, in the right valve. Merodont hingement in the penultimate instars.

Young instars: Lateral outline of young instars changes with each instar stage, from subtriangular in A-3 or earlier stages to subrectangular in A-1 and A-2 stages. Valve surface is ornamented with coarse reticulation entirely in A-1 and A-2 stages, and nearly smooth with numerous micropuncta in A-3 or earlier stages. No posteroventral and posterodorsal nodes are observed in all of young instars.

Remarks: Specimens from the upper part (samples SGF-17, SGF-18, SGF-19) of the Seogwipo Formation exhibit more weakly ornamented surface than those from its lower part. According to Lee (1990), Lee and Paik (1992) and Yi et al. (1998), the lower part of the Seogwipo Formation, which produces specimens with coarsely reticulated surface, were formed in an environment strongly affected by cold water mass, while the upper part of the formation, which yields specimens with weakly ornamented surface, in an environment more influenced by warm water mass than cold water mass. Therefore, the variation in strength of surface ornamentation between populations of this species may probably be controlled by environmental factors such as temperature and depth.

This new species is distinguished from *Normanicythere leioderma* (Norman, 1869), redescribed and illustrated in detail by Neale (1959), by its smaller carapace size, reticulated surface, more numerous radial pore canals and difference in muscle scar pattern. The species resembles *Yezocythere hayashii* Hanai and Ikeya, 1991 from the lower Pleistocene Setana Formation of Japan, in lateral outline and marginal area, but differs in having a subdued surface ornamentation, a stepped anterior hinge element, two frontal scars and an elongate, undivided ventromedian adductor scar.

Dimensions: Measurements of the pooled specimens from samples SGF-05, SGF-12, SGF-13, SGF-17 and SGF-19 are given in Table 1.

Occurrence: Abundant at samples SGF-01 to SGF-08, SGF-14, SGF-19, common at SGF-09, SGF-10, SGF-13, SGF-17, SGF-18 and rare at SGF-11, SGF-12, SGF-15 and SGF-16.

Distribution: ***Recent***: Unknown. ***Fossils***: Late Pliocene to Early Pleistocene Seogwipo Formation of Jeju Island, Korea; Late Pliocene and Early Pleistocene strata (Hamada, Omma and Tomikawa formations) distributed in coastal areas on the East Sea (Sea of Japan) side of central and northern Honshu and southern Hokkaido, Japan.

Family EUCYTHERIDAE Puri, 1954
Subfamily PECTOCYTHERINAE Hanai, 1957
Genus *KOTORACYTHERE* Ishizaki, 1966

Type species: *Kotoracythere abnorma* Ishizaki, 1966.

Diagnosis: A genus of subfamily Pectocytherinae characterized by the following characters. Surface ornamented with ridges and reticulation. Anterior and ventral marginal ridges bold and longitudinal ridges distinct. Ventral marginal ridge sometimes terminates in a distinct sub-alar protuberance or a bold spine at its posterior end. Pentodont hingement with separated terminal elements (upper and lower ones) at each end of median bar in left valve. Vestibule wide in lower half of anterior margin.

Remarks: In 1966, Ishizaki erected the genus *Kotoracythere* on the basis of two species, *K. abnorma* and *K. tatsunokuchiensis*, from Miocene Hatatate Formation and Pliocene Tatsunokuchi Formation of northern Japan. In generic description, he defined the hingement of genus *Kotoracythere* based on the hinge structure of *Kotoracythere abnorma*, the type species of the genus. However, he made an additional

Table 1. Measurements of the pooled specimens of *Tamnacythere seogwipoensis* gen. et sp. nov. from samples SGF-05, SGF-12, SGF-13, SGF-17 and SGF-19

	Sp	Me	N	X	Sd	OR
ADULT (Male)	LV	L	7	0.935	0.032	0.88–0.98
		H	7	0.459	0.018	0.43–0.49
	RV	L	8	0.930	0.039	0.85–0.98
		H	8	0.437	0.011	0.41–0.45
ADULT (Female)	LV	L	14	0.862	0.016	0.84–0.88
		H	14	0.477	0.010	0.46–0.49
	RV	L	8	0.865	0.041	0.80–0.92
		H	8	0.468	0.017	0.44–0.48
ADULT-1	LV	L	18	0.718	0.033	0.66–0.78
		H	18	0.404	0.009	0.39–0.42
	RV	L	14	0.734	0.023	0.69–0.77
		H	14	0.391	0.010	0.36–0.40
ADULT-2	LV	L	29	0.579	0.016	0.55–0.61
		H	29	0.342	0.009	0.33–0.36
	RV	L	35	0.587	0.017	0.55–0.62
		H	35	0.335	0.008	0.32–0.35
ADULT-3	LV	L	23	0.460	0.011	0.44–0.48
		H	23	0.277	0.007	0.26–0.29
	RV	L	9	0.464	0.011	0.44–0.48
		H	9	0.275	0.010	0.26–0.29
ADULT-4	LV	L	6	0.362	0.015	0.34–0.38
		H	6	0.226	0.010	0.21–0.24
	RV	L	7	0.367	0.003	0.36–0.37
		H	7	0.225	0.004	0.22–0.23
ADULT-5	LV	L	3	0.285	0.010	0.27–0.29
		H	3	0.185	0.008	0.18–0.19
	RV	L	4	0.287	0.005	0.28–0.29
		H	4	0.177	0.005	0.17–0.18
ADULT-6	LV	L	1	0.24	0	0.24
		H	1	0.15	0	0.15
	RV	L	1	0.23	0	0.23
		H	1	0.15	0	0.15

remark that in case of *K. tatsunokuchiensis*, the terminal thickening of median hinge bar is separated into upper and lower elements.

Stratigraphic range: Miocene to Pleistocene.

Kotoracythere paiki sp. nov.
Pl. 2, figs. 1–8; Figure 4.

1985 *Kotoracythere* sp.; Ishizaki and Matoba, pl. 4, fig. 9.
1986 *Pectocythere* sp. A; Paik and Lee, pl. 1, fig. 5.
1986 *Kotoracythere* sp.; Tabuki, p. 61, pl. 1, figs. 14–19.
1987 *Kotoracythere* sp. A; Cronin and Ikeya, p. 76, pl. 3, fig. 18.
1988 *Pectocythere* sp. A; Paik and Lee, pl. 1, fig. 5.
1992 *Kotoracythere* sp.; Lee and Paik, pl. 2, fig. 1.
1996 *Kotoracythere* sp. 1; Ozawa, pl. 5, fig. 9.
2001 *Kotoracythere* sp.; Kamiya et al., fig. 15(17).
2001 *Kotoracythere* sp.; Chun et al., fig. 6(A).
2004 *Kotoracythere* sp.; Lee and Huh, pl. 3, fig. 4.
2010 *Kotoracythere* sp.; Ozawa, fig. 7(19)

Etymology: In honor of Dr. Kwang-Ho Paik, the former professor of Korea University, who is one of the Korean ostracod workers.

Holotype: C, PLKU-O-621 (**RV**: Pl. 2, figs. 1a, b; L, 0.60; H, 0.30. **LV**: Pl. 2, figs. 2a, b; L, 0.60; H, 0.30).

Type locality: Sample horizon SGF-05 from the type section of Seogwipo Formation which crops out in sea cliffs along the southern coast of Namseongri village, Seogwipo City, Jeju Island, Korea (Lat. 33E14′10″N, Long. 126E33′26″E).

Illustrated specimen: Holotype, C, PLKU-O-621 (**RV**: Pl. 2, figs. 1a, b. **LV**: Pl. 2, figs. 2a, b), sample SGF-05; paratype, C, PLKU-O-622 (**LV**: Pl. 2, figs. 3a, b, 7; L, 0.59; H, 0.31. **RV**: Pl. 2, figs. 4, 8; L, 0.59; H, 0.30), sample SGF-05; paratype, C, dorsal side, PLKU-O-623 (Pl. 2, fig. 6; L, 0.60; H, 0.31; W, 0.29), sample SGF-06; paratype, RV, PLKU-O-624 (Pl. 2, fig. 5; L, 0.60; H, 0.30), sample SGF-06; paratype, LV, PLKU-O-625 (Fig. 4a; L, 0.61; H, 0.32), sample SGF-15; paratype, RV, PLKU-0-626 (Fig. 4b; L, 0.59; H, 0.30), sample SGF-17.

Diagnosis: A species of *Kotoracythere* distinguished by

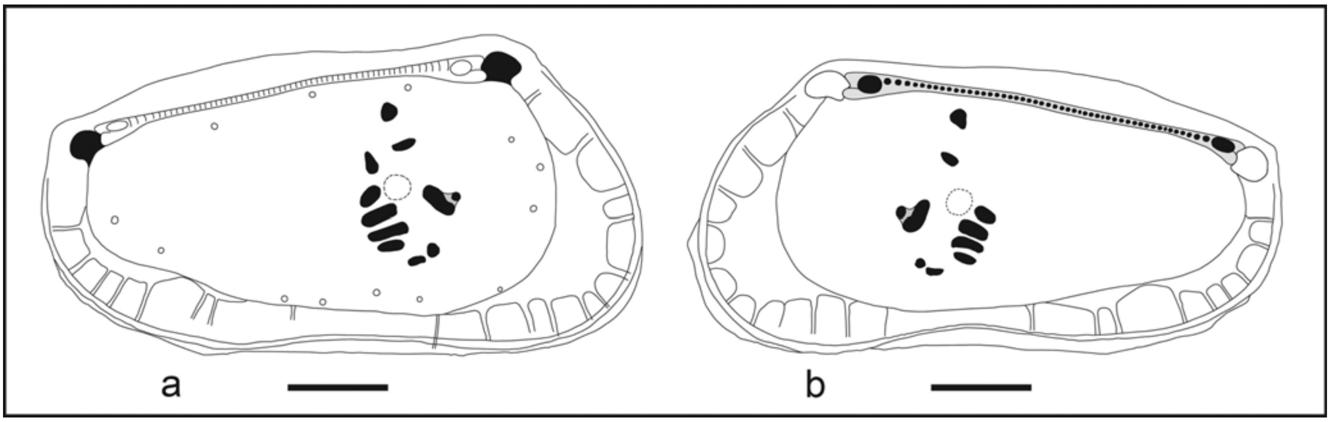

Fig. 4. *Kotoracythere paiki* n. sp. Interiors of (a) left valve, paratype (PLKU-O-625) and (b) right valve, paratype (PLKU-O-626). Bar scales: 100 μm.

heavily calcified, subrhomboidal lateral outline; carapace surface ornamented with coarse reticulation and strong ridges; an anterior marginal ridge, a short and vertical anterodorsal ridge, a wide ventrolateral ridge with coarsely pitted surface and a distinct bold spine in its posterior terminal, a long ventro-posterior marginal ridge, a longitudinal dorsomedian ridge, and a weak mid-dorsal ridge; a triangular posterodorsal compressed area and a deep posteroventral depression; pentodont hingement with the separated terminal elements at each end of median hinge bar in left valve.

Description: Carapace heavily calcified, subrhomboidal in lateral view, highest at anterocardinal angle. Dorsal margin slightly arched; its anterior half slightly sinuate in left valve, nearly straight in right valve; its posterior half slightly convex, due to the overreaching of dorsal marginal ridge. Ventral margin nearly straight. Anterior end obliquely rounded. Posterior end truncated dorsally and rounded ventrally. Anterior and posterior cardinal angles distinct. Posterodorsal marginal area highly compressed laterally. Viewed dorsally, carapace elongate subquadrate in outline; sides slightly converging anteriorly; anterior end broad and concave by the overreaching of anterior marginal ridge, posterior end bluntly pointed; greatest width at posterior third, due to the bold spine-like termination of ventrolateral ridge; hinge line straight and marked by a shallow trough.

Surface ornamented with coarse reticulation and bold ridges. Surface coarsely reticulated in low and flat areas between bold ridges. Anterior marginal ridge blunt and bold, extending parallel to anterior margin from just below the anterocardinal angle to anterior sixth of ventral margin, becoming wider ventrally to show a crescent-shaped and plateau-like appearance with deep and round pits on its surface, and overreaching anterior margin in anteroventral corner. A bold and short ridge extends vertically from posterior to anterocardinal angle to anterodorsal area. A ventrolateral ridge blunt, wide and strong and coarsely pitted, arising in anteroventral area, running parallel to ventral margin toward posterior, terminating at posterior third of ventral area to form a distinct bold spine or sub-alar protuberance. A ventro-posterior marginal ridge very long and strong, starting at anterior fifth of ventral margin, running posteriorly along ventral and posteroventral margins, bending anteriorly in mid-height of posterior area, and running straightly toward posterior two-fifths of dorsal margin where it terminates, forming triangular compressed area posterodorsally. Posteroventral depression distinct, owing to the strong development of ridges. A longitudinal dorsomedian ridge blunt, bold and undulate, starting at about anterior two-fifths of valve length in dorsomedian area, running posteriorly parallel to dorsal margin, being inclined ventrally at about posterior third of valve length, and bending upward to meet ventro-posterior marginal ridge in posterodorsal area. A mid-dorsal ridge short and undulate, showing rather an elongate node-like appearance, extending downward anteriorly and obliquely from posterior two-fifths of dorsal margin to dorsomedian area.

Marginal infold wide anteriorly, moderately wide posteriorly. Vestibule deep anteriorly, shallow posteroventrally. Radial pore canals simple, straight, few in number, approximately 11 along anterior margin and 9 along posterior margin. Normal pore canals moderate in number, large, evenly scattered. Pentodont hingement; the terminal thickening at each end of median hinge bar in left valve is separated into upper and lower elements, of which the upper ones at each end of median bar are differentiated into proximal one (a large, round projection) and distal one (a lower and flat area) and the lower ones have an elongate round projection at anterior end of median bar and a blunt projection at posterior end of median bar. Muscle scars consisting of an oblique row of four adductor scars, two separated frontal scars and two mandibular scars; frontal scars, which consist of a small round anterior muscle node and a large elongate posterior muscle node, may look like a V-shaped scar at first sight, owing to the depressed area between two nodes. Fulcral point subrounded.

Table 2. Measurements of the pooled specimens of *Kotoracythere paiki* sp. nov. from samples SGF-04, SGF-05, SGF-07 and SGF-15

	Sp	Me	N	X	Sd	OR
ADULT (Male)	LV	L	4	0.597	0.015	0.58–0.61
		H	4	0.302	0.006	0.30–0.31
	RV	L	3	0.594	0.006	0.59–0.60
		H	3	0.294	0.005	0.29–0.30
	C	L	2	0.58	0	0.58
		H	2	0.29	0	0.29
ADULT (Female)	LV	L	9	0.598	0.014	0.58–0.62
		H	9	0.316	0.008	0.31–0.33
	RV	L	10	0.592	0.016	0.57–0.62
		H	10	0.300	0.008	0.28–0.31
ADULT-1	LV	L	8	0.495	0.007	0.49–0.51
		H	8	0.274	0.012	0.26–0.29
	RV	L	4	0.487	0.004	0.48–0.49
		H	4	0.261	0.004	0.26–0.26
	C	L	1	0.50	0	0.50
		H	1	0.27	0	0.27
ADULT-2	LV	L	5	0.397	0.009	0.38–0.40
		H	5	0.227	0.005	0.22–0.23
	RV	L	4	0.387	0.007	0.38–0.39
		H	4	0.218	0.006	0.21–0.23
	C	L	6	0.396	0.011	0.38–0.41
		H	6	0.229	0.007	0.22–0.24
ADULT-3	LV	L	3	0.326	0.003	0.32–0.33
		H	3	0.196	0.003	0.19–0.20
	RV	L	4	0.325	0.006	0.32–0.33
		H	4	0.196	0.009	0.19–0.21
	C	L	8	0.316	0.010	0.30–0.33
		H	8	0.190	0.006	0.18–0.20
ADULT-4	C	L	4	0.278	0.015	0.26–0.29
		H	4	0.166	0.003	0.16–0.17

Remarks: The present species is very close to *Kotoracythere abnorma* Ishizaki, 1966, the type species of genus *Kotoracythere* from Miocene Hatatate Formation and Pliocene Tatsunokuchi Formation of northern Japan, in general outline, carapace size, general surface features ornamented with reticulation and well-developed ridges, but differs in the distribution pattern of ridges and the structures of antero- and postero-median hinge elements. It resembles *Kotoracythere tatsunokuchiensis* Ishizaki, 1966, from Miocene Hatatate Formation and Pliocene Tatsunokuchi Formation of northern Japan, in having the separated terminal elements of median hinge bar in left valve, but the latter species is easily distinguishable from this species by its delicate surface ornamentation without any prominent ridges. *Kotoracythere koreana* Huh, Whatley and Paik, 1995 from the Lower Yeonil Group of the Pohang Basin (Miocene), Korea differs in its lateral outline, smaller carapace size, the developmental and distributional pattern of ridges, and the details of terminal elements of median hinge bar in left valve.

Dimensions: Measurements of the pooled specimens from samples SGF-04, SGF-05, SGF-07 and SGF-15 are given in Table 2.

Occurrence: Common at samples SGF-01 to SGF-10 and rare at SGF-14, SGF-15, SGF-17 and SGF-18.

Distribution: ***Recent***: Unknown. ***Fossils***: Late Pliocene to Early Pleistocene Seogwipo Formation of Jeju Island, Korea; Late Pliocene and Early Pleistocene strata (Daishaka, Omma, Sasaoka, Shibikawa and Tomikawa formations) distributed in coastal areas on the East Sea (Sea of Japan) side of central and northern Honshu and southern Hokkaido, Japan.

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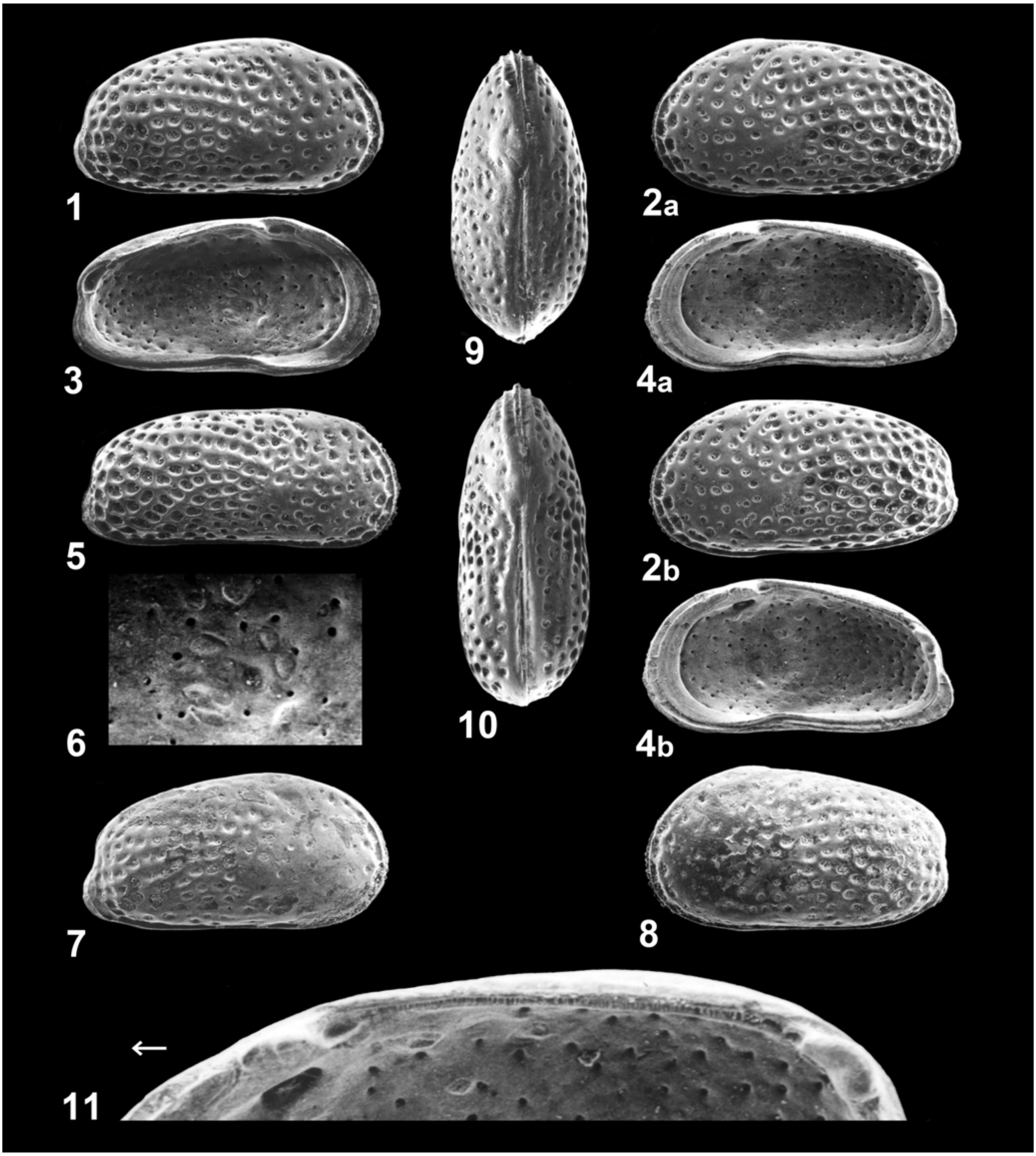

Plate 1. 1–11. *Tamnacythere seogwipoensis* n. gen. n. sp. Fig. 1, lateral view, right valve, female, paratype (PLKU-O-694, sample SGF-10), ×60; Figs. 2a, b, stereo pair of lateral view, left valve, female, holotype (PLKU-O-693, sample SGF-10), ×60; Fig. 3, internal view, left valve, female, paratype (PLKU-O-695, sample SGF-05), ×59; Figs. 4a, b, stereo pair of internal view, right valve, female, paratype (PLKU-O-696, sample SGF-05), ×57; Fig. 5, lateral view, right valve, male, paratype (PLKU-O-697, sample SGF-05), ×56; Fig. 6, internal view, left valve, female, paratype (PLKU-O-695, sample SGF-05), detail of the muscle scar, ×150; Fig. 7, lateral view, right valve, female, paratype (PLKU-O-701, sample SGF-17), ×60; Fig. 8, lateral view, left valve, female, paratype (PLKU-O-700, sample SGF-17), ×60; Fig. 9, dorsal view, complete carapace, female, paratype (PLKU-O-698, sample SGF-02), ×59; Fig. 10, dorsal view, complete carapace, male, paratype (PLKU-O-699, sample SGF-03), ×59; Fig. 11, internal view, right valve, female, paratype (PLKU-O-696, sample SGF 05), detail of the hinge, ×170.

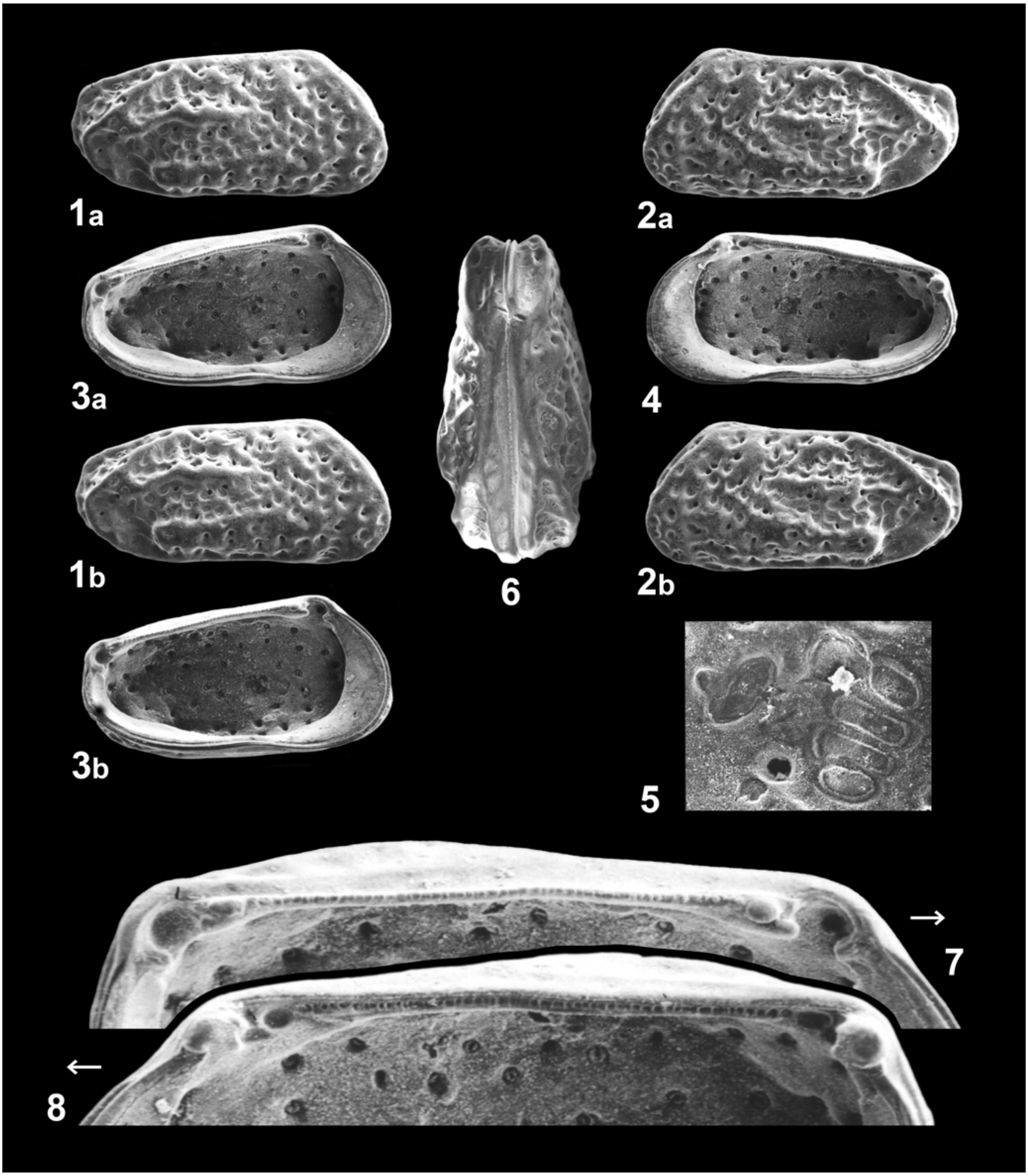

Plate 2. 1–8. *Kotoracythere paiki* n. sp. Figs. 1a, b, stereo pair of lateral view, right valve of a carapace, holotype (PLKU-O-621, sample SGF-05), ×90; Figs. 2a, b, stereo pair of lateral view, left valve of a carapace, holotype (PLKU-O-621, sample SGF-05), ×90; Figs. 3a, b, stereo pair of internal view, left valve of a carapace, paratype (PLKU-O-622, sample SGF-05), ×90; Fig. 4, internal view, right valve of a carapace, paratype (PLKU-O-622, sample SGF-05), ×90; Fig. 5, internal view, right valve, paratype (PLKU-O-624, sample SGF-06), detail of the muscle scar, ×356; Fig. 6, dorsal view, complete carapace, paratype (PLKU-O-623, sample SGF-06), ×94; Fig. 7, internal view, left valve of a carapace, paratype (PLKU-O-622, sample SGF-05), detail of the hinge, ×260; Fig. 8, internal view, right valve of a carapace, paratype (PLKU-O-622, sample SGF-05), detail of the hinge, ×260.