



# *Cypridea* species (Crustacea, Ostracoda) from the Lower Cretaceous Jinju Formation of the Gyeongsang Basin, South Korea

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## Abstract

Based on a large quantity of fossil material and more detailed description of the morphological features, two *Cypridea* species are recognized from the Jinju Formation of the Gyeongsang Basin: *Cypridea jinjuria* Choi, 1990 and *Cypridea samesi* n. sp. These two species do not co-occur and are endemic to South Korea. However, they share the same morphological feature, a swelling/node-like swelling at the anterior cardinal angle area, with some other *Cypridea* species from the Lower Cretaceous sediments of China and Mongolia. This may suggest a close relationship between these species. Paleobiologically, we infer a parthenogenetic reproduction mode for *Cypridea jinjuria* Choi, 1990 and *Cypridea samesi* n. sp., and suggest that the Jinju Formation was deposited under conditions with long hydroperiods.

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**Keywords:** Cypridoidea; Cyprideidae; Taxonomic revision; Albian; Palaeoenvironment

## 1. Introduction

Ostracods, small crustacean arthropods characterized by a bivalved carapace that can totally enclosed their soft body, have an excellent fossil record by virtue of their small size and calcite shells (valves) (e.g., Horne, 2004). *Cypridea* Bosquet, 1852 is a well-known Late Mesozoic non-marine ostracod genus (Kimmeridgian to Eocene) of the superfamily Cypridoidea, and the extinct family Cyprideidae (Sames, 2011a). It is globally distributed except in Antarctica and Australia (Horne and Colin, 2005; Sames, 2011a). Recently, several studies of the genus *Cypridea* have recognized morphologic variants, which either represent sexual dimorphs, ontogenetic stages or ecophenotypes (e.g., Nye et al., 2008; Sames, 2011a; Wang et al., 2013, 2017).

Non-marine ostracods from the Jinju Formation of the Gyeongsang Basin have been studied by several authors (e.g., Paik et al., 1988; Choi, 1990; Seo, 1996; Choi and Huh, 2016). Many typical Mesozoic genera were recorded by previous studies; however, neither cytheroidean nor darwinuloidean ostracods were found in this formation. Paik et al. (1988) concluded that the ostracod fauna from the Jinju Formation was dominated by species of *Cypridea* and is very closely related to the Cretaceous ostracod fauna of China. However, Paik et al. (1988) could not produce more detailed taxonomic and biostratigraphic results, because of the lack of well-preserved specimens. Two years later, Choi (1990) described some non-marine fossils (charophytes, clam shrimps, and ostracods) from the Gyeongsang Basin, including a new ostracod species from the Jinju Formation, *Cypridea (Pseudocypridina) jinjuria*.

Here, we restudy original material of *Cypridea jinjuria* Choi, 1990. In addition, on the basis of newly collected samples from the Jinju Formation, we also describe the new species *Cypridea samesi* n. sp.

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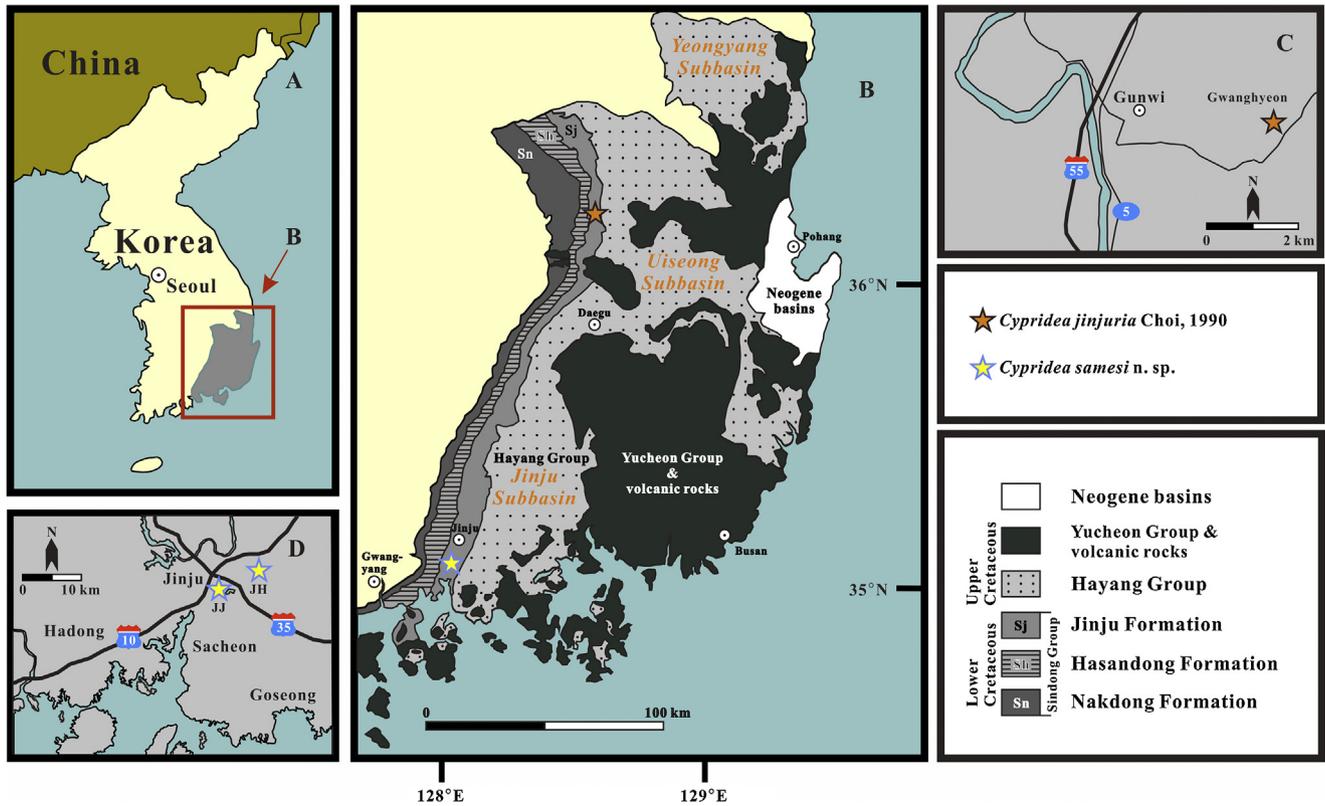


Fig. 1. (A) Location map of the Gyeongsang Basin, southeastern Korean Peninsula. (B) Geological map of the Gyeongsang Basin and fossil localities. (C) Location map of Gwanghyeon section in Gunwi County. (D) Location map of Jeongchon (JJ) and Hotan (JH) sections in Jinju City (modified from Lee et al., 2010).

## 2. Geological setting

Non-marine Cretaceous (Barremian–Campanian) sedimentary rocks are widely distributed in the Gyeongsang Basin (e.g., Chang, 1975; Kang and Paik, 2013), located in the southeastern part of the Korean Peninsula (Fig. 1). According to Chough and Sohn (2010), the Gyeongsang Basin is divided into the three subbasins (Jinju, Uiseong, and Yeongyang). The sedimentary successions of the Jinju Subbasin are subdivided into the Nakdong, Hasandong, Jinju, Chilgok, Silla, Haman, and Jindong formations (in ascending order). The sedimentary sequence of the Uiseong Subbasin consists of ten formations (in ascending order): the Nakdong, Hasandong, Jinju, Iljik, Gumidong, Gugyedong, Jeomgok, Sagok, Chunsan, and Shinyangdong formations (Chough and Sohn, 2010). The studied material was collected from the Jinju Formation of the Jinju and Uiseong subbasins.

The Jinju Formation is the upper part of the Sindong Group (Fig. 1), which is composed mainly of gray to black shale, mudstone and gray to dark gray coarse or pebbly sandstone (Chough and Sohn, 2010). This formation was deposited in a fluvio-lacustrine environment (see Choi, 1986; Paik, 2005; Chough and Sohn, 2010; Lee et al., 2010). Palynological studies suggest a “Neocomian” (in the sense of pre-Aptian Early Cretaceous including all four stages from the Berriasian to Barremian (Sames et al., 2010)) (Choi, 1985; Choi and Park, 1987) or Barremian (Yi et al., 1994) or Aptian–Albian (Yi et al., 1993) age of the Jinju Formation. According to radiometric dates, the

Jinju Formation is Albian (Lee et al., 2010; Kim et al., 2011; Kang and Paik, 2013). The Jinju Formation yields many vertebrate (dinosaurs, pterosaurs and fishes), invertebrate (insects, crustaceans and molluscs), plant, and trace fossils (Choi, 1990; Yun and Yang, 2001, 2004; Baek and Yang, 2004; Kim et al., 2012; Park et al., 2012, 2013; Selden et al., 2012; Kim et al., 2014; Lee, 2017).

## 3. Localities and material

The reference material of *C. jinjuria* of Choi (1990), hitherto unfigured, has been restudied herein by kind permission of Dr. Sung-Ja Choi (Korea Institute of Geoscience and Mineral Resources (= KIGAM)). Choi (1990) discovered *C. jinjuria* from the Gwanghyeon section of the Jinju Formation located in Gunwi County, Gyeongsangbuk-do Province, South Korea (Fig. 1). However, details of the Gwanghyeon section remain uncertain, because only the locality was given in Choi (1990). Although the type section has been visited by the first author, it was very difficult to identify the outcrop (BDC pers. observ., March 2015). Specimens of *Cypridea samesi* n. sp. were collected from two sections several kilometers apart (Hotan section [JH], sample number Hotan-1, N35°09'36", E128°07'26" and Jeongchon section [JJ], sample number JJ-1-2, N35°07'–35°08', E128°05'–128°06'). Both sections are located in Jinju City, Gyeongsangnam-do Province, South Korea (Figs. 1 and 2; see Ha et al., 2015; Choi and Huh, 2016).

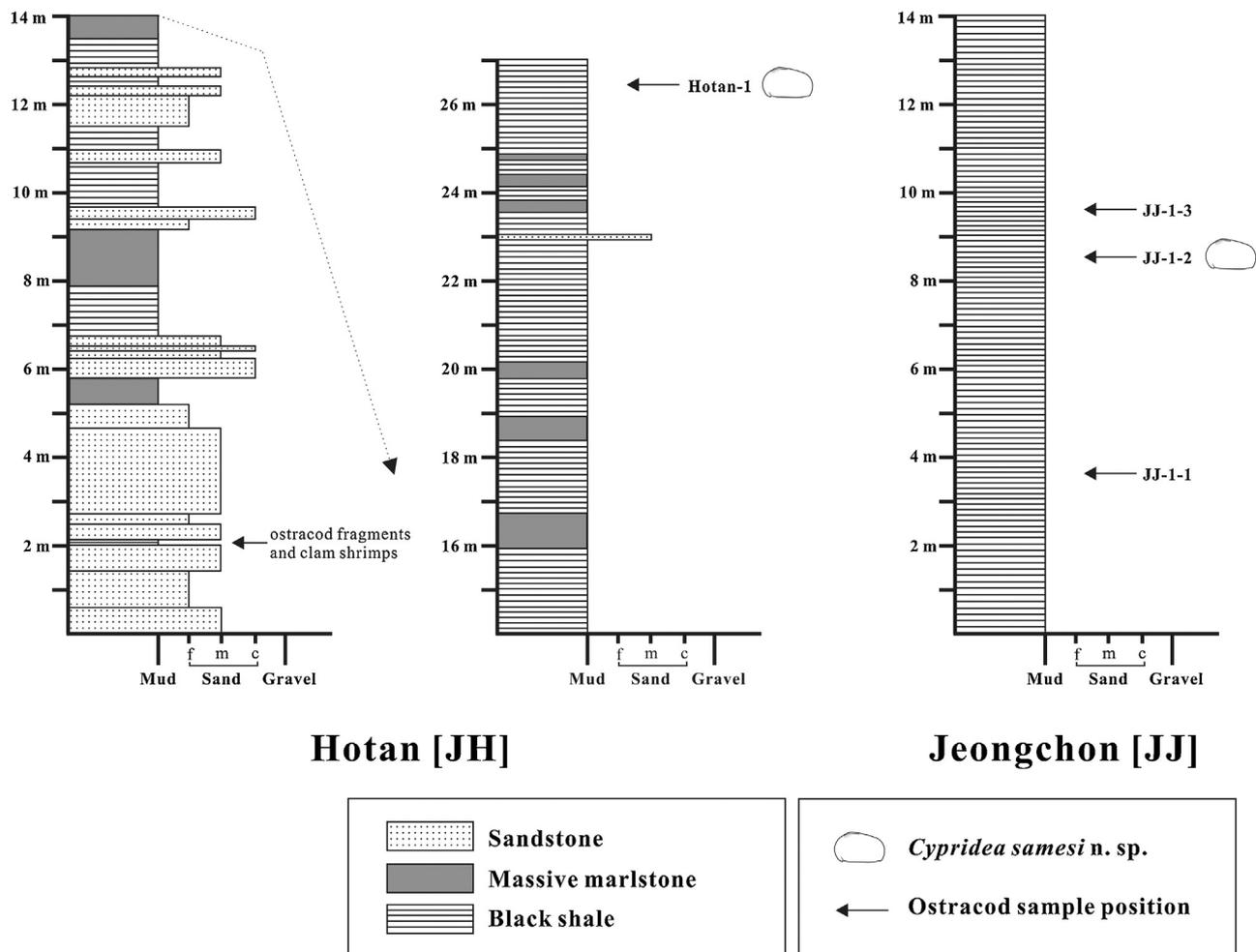


Fig. 2. Studied sections (Hotan and Jeongchon sections of Jinju City) and occurrence of ostracods from the Jinju Formation at Jinju City. Lithology of Hotan section modified from Ha et al. (2015).

Ostracod fossils have been recovered mainly from black shales. The rock samples were processed by the method that was introduced by Choi and Huh (2016). Illustrations of carapaces and valves were scanned using a Hitachi S-4700 Scanning Electronic Microscope at the Korea Basic Science Institute (Gwangju Center) at Chonnam National University (Gwangju, South Korea).

The studied material of *Cypridea jinjuria* is deposited in the Geology Division of KIGAM at Daejeon, South Korea, under the prefix KIER. Specimens of *Cypridea samesi* n. sp. are housed in the Korea Dinosaur Research Center at the Chonnam National University, Gwangju, South Korea (prefix KDRC-JH and KDRC-JJ).

#### 4. Systematic paleontology

Terminology used in this study follows Sames (2011b), and abbreviations are as follows: LV = left valve, RV = right valve, AMS = adductor muscle scars, FS = frontal scars, MS = mandibular scars. The size ranges used here are followed Ayress and Whatley (2014): very small: <0.40 mm, small:

0.40–0.50 mm, medium: 0.51–0.70 mm, large: 0.71–1.00 mm, very large: 1.01–2.00 mm, gigantic: >2.0 mm.

Class **OSTRACODA** Latreille, 1802

Order **PODOCOPIDA** Müller, 1894

Superfamily **CYPRIDOIDEA** Baird, 1845

Family **CYPRIDEIDAE** Martin, 1940

Genus *Cypridea* Bosquet, 1852

*Cypridea jinjuria* Choi, 1990 emend.

(Fig. 3A–J)

1990 *Cypridea* (*Pseudocypridina*) *jinjuria* – Choi, p. 173, pl. 3, figs. 1–6, 8.

? 1998 *Cypridea* (*Pseudocypridina*) *jinjuria* Choi – Hayashi, p. 96, pl. 2, fig. 5.

**Holotype:** KIER-2-3 (lost).

**Paratype:** KIER-2-4 (lost).

**Neotype:** KIER-2-17 (Fig. 3E), complete carapace, sample number 436 from Gwanghyeon section, length: 0.77 mm, height: 0.50 mm, width: 0.33 mm.

**Material:** 10 carapaces and about 90 valves from the Albian

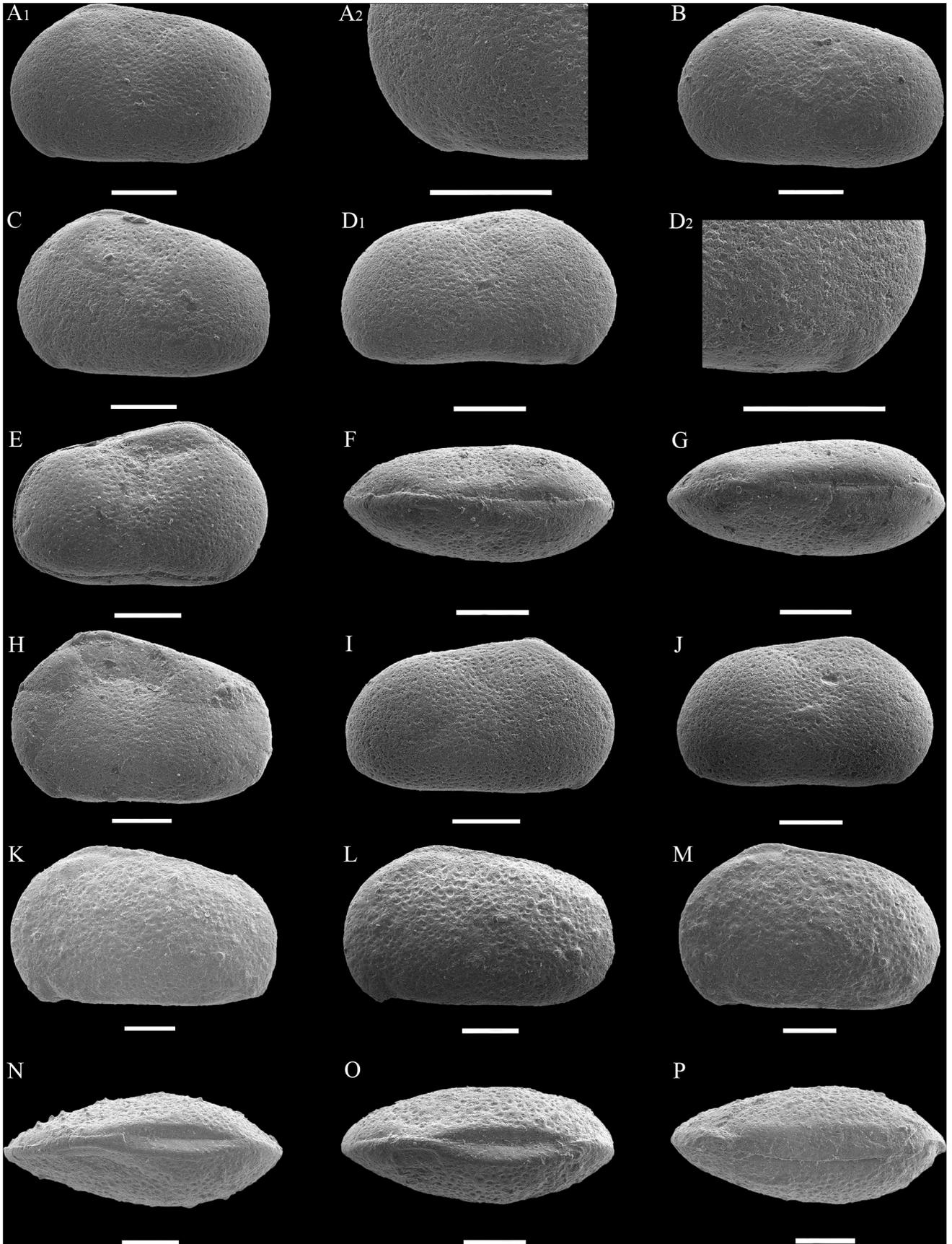


Fig. 3. (A–J) *Cypridea jinjuria* Choi, 1990 (all specimens from sample number Gwanghyeon 436) from the Jinju Formation; (A1) left view of LV, KIER-2-13; (A2) idem, detail of the anteroventral area; (B) lateral view of LV, KIER-2-14; (C) lateral view of LV, KIER-2-15; (D1) lateral view of RV, KIER-2-16; (D2) idem, detail of

Jinju Formation of the Gwanghyeon section, Gunwi-eup town, Gunwi County, Gyeongsangbuk-do, South Korea (sample number 436 of Choi, 1990, p. 175).

**Size (in mm):** Length: 0.71–0.88; height: 0.43–0.58; width: 0.32–0.33.

**Diagnosis (new):** Large sized, carapace shape oblong, dorsal margin moderately inclined towards the posterior end. Surface covered by small puncta, devoid of local ornamentation elements (tubercles and/or nodes). Anterior cardinal angle protruding in both valves; node-like swelling small but distinct at anterior cardinal angle area in the LV. Dorsal furrow shallow. Rostrum small, but somewhat broad. Alveolar notch weak, alveolar furrow shallow but well-defined. Cyathus inconspicuous.

**Description:** Large sized. Carapace shape oblong with moderately inclined towards posterior end, and broad anterior margin compared with posterior margin in lateral view. LV larger than RV. Maximum length at middle of height or slightly below middle of height, maximum height at 1/3 of length (anterior cardinal angle) and maximum width at middle of length. Anterior margin broad and equicurved to somewhat infracurved. Anterior cardinal angle distinct both valves, but more remarkable in LV, 140–150°; distinct but small node-like swelling developed below the anterior cardinal angle. Rostrum small and blunt, but broad; its point slightly bending backwards and, does not reaching the ventral margin. Alveolar notch very weak, alveolar furrow shallow and short, but well-defined. Posterior margin narrow and equicurved to infracurved in LV; the RV somewhat narrower and more infracurved than LV (but variable); posterior cardinal angle strongly rounded and indistinct, about 130°. Dorsal margin straight and inclined towards posterior end; hinge type unknown. Ventral margin nearly straight to weakly convex in LV, and slightly concave in RV. Cyathus somewhat rounded, and inconspicuous. Surface covered by small-sized puncta, and devoid of local ornamentation elements (tubercles and/or nodes).

**Muscle scar pattern:** It consists of six AMS and two mandibular (coxa) scars. AMS pattern: anterior row of four scars moderately arched, all of different size; and two scars of the different size behind the main group; one MS slight higher than AMS, another one lower than AMS (based on Choi, 1990, fig. 1).

**Morphologic variation:** Dorsal margin of some specimens more inclined towards to posterior end (regardless of carapace size). Posterior margin variable (equicurved to infracurved) in lateral view.

**Remarks:** Choi (1990) considered that *Cypridea jinjuria* belonged to the subgenus *Pseudocypridina*. Sames (2011a) emended the genus *Cypridea* and subgenus *Pseudocypridina* in characterising the latter by the relatively large-sized carapace

(valve) (up to 2 mm), alveolar notch almost absent, and alveolar furrow weakly defined or even absent. However, the length of each *Cypridea jinjuria* specimen is less than 1 mm. Therefore, the assignment of *Cypridea jinjuria* to subgenus *Pseudocypridina* is questionable.

Choi (1990, p. 173) stated in her diagnosis that *Cypridea jinjuria* lacks a rostrum: “. . .Hinge simple and beak absent”. However, she also noted the presence of a rostrum in the description of the species: “Antero-ventral margin of right valve having an inconspicuous beak, but most specimens not having notch and beak”. The first author’s examination of Choi’s specimens (not figured before) revealed a small but distinct rostrum and alveolus in both valves (Fig. 3A–J). Unfortunately, the holotype and paratype have been lost (BDC pers. observ., June 2016). Thus, we designate a neotype that comes from the same sample number as the holotype and paratype collected and designated by Dr. Sung-Ja Choi.

*C. jinjuria* differs from *C. samesi* n. sp. in the shape and degree of development of the anterior cardinal angle, rostrum, alveolus and ornamentation (see remarks of *C. samesi* n. sp. below). Hayashi (1998) reported *Cypridea (Pseudocypridina) jinjuria* from the Wakamiya Formation (Lower Cretaceous) of Japan. The problem is that no description was given and the illustration was of poor quality; for further confirmation, we need to examine the original material. For this reason, we only tentatively synonymise *C. (P.) jinjuria* of Hayashi (1988) with *C. jinjuria*.

*Cypridea samesi* n. sp.

(Figs. 3K–P, 4)

1988 *Cypridea (Cypridea)* sp. 4 – Paik et al., p. 98, pl. 1, figs. 6, 7.

1988 *Cypridea (Cypridea)* sp. 7 – Paik et al., p. 101, pl. 2, figs. 1, 3.

1988 *Cypridea (Cypridea)* sp. 8 – Paik et al., p. 102, pl. 2, figs. 2, 4.

**Etymology:** In honor of Dr. Benjamin Sames in recognition of his considerable contribution to Mesozoic ostracod research (including the taxonomy of the genus *Cypridea*), and also for being a mentor to BDC and YQW over many years.

**Holotype:** KDRC-JH-001 (Fig. 3K), complete carapace, sample number Hotan-1, length: 1.07 mm, height: 0.63 mm, width: 0.46 mm.

**Paratype:** KDRC-JH-002 (Fig. 3L), complete carapace, sample number Hotan-1, length: 0.97 mm, height: 0.58 mm, width: 0.42 mm.

**Material:** More than 500 carapaces and 15 valves from the Jinju Formation (Albian); sample number Hotan-1 of Hotan (JH) section in Hotan-dong, and sample number JJ-1-2 of Jeongchon (JJ) section in Jeongchon-eup (town), Jinju City, Gyeongsangnam-do, South Korea (Figs. 1 and 2).

**Size (in mm):** Length, 0.79–1.08; height, 0.46–0.64; width,

the anteroventral area; (E) right view of carapace, KIER-2-17 (neotype); (F) dorsal view of carapace (anterior end to the left), KIER-2-18; (G) dorsal view of carapace (anterior end to the left), KIER-2-19; (H) left view of LV, KIER-2-20; (I) lateral view of RV, KIER-2-21; (J) lateral view of RV, KIER-2-22. (K–P) *Cypridea samesi* n. sp. (all specimens from sample number Hotan-1); (K) left view of carapace, KDRC-JH-001 (holotype); (L) left view of carapace, KDRC-JH-002 (paratype); (M) left view of carapace, KDRC-JH-003; (N) dorsal view of carapace (anterior end to the left), KDRC-JH-004; (O) dorsal view of carapace (anterior end to the left), KDRC-JH-005; (P) ventral view of carapace (anterior end to the left), KDRC-JH-006. Scale bar = 200 µm.

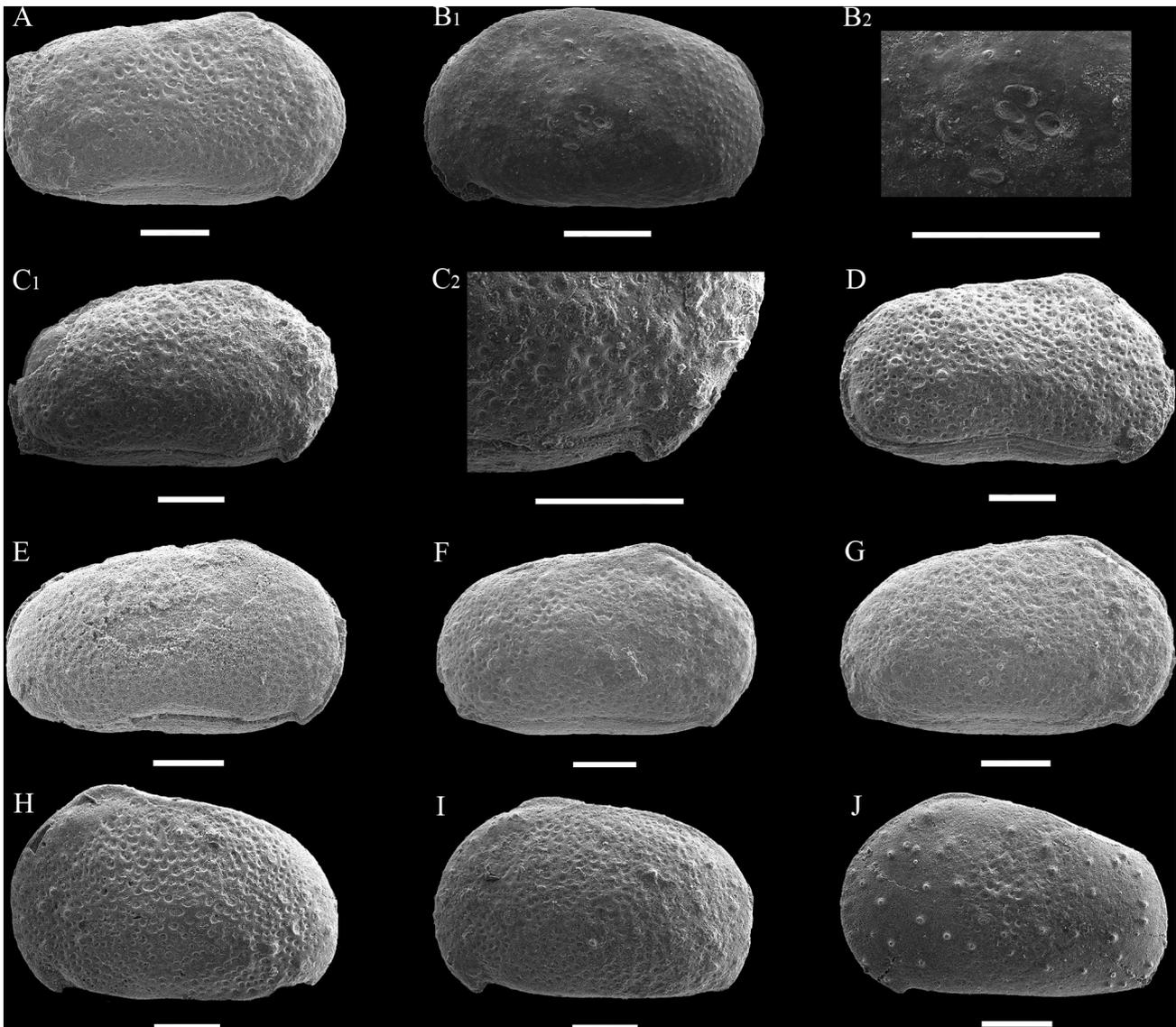


Fig. 4. *Cypridea samesi* n. sp. from the Jinju Formation; (A) right view of carapace, KIER-JH-007, sample Hotan-1; (B1) left view of dissolved carapace, KDRC-JH-008, sample Hotan-1; (B2) idem, detail of the muscle scars; (C1) right view of carapace, KDRC-JH-009, sample Hotan-1; (C2) idem, detail of the anteroventral area; (D) right view of carapace, KDRC-JH-010, sample Hotan-1; (E) right view of carapace, KDRC-JH-011, sample Hotan-1; (F) right view of carapace, KDRC-JH-012, sample Hotan-1; (G) right view of carapace, KDRC-JH-013, sample Hotan-1; (H) left view of LV, KDRC-JH-014, sample Hotan-1; (I) left view of LV, KDRC-JH-015, sample Hotan-1; (J) lateral view of LV, KDRC-JJ-020, sample JJ-1-2. Scale bar = 200  $\mu$ m.

0.33–0.46.

**Diagnosis:** Carapace rounded-oblong to suboblong. Anterior cardinal angle prominent in the LV, and overreaching dorsal margin; node-like swelling distinct at below of anterior cardinal angle area in both valves, but remarkable in LV. Rostrum well-developed but not overreaching the ventral margin. Alveolar notch moderately incised but broad. Alveolar furrow deeply incised and slightly crescent in the LV, but broad and relatively short in the RV. Ventrolateral ridge weakly developed in the LV. Cyathus weak to moderately developed. Surface covered with puncta and tubercles.

**Description:** Large to very large sized. Carapace shape rounded-oblong to suboblong, and dorsal margin slightly incline towards posterior end in lateral view. LV larger than RV; LV overlapping

entire margins, but somewhat weak in dorsal margin. Maximum length at middle of height, maximum height at 1/3 of length (anterior cardinal angle), and maximum width at middle of length. Anterior margin broadly equicurvate to infracurvate, with a distinct node-like swelling below the anterior cardinal angle in both valves, but more remarkable in LV; anterior cardinal angle rounded and being moderately protruding at LV, 135–140°. Rostrum well-developed, but not overreaching the ventral margin and its point moderately acute. Alveolus relatively well-developed; alveolar notch weak but distinct and somewhat broad, alveolar furrow slightly crescent and distinctly incised but not overreaching 1/5 of height in the LV, less prominent in RV. Posterior margin narrow and nearly equicurvate to slightly infracurvate; posterior cardinal angle nearly rounded and indistinct, 125–140°. Dorsal margin straight to slightly con-

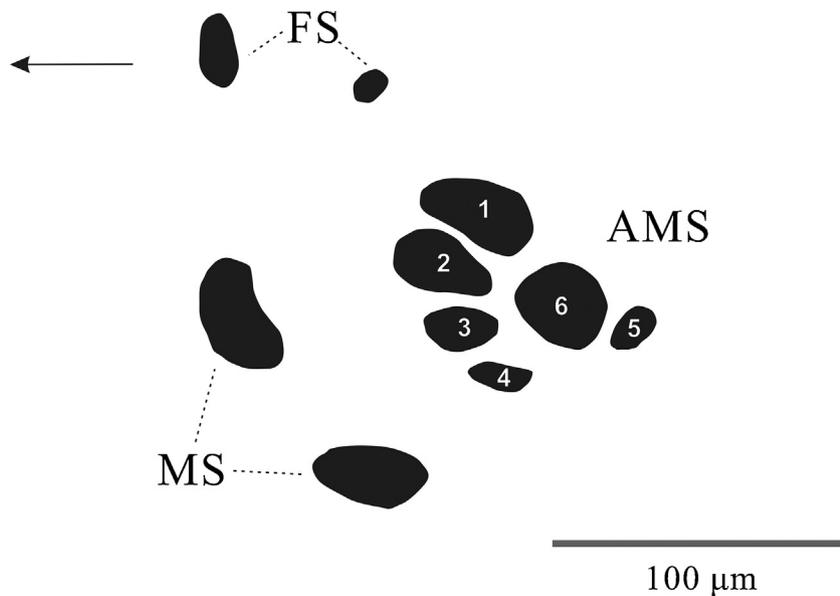


Fig. 5. Muscle scar pattern of *Cypridea samesi* n. sp. (based on specimen KDRC-JH-008).

vex and inclined towards posterior end; hinge type unknown. In dorsal view, hinge margin deeply incise forming a dorsal furrow. Ventral margin straight to slightly convex with weakly developed ventrolateral ridge towards left side in LV, and moderately concave at mid-length in RV. In ventral view, LV strongly overlaps entire ventral margin of RV and distinct in mid-length. Cyathus weak to moderately developed and more visible in LV. Surface covered by numerous and deep puncta (21–23 μm diameter) and scattered tubercles; smaller tubercles distributed along the anterior margin area.

**Muscle scar pattern:** As identified in the LV of the partially dissolved specimen KDRC-JH-008 (Figs. 4B and 5), the AMS consists of 6 scars; Number 1–4 are toward anterior end, and among those, Number 1 is longest one which tapering towards anterior end whereas Number 2 and 3 are being thicker in anterior part and piriform. Number 4 and 5 are slender and small. Number 6 is rounded and slightly obtuse-angled towards anterior end. FS consists of 2 scars which located higher than AMS; anterior one rather elongate than behind one. Two MSs comparatively large, the anterior one is crescentic in shape, the posterior one is of oval shape.

**Sexual dimorphism:** Unknown, but some valves are rather inflated laterally (Fig. 4H); thus, these specimens might be interpreted as females. However, the differences in lateral inflation of the specimens might also be the result of diagenetic compression of the sediment.

**Remarks:** *Cypridea (Cypridea)* sp. 4, *C. (C.)* sp. 7 and *C. (C.)* sp. 8 of Park et al. (1988) fit all diagnostic characters of our *C. samesi* n. sp., such as suboblong carapace shape, the development of the anterior cardinal angle, and a node-like swelling at the anterior cardinal angle area. Furthermore, all specimens of these three species are from approximately the same locality. Hence, *Cypridea (Cypridea)* sp. 4, *C. (C.)* sp. 7 and *C. (C.)* sp. 8 of Park et al. (1988) are merged with *C. samesi* n. sp.

*C. samesi* n. sp. differs from most of the known *Cypridea* species by its carapace shape and the development of the alveolus. *C. samesi* n. sp. has more well-developed alveolar notch, broad alveolar furrow in the RV, and develops the node-like swellings in the anterior cardinal angle area of both valves, which can be distinguished from *C. granulosa mongolica* Neustrueva, 1974 of Mongolia (Neustrueva et al., 2005, pl. 3, figs. 1, 2). *C. favosa* syn. *C. formosa* Ye (according to Hou et al., 2002, *C. formosa* is a junior synonym of *C. favosa*) from the Upper Cretaceous of the Songliao Basin (Santonian in Xi et al., 2012) is similar to *C. samesi* n. sp. by general shape. But, *C. favosa* shows larger carapace size and has less distinct alveolar notch and more developed alveolar furrow. *C. ganzhaoensis* Su and Li (in Wang et al., 2017) differs from *C. samesi* n. sp. by its one central robust circular tubercle on each valve and weak alveolus. *C. liaoningensis* Zhang, 1985 is more oval than *C. samesi* n. sp. in lateral view, and a well-developed ventral ridge on each valve. Also, *C. samesi* n. sp. resembles *C. vitimensis* Mandelstam (in Lübmimova, 1956), but the latter shows the less developing rostrum and alveolus. *C. concina* Hou, 1958 is similar to *C. samesi* n. sp. in general carapace/valve outline and the degree of the anterior cardinal angle, but the latter has a more-developed node-like swelling in the anterior cardinal angle area and distinct cyathus. *C. samesi* n. sp. differs from *C. yanjiensis* Gou, 1983 from the Yanji Basin of China by its much broader posterior margin and distinct cyathus.

*C. samesi* n. sp. shows a similar carapace outline with *C. jinjurja* (Fig. 6); therefore, two species seem similar in adult and juvenile morphs. However, *C. samesi* n. sp. does not belong to *C. jinjurja* for the following reasons: (1) Rostrum shape: *C. samesi* n. sp. shows a much longer, broader and moderately acute rostrum, whereas *C. jinjurja* has a very small and blunt shaped rostrum; (2) Alveolus shape: In case of *C. samesi* n. sp., the alveolar notch is considerably broad and moderately incised. Also, the deeply incised alveolar furrow reaches up to 1/5 of

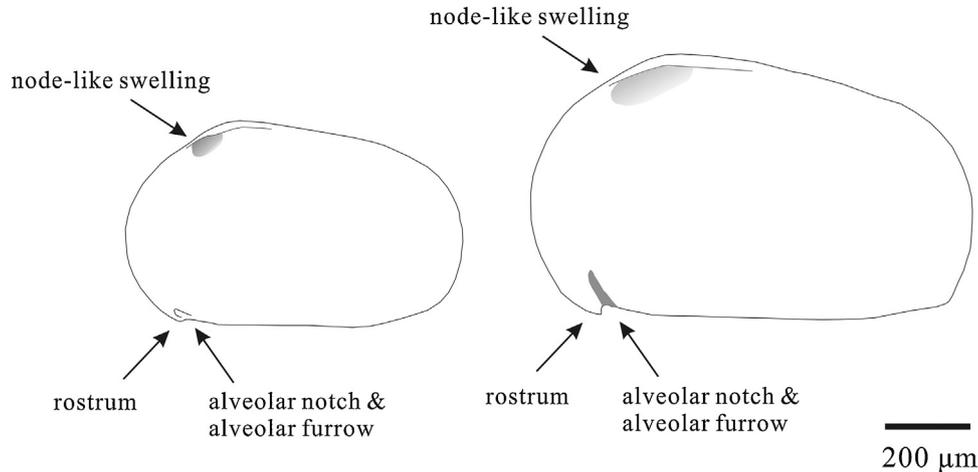


Fig. 6. Line drawings of the outlines and features of *Cypridea jinjuria* (left) and *C. samesi* n. sp. (right).

height in the LV of *C. samesi* n. sp. In contrast, *C. jinjuria* has a weakly developed alveolar notch with a faint and short alveolar furrow; (3) Node-like swelling: It is developed in each valve of *C. samesi* n. sp., whereas *C. jinjuria* has that character only in the LV; (4) Size: At first glance, *C. jinjuria* seems like a juvenile of *C. samesi* n. sp., but the size range (0.79–1.08 mm) of *C. samesi* n. sp. is not much larger than the large specimens of *C. jinjuria* (average length circa 0.8 mm but maximum length less than 0.9 mm). Thus, the size difference is insufficient for separating these species as adult and juvenile; (5) Dorsal outline and dorsal furrow: In dorsal view, the dorsal furrow of *C. jinjuria* is shallow, and less developed than *C. samesi* n. sp. This clearly different development of the dorsal furrow is observed in the similar sized specimens of both species (see Fig. 3G, O; *C. jinjuria* is 0.79 mm, and *C. samesi* n. sp. is 0.89 mm). The dorsal outline of both species is not very different, but *C. jinjuria* is somewhat slender than *C. samesi* n. sp. in outline; (6) Cyathus shape: The cyathus of *C. samesi* n. sp. is somewhat obtuse and more visible, whereas *C. jinjuria* shows an inconspicuous and rounded cyathus; (7) Other morphologic characters: *C. samesi* n. sp. has some minor morphologic characters such as ventrolateral ridge and local ornamentation elements (tubercles). *C. jinjuria* lacks these characters. Also, the diameter of puncta of *C. samesi* n. sp. is larger than in *C. jinjuria*. These are not considered as taxonomically significant features (Sames, 2011a), but nevertheless are clearly different between the two species. For these reasons, we separate these two species.

## 5. Conclusion and discussion

Two *Cypridea* species are recognized in the Jinju Formation of the Gyeongsang Basin, South Korea: *Cypridea jinjuria* and *C. samesi* n. sp. *Cypridea jinjuria* shows a clear rostrum and alveolus (alveolar notch and furrow), but these features had not been described previously. *C. samesi* n. sp. has more distinct features than *C. jinjuria*, such as well-developed rostrum/alveolus, larger puncta, deeply incised dorsal furrow, and distinct cyathus (see above remarks of *C. samesi* n. sp.). Moreover, *C. samesi* n. sp.

exhibits a node-like swelling in the RV, and a weakly developed ventrolateral ridge in the LV.

Both species develop a node-like swelling in the anterior cardinal angle area (only in the LV of *C. jinjuria*, and in both valves in *C. samesi* n. sp.); however, the node-like swelling is identified in *Cypridea jinjuria* for the first time. The term ‘swelling’ for *Cypridea* (also called the node-like swelling in Wang et al., 2017) was first proposed by Wang et al. (2013), and this feature is a protruding bulge slightly below the anterior cardinal angle area as described above. Wang et al. (2013) suggested that this “swelling” in both valves of *C. liaoningensis* may be an eye tubercle. However, the node-like swelling of *Cypridea jinjuria* only develops in the LV (larger valve), even in some other *Cypridea* species such as *C. vitimensis* and *C. concina*. It may be a result of the imprint of the anterior hinge element; a tooth in the smaller RV and the corresponding groove that pushes through the thin larger LV. *C. samesi* n. sp. develops the node-like swelling in both valves, but it is indistinct in the RV. However, its internal characters are unknown thus far; therefore, the internal structure of the node-like swelling in this species remains to be investigated. The swelling is also identified in many different Early Cretaceous *Cypridea* species from East Asia (China and Mongolia), such as *C. vitimensis*, *C. concina*, *C. verrucata*, and *C. gujialingensis* (because of its small sized, node-like tubercle/swelling used in this species from Wang et al., 2017). Some European taxa, such as *Cypridea tumescens acrobeles* and *C. tumescens granulosa* from the ‘Purbeckian’ of Poland (Sztejn, 1991), also show a similar feature (but uncertain). However, the holotypes of subspecies of *C. tumescens* from England do not have the swelling (see Anderson, 1985, pl. 1, figs. 13, 14, 16, *C. tumescens tumescens*, *C. tumescens acrobeles*, and *C. tumescens praecursor*); hence, subspecies of the Polish specimens needs further investigation.

In the Gwanghyeon section, the ostracod fauna consists of a single species — *C. jinjuria*. Ninety-nine percent of the ostracod specimens from the Hotan section are *Cypridea samesi* n. sp. The ostracod fauna from the Jeongchon section contains abundant specimens of *C. samesi* n. sp. and *Mongolocypis kohi*, as well as a few poorly preserved specimens of *Cypridea* spp. and *Candona*

sp. Up to now, we find that *C. jinjuria* and *C. samesi* n. sp. do not co-occur.

The genus *Cypridea* has a stratigraphic range from the Late Jurassic to Palaeogene (Horne and Colin, 2005; Sames, 2011a, 2011c). Like many recent cypridoidean taxa, species of *Cypridea* Bosquet, 1852 are thought to have had resting eggs, enabling them to colonize temporary (ephemeral) as well as permanent water bodies (Horne and Martens, 1998). The three sections of the Jinju Formation, in which two *Cypridea* species occur, may represent such depositional conditions. The deposits outcropped in these three sections were accumulated in an ephemeral environment, because of the lack of taxa of the Darwinulidae and Linnocytheridae (Cytheroidea). Both have brood pouches to care for eggs and juveniles, which confine them to permanent water bodies.

Most *Cypridea* species have been considered to be entirely asexual in their modes of reproduction (e.g., Whatley, 1992) though considerations of sexual dimorphism in *Cypridea* were first reported by Hanai (1951). This assumption is derived mostly from the fact that sexual dimorphism in *Cypridea* has rarely been reported or considered (Sames, 2011a; Wang et al., 2017). According to Sames (2011a, p. 410), some species of the genus *Cypridea* have had mixed reproductive modes. The sexual reproduction mode may indicate more variable environmental conditions with short hydroperiods, and higher habitat stochasticity (Schmit et al., 2013; Wang et al., 2017). The parthenogenetic reproduction mode may indicate environments with long hydroperiods (Schmit et al., 2013; Wang et al., 2017). Two *Cypridea* species from the Gwanghyeon, Jeongchon, and Hotan sections lack obvious sexually dimorphic characters. Therefore, we tend to put them in parthenogenetic populations, which may indicate environmental conditions with long hydroperiods.

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