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Pleistocene decapod crustaceans from the Sahama Mud Member, Hamamatsu Formation, Shizuoka Prefecture, central Japan

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Abstract

Ten species of decapod crustaceans are described from the middle Pleistocene Sahama Mud Member of the Hamamatsu Formation, Shizuoka Prefecture, central Japan. The decapod assemblage is dominated by *Raphidopus ciliatus* Stimpson, 1858, *Asthenognathus inaequipes* Stimpson, 1858, and *Mariaplax* sp. Occurrence of *Xenophthalmus* sp. is not only the first fossil record from Japan but the second fossil evidence for the genus. *Raphidopus ciliatus* extends the known geologic range into the middle Pleistocene of Japan.

Key words: Crustacea, Decapoda, fossil, Hamamatsu Formation, Pleistocene, Sahama Mud Member, Japan

Introduction

The middle Pleistocene Sahama Mud Member of the Hamamatsu Formation consists of loosely consolidated silt and sandy silt that have been deposited in the inner bay environment so called the “Paleo-Hamana Bay” (Irizuki and Seto, 2004), similar to the Recent lagoon Hamana-ko (Fig. 1A). Various fossils have been recorded from this member including foraminifera (Chiji, 1964), ostracods (Irizuki and Seto, 2004), molluscs (Tsuchi, 1960; Isomi and Inoue, 1972; Nobuhara, 2003), vertebrates (e.g. Makiyama, 1924; Nojima et al., 2003; Takahashi et al., 2003), chlorophycean algae and diatom (Matsuoka and Hase, 1977), and plants (e.g. Yoshikawa, 2002; Yoshikawa et al., 2002).

Decapod Crustacea has also been known from the

member. Nomura et al. (1978) reported the occurrences of *Enoplolambrus validus* (De Haan, 1837), *Scylla “serrata”* (Forskål, 1775), *Macrophthalmus japonicus* (De Haan, 1835) and *Hemigrapsus* sp.

Recently, the junior author (KK) collected decapod fossils from two outcrops of the Sahama Mud Member. We here describe these specimens that consists of 10 species of decapod crustaceans including the first fossil record.

The decapod fossils described herein are stored in the Natural History Museum and Institute, Chiba (CBM-PI).

Geological setting

The Hamamatsu Formation distributed in north and east of the Hamana-ko, the western part of Shizuoka

Prefecture, consists of non-marine alluvial deposits and marine to brackish mud layers. The formation is subdivided into the Miyakoda Gravel Member, Tenmabira Mud Member, Hosoe Gravel Member, Sahama Mud Member and Kamoe Gravel Member, in ascending order (Muto, 1987; Sugiyama, 1991) (Fig. 2).

The Sahama Mud Member has a maximum of more than 18 m in thickness (Sugiyama, 1991). Isomi and Inoue (1972) described two key volcanic-ash layers, H-1 and H-2 intercalated in the Sahama Mud Member. On the other hand, Sugiyama (1991) recognized four key ash layers, Ha-4, 5, 6, and 7 in the Sahama Mud Member in ascending order (Fig 2). According to Sugiyama (1991), Ha-6 is correlated to the H-1, but the relationships between Ha-4–Ha-7 and H-2 are confused and unsolved.

Decapod crustaceans were obtained from the two localities (Fig. 1B). SHM-1 is the small outcrops in the river bed of the Higashikandagawa River at Kami-

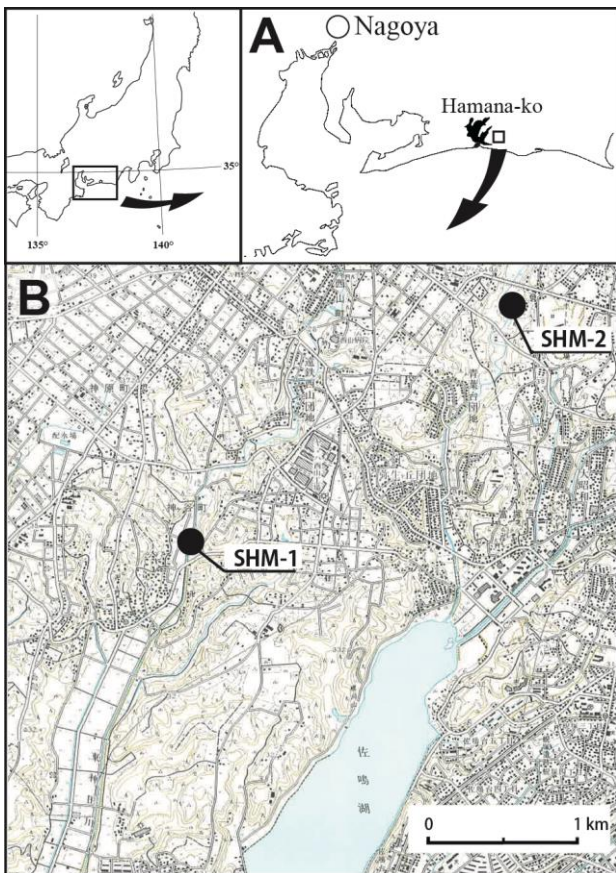


Fig. 1. Index map of studied area (A) and decapod fossil localities in the present study (B). Shaded area in the map A indicates Hamana-ko. The topographic base map is from the 1:25,000 “Hamamatsu” map sheet by GSI.

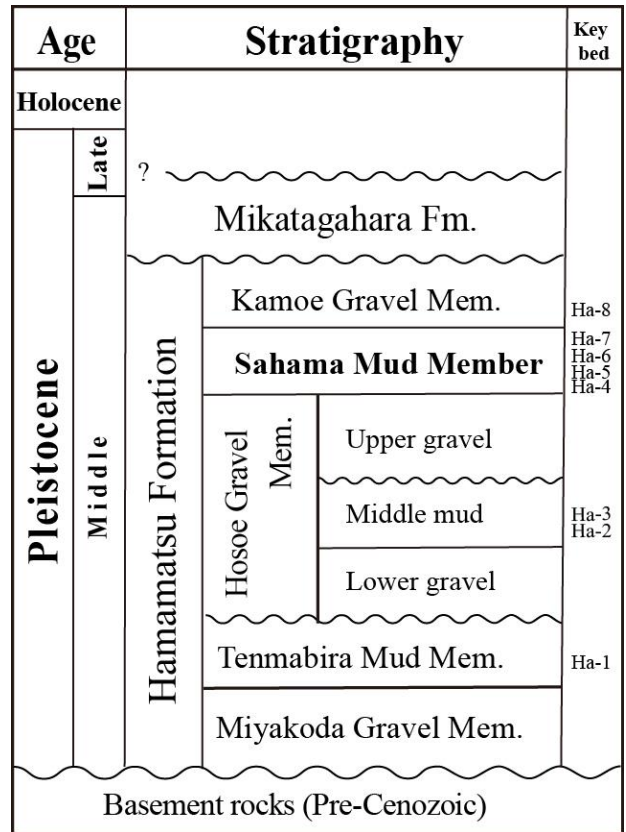


Fig. 2. Stratigraphy of the Hamamatsu Formation. Compiled after Sugiyama (1991), Nakashima et al. (2008) and Nojima et al. (2014).

gaya Town, Hamamatsu City where mainly exposed at the time of the construction for river conservation. SHM-2 is also small outcrops along the Shinkawa River, Wago Town, Hamamatsu City. These decapod-bearing localities are situated about 8 to 10 km south of the decapod fossil sites in Nomura et al. (1978).

Because no key ash layer was found in the present study, detailed stratigraphic horizons of the decapod fossils are unknown. Isomi and Inoue (1972) documented the molluscan assemblage indicative of the muddy bottom of an inner bay represented by the abundant occurrences of *Raeta yokohamensis* and *Theora lubrica* from the several localities nearby SHM-1. They documented the similar molluscan assemblage from approximately 500 m southwest of SHM-2. Moreover, they appended the occurrence of the “crab” from their locality number “18t Tomishin-tanigashi” where is situated about 1.5 km southeast of SHM-2, in association with the muddy bottom inhabitants of mollusks. Unfortunately, the entity of this “crab” is no longer revealed.

Tsuchi (1984) documented the fission track age of 0.39 ± 0.04 Ma from the ash layer in the Sahama Mud Member. Subsequently, Sugiyama (1991) assigned the age of the Sahama Mud Member to the younger part of MIS 7 on the basis of tephrochronology, pollen assemblages and plant fossils. Nakashima et al. (2008) followed this interpretation and correlated the Ha-4 to the BT51 tephra (Yoshikawa and Inouchi, 1991) which was estimated at 0.216 Ma (Nagahashi et al., 2004). Recently, Nojima et al. (2014) deduced the geologic age of Ha-4 to the MIS 7.3 in the tephrochronological study of the Hamamatsu area.

Systematic Paleontology

Order Decapoda

Infraorder Anomura MacLeay, 1838

Superfamily Galatheoidea Samouelle, 1819

Family Porcellanidae Haworth, 1825

Genus *Raphidopus* Stimpson, 1858

Geologic range: Middle Pleistocene to Recent.

Raphidopus ciliatus Stimpson, 1858

(Figs. 5.1–3)

Material examined: CBM-PI 2860–2863, 2865, 2873, 2874, 2877–2880, 3439, 3441, 3454, 3456, 3460, 3461, 3464, 3465 (carapace).

Description: Carapace ovoid; vaulted longitudinally and transversely; width 1.21–1.45 times length (Fig. 3). Fronto-orbital margin narrow. Frontal margin bluntly trilobed; tips weakly projecting anteriorly. Anterolateral margin convex, divided into two parts by deep, V-shaped anterolateral cleft; bearing several minute epibranchial spines. Branchiocardiac groove distinct. Shallow groove branching from branchiocardiac groove, running parallel to anterolateral cleft. Branchial region transversely rugose.

Remarks: The present specimens are identical to *Raphidopus ciliatus* by having the carapace with distinct V-shaped anterolateral cleft and several minute epibranchial spines. *Raphidopus ciliatus* is one of the dominant species in the present materials, representing by the carapaces of variable size (Fig. 3).

The only fossil record for this genus previously known is two isolated dactyli of unidentified species

from the middle Pleistocene Atsumi Group (Karasawa et al., 2014). The extant *R. ciliatus* is widely distributed in the Indo-Pacific from Pakistan to Japan (Osawa and Ng, 2018). In addition to the free living on the muddy bottom, *R. ciliatus* is occurred in the burrows of holothurian and polychaetes (Miyake, 1978, 1982; Ng and Nakasone, 1994; Osawa and Ng, 2018).

Occurrences: SHM-1 and SHM-2.

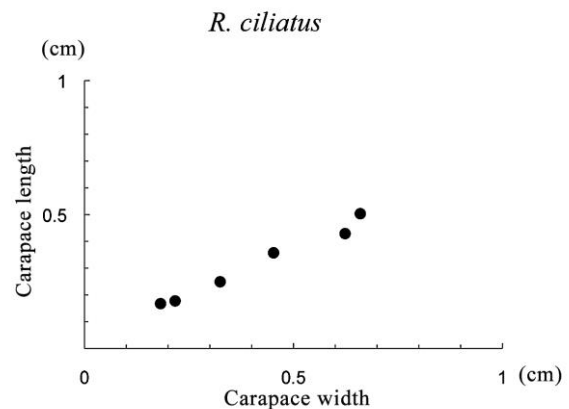


Fig. 3. Relationship of the maximum carapace width and length of fossils of *Raphidopus ciliatus* Stimpson, 1858.

Section Eubrachyura de Saint Laurent, 1980

Subsection Heterotremata Guinot, 1977

Superfamily Dorippoidea MacLeay, 1838

Family Dorippidae MacLeay, 1838

Genus *Heikeopsis* Ng, Guinot and Davie, 2008

Geologic range: Pleistocene to Recent.

?*Heikeopsis* sp.

(Fig. 5.4)

Material examined: CBM-PI 2886 (carapace).

Description: A fragmentally, external mold of carapace was obtained. Frontal margin with bilobed, triangular rostral spine. Orbital fissure present. Outer orbital spine less projected than rostral one. Dorsal regions moderately convex, smooth, without nodes or tubercles. Cervical, branchial, and branchiocardiac grooves distinct. Anterolateral margin rimmed in between outer orbital spine and outer margin of epibranchial lobe.

Remarks: The carapace has typical characters of the Dorippidae and the dorsal surface is smooth without

nodes or tubercles. Because the detailed features of fronto-orbital margin and appendages are not available, precise identification is difficult.

Occurrence: SHM-1.

Superfamily Portunoidea Rafinesque, 1815

Family Portunidae Rafinesque, 1815

Portunidae gen. et sp. indet. 1

(Fig. 5.17)

Material examined: CBM-PI 3449 (fingers of right chela).

Description: Distal part of dactylus and fixed finger of right cheliped relatively slender; tips curved inward. Occlusal margins of both fingers armed with large, triangular teeth. Preserved distal part of outer surface of fingers exhibiting generally smooth without distinct longitudinal carina or groove; medial surface with a shallow longitudinal groove medially.

Remarks: The external mold of the distal parts of the fingers of right cheliped were obtained. Large, relatively slender fingers resemble those of the genus *Portunus* Weber, 1795 rather than the thick, broad triangular fingers of the genus *Scylla* De Haan, 1833. Although the preservation is not enough to determine, the present fingers also dissimilar to those of the genera *Charybdis* De Haan, 1833 and *Thalamita* Latreille, 1829 by lacking a distinct longitudinal groove and carina. Among the living species of *Portunus*, the present fingers are similar to those of *P. trituberculatus* (Miers, 1876) in the surface ornamentation and dentition of occlusal margins.

Occurrence: SHM-1.

Portunidae gen. et sp. indet. 2

(Pl. 1; Fig. 5.16)

Material examined: CBM-PI 3448 (fixed finger of left chela).

Description: A slender, relatively long fixed finger with a distinct longitudinal groove on medial surface. Occlusal margin with triangular spines.

Remarks: The general shape and the longitudinal groove on medial surface is typical for the fingers of Portunidae, and apparently differs from Portunidae gen. et sp. indet. 1.

Occurrence: SHM-1.

Superfamily Goneplacoidea MacLeay, 1838

Family Goneplacidae MacLeay, 1838

Genus *Entricoplax* Castro, 2007

Geologic range: Middle Pleistocene to Recent.

***Entricoplax vestita* (De Haan, 1833)**

(Figs. 6.1, 2)

Material examined: CBM-PI 2890 (right manus), 3463 (carapace).

Description: A carapace rounded hexagonal in outline, moderately swollen; widest at between last anterolateral spine; width excluding third anterolateral spine about 1.37 times its length. Fronto-orbital margin poorly preserved. Three anterolateral spines of carapace broken.

Large right manus lacking distal part of fixed finger. Palm trigonal in cross section. Slightly crushed upper surface broad with scattered minute papillae. Lower part of lateral and medial surfaces smooth. Lower part of medial surface strongly swollen proximally; thinning distally and forming a remarkable concavity at basal part of fixed finger. Fixed finger relatively slender, strongly curved inward. Aligned hollows had being bases of small conical occlusal teeth; no molar-shaped tooth.

Remarks: In addition to a relatively large carapace, a large right palm is identical with that of the extant *E. vestita*. The upper surface of the palm that is considered to have had been pubescent in living time, bears the dense, minute papillae. Fossil records of the present species have been known from the middle Pleistocene Ogushi Formation, Kyushu (Ando et al., 2015), and the Holocene of Chiba Prefecture (Kato, 2017) and Aichi Prefecture (Umemoto and Karasawa, 1998).

Occurrence: SHM-1.

Family Euryplacidae Stimpson, 1871

Genus *Eucrate* De Haan, 1835

Geologic range: Oligocene to Recent.

***Eucrate* sp.**

(Fig. 6.6)

Material examined: CBM-PI 3447 (carapace).

Description: Carapace hexagonal. Frontal margin straight with a faint median sulcus. A notch existing between lateral end of frontal margin and orbital margin. Orbital margin concave; indistinct two closed orbital fissures, where margin slightly undulated. Three anterolateral spines including blunt outer orbital spine; second one smallest; third one has a tip broken but a broad base. Dorsal surface of carapace moderately convex; regions poorly defined.

Remarks: A relatively large carapace identified with *Eucrate* was obtained. Although the morphology of the anterior and anterolateral margins of the carapace coincide with those of the genus, the incomplete posterior part of the carapace seems more narrowing posteriorly than the living *Eucrate* species. Therefore, additional specimens including well-preserved carapace are indispensable for the precise identification.

Occurrence: SHM-1.

Superfamily Hexapodoidea Miers, 1886

Family Hexapodidae Miers, 1886

Genus *Mariaplax* Rahayu and Ng, 2014

Geologic range: Middle Pleistocene to Recent.

Remarks: Rahayu and Ng (2014) defined 16 genera within the family Hexapodidae Miers, 1886, and re-classified the entities of the several known species of the family. In that study, they moved *Hexapus anfractus* De Haan, 1833 to their new genus *Mariaplax*. Moreover, they showed that *H. anfractus* known from Japan was not conspecific. Fossils of *Hexapus anfractus* have been recorded from the Japanese Pleistocene and Holocene deposits (Kaneko, 1958; Kaneko and Kajiyama, 1962; Tokai Fossil Society, 1977; Kato and Koizumi, 1992; Karasawa et al., 2014). However, the identification of the species within *Mariaplax* requires the detailed characters of the third maxillipeds, male thoracic sternites and abdominal somites and is not easy in the fossil material.

Mariaplax sp.

(Figs. 5.5–11, 18)

Material examined: CBM-PI 2852, 2853, 2857, 2868–2870, 3444, 3445, 3451, 3462 (carapace), 2851

(carapace, male thoracic sternum), 2871 (male thoracic sternum), 2858 (female thoracic sternum), 3440 (impression of thoracic sternum and pereopods), 2866 (female thoracic sternum, abdomen, pereopods).

Description: Carapace quadrilateral, much wider than long; width 1.27–1.66 times length (mean = 1.47, n = 10, Fig. 4). Fronto-orbital margin almost 40 percent of maximum carapace width. Lateral margin slightly convex. Dorsal surface smooth, median H-shaped groove distinct. Left chela short, thick with sparse minute spines on lateral surface of manus. Lateral surface of merus of pereopod 4 exhibits a longitudinal groove medially.

Male sterno-abdominal cavity widening on suture between sternites 4 and 5, narrowing proximally on sternite 5. Sternal groove deep, extending beyond middle of sternite 4. Male abdomen narrow.

Female thoracic sternum broad; sterno-abdominal cavity widest around border of somites 5 and 6. Female abdomen moderately broad for genus, with 6 somites and subtriangular telson.

Remarks: Although the present material is generally well preserved, key characters adopted in Rahayu and Ng (2014), including the male abdominal somites and third maxillipeds, can not be observed. Therefore, determination of species has to be awaited further material.

Occurrences: SHM-1 and SHM-2.

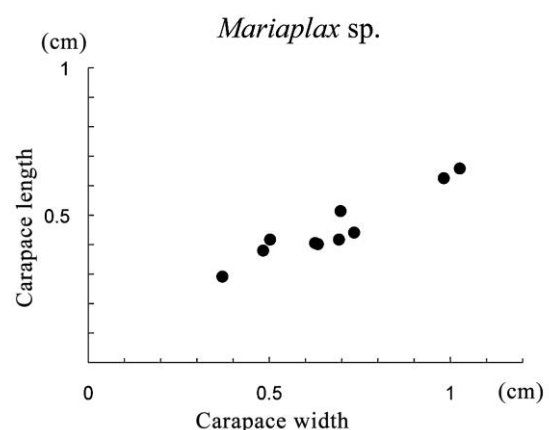


Fig. 4. Relationship of the maximum carapace width and length of fossils of *Mariaplax* sp.

Subsection Thoracotremata Guinot, 1977

Superfamily Grapsoidea MacLeay, 1838

Family Varunidae H. Milne Edwards, 1853

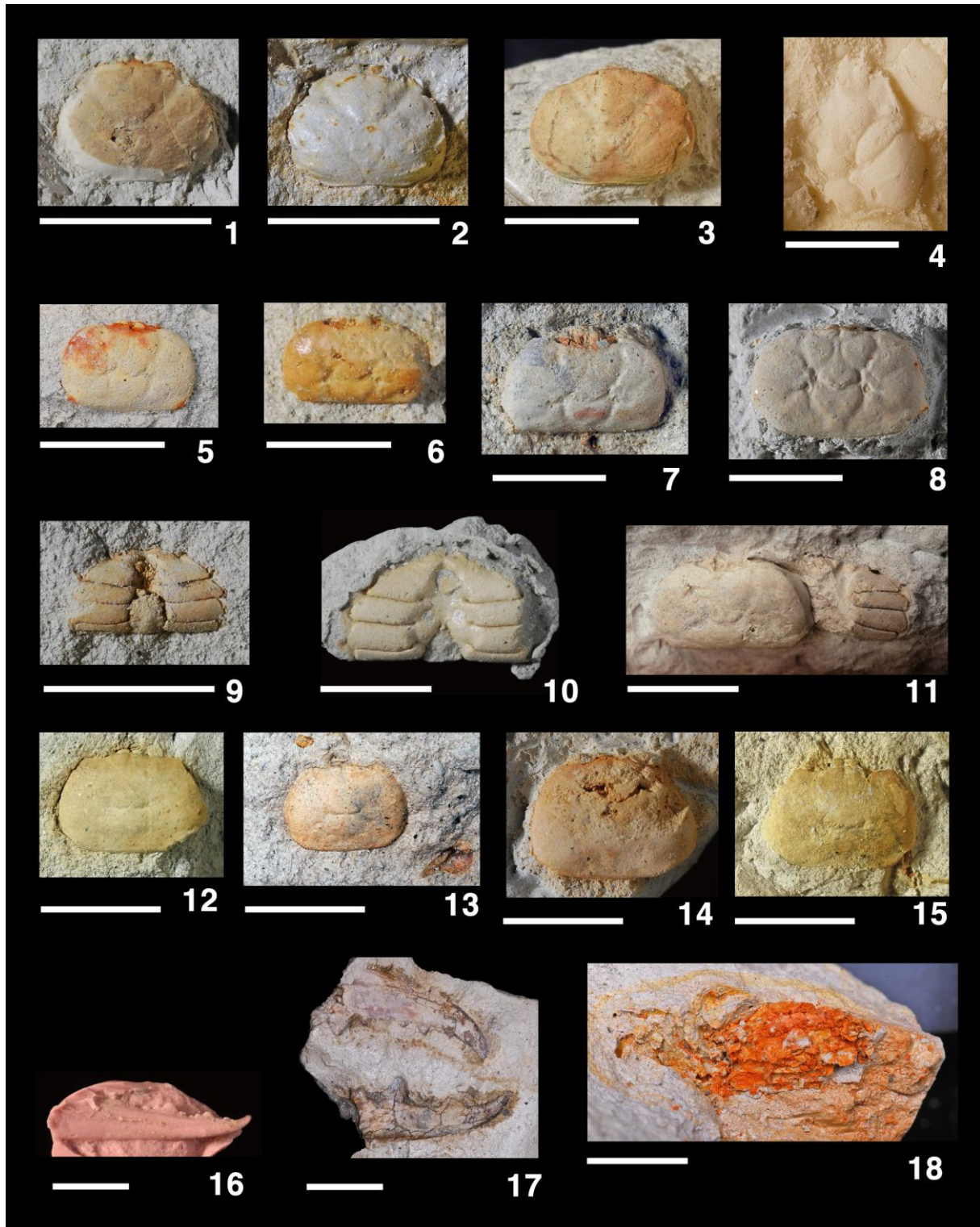


Fig. 5. 1–3. *Raphidopus ciliatus* Stimpson, 1858. Carapace. 1, CBM-PI 2874, SHM-1; 2, CBM-PI 2863, SHM-2; 3, CBM-PI 2860, SHM-1. 4. *?Heikeopsis* sp. Carapace (silicone cast). CBM-PI 2886, SHM-1. 5–11, 18. *Mariaplax* sp. 5–8, carapace. 5, CBM-PI 3444, SHM-1; 6, CBM-PI 2852, SHM-1; 7, CBM-PI 2869, SHM-1; 8, CBM-PI 2870, SHM-1. 9, male thoracic sternum and abdomen. CBM-PI 2871, SHM-1; 10, female thoracic sternum. CBM-PI 2858, SHM-1; 11, male carapace and thoracic sternum. CBM-PI 2851, SHM-1; 18, impression of thoracic sternum, abdomen and pereopods. CBM-PI 3453, SHM-1. 12–15. *Asthenognathus inaequipes* Stimpson, 1858. 12, 14, 15, carapace. 12, CBM-PI 2875, SHM-1; 14, CBM-PI 2839, SHM-1; 15, CBM-PI 2882, SHM-1. 13, carapace and external mold of right manus. CBM-PI 3446, SHM-1. 16. *Portunidae* gen. et sp. indet. 2. Medial surface of fixed finger of left cheliped (silicone cast). CBM-PI 3448, SHM-1. 17. *Portunidae* gen. et sp. indet. 1. Medial surfaces of dactylus and fixed finger of right cheliped. CBM-PI 3449, SHM-1. Scale bars = 1–15, 18: 5 mm; 16, 17: 10 mm.

Genus *Asthenognathus* Stimpson, 1858

Geologic range: Eocene to Recent.

***Asthenognathus inaequipes* Stimpson, 1858**

(Figs. 5.12–15)

Material examined: CBM-PI 2852, 2854, 2855, 2859, 2875, 2882, 3442, 3443, 3457 (carapace), 2883, 2885, 3446, 3455, 3458 (carapace with fragments of pereopods).

Description: Carapace rounded hexagonal; longitudinally strongly vaulted and transversely moderately swollen; wider than long; ratio between maximum length and maximum width almost 1.3–1.35. Frontal margin about 20 percent of maximum carapace width. Rostrum bilobed with medial longitudinal furrow. Dorsal surface smooth. Anterolateral margin diverging posteriorly; fringed by a faint ridge of rows of granules that branched and one extending inward onto branchial region. A small facet existing at angle between antero- and posterolateral margins. Posterior margin almost straight; slightly broader than fronto-orbital margin.

Ambulatory legs relatively long.

Remarks: The fossil records of the extant species *A. inaequipes* are relatively rich in the Holocene deposits in Japan (Kaneko, 1958; Kaneko and Kajiyama, 1962; Tokai Fossil Society, 1977; Umemoto et al., 1994). *Asthenognathus* cf. *inaequipes* is also recorded in the list of decapod species from the middle Pleistocene Takamatsu Formation, Atsumi Group (Karasawa et al., 2014). In addition to three extant species, 9 species are documented from the Eocene to Pleistocene of North and South America, Europe and Japan (see Karasawa, 2018).

The extant *A. inaequipes* lives in the muddy bottom of depth of 10 to 65 m of Japan (Sakai, 1976), Korea (Lee et al., 2010) and East China Sea (Jiang et al., 2007). As are often case with *Rahidopus ciliatus* and ‘*Mariaplax anfractus*’, this species is also known from the holothurian burrow (Kai and Henmi, 2008; Lee et al., 2010).

Occurrences: SHM-1 and SHM-2.

Genus *Hemigrapsus* Dana, 1851

Geologic range: Pleistocene to Recent.

?*Hemigrapsus* sp.

(Fig. 6.5)

Material examined: CBM-PI 2889 (carapace, thoracic sternum, pereopods).

Description: Carapace hexagonal in outline. Frontal margin broad, straight with a shallow median longitudinal depression. Orbital margin broad, rounded concavity. Anterolateral margin with two or three triangular spines.

Male thoracic sternum hexagonal in outline. Male abdominal somites narrow.

Merus of ambulatory legs slender. Length of carpus plus manus of P3 and P4 almost equal or slightly shorter than merus.

Remarks: In addition to the general outline of carapace, thoracic sternum, abdomen and pereopods are recognized. Although these preserved portions resemble those of *Hemigrapsus* spp., the detailed morphologies are unclear so that further identification is difficult. Nomura et al. (1978) also recorded a carapace of *Hemigrapsus* sp. which is larger than the present specimen (21 × 23 mm), from the Sahama Mud Member. However, their description without figures is not enough to compare it with the present specimen.

Occurrence: SHM-1.

Superfamily Ocypodoidea Rafinesque, 1815

Family Xenophthalmidae Stimpson, 1858

Genus *Xenophthalmus* White, 1846

Geologic range: Pliocene to Recent.

***Xenophthalmus* sp.**

(Figs. 6.3, 4)

Material examined: CBM-PI 2856 (external mold of carapace and pereopods), 2884 (carapace, thoracic sternum, pleonites and right pereopods).

Description: Carapace subtrapezoidal; wider than long; surface evenly punctuated. Fronto-orbital margin narrow, less than 20 percent of maximum carapace width. Orbits extending longitudinally on dorsal surface of carapace. Longitudinal sulci running from posterior end of orbit and demarcate lateral margin of gastric regions. Anterolateral margin rounded, diverging posteriorly, sharply rimmed with fine granules.

Female thoracic sternum broad; sternite 5 much longer than 6; shallow sterno-abdominal cavity.

Merus and carpus of cheliped short. Pereopods 3

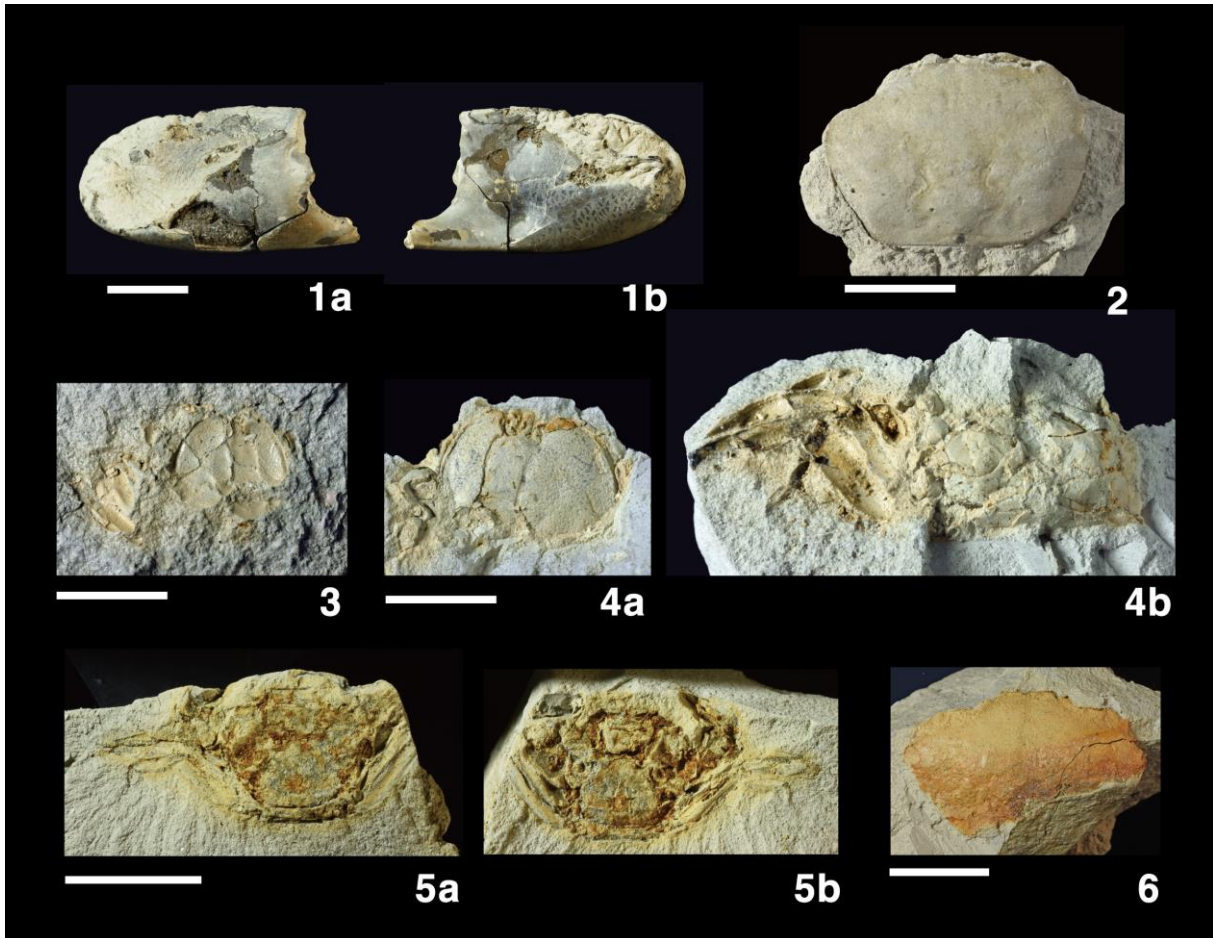


Fig. 6. 1, 2. *Entricoplax vestita* (De Haan, 1833). 1a and 1b, lateral and medial surfaces of right chela. CBM-PI 2870, SHM-1. 2, carapace, CBM-PI 3463, SHM-1. 3, 4. *Xenophthalmus* sp. 3, external mold of the carapace and pereiopods. CBM-PI 2856, SHM-1. 4a, dorsal surface of carapace; 4b, abdomen, thoracic sternum and pereiopods, CBM-PI 2884, SHM-1. 5. *?Hemigrapsus* sp. 5a and 5b: impression of thoracic sternum, abdomen, and pereiopods. CBM-PI 2889, SHM-1. 6. *Eucrate* sp. Carapace. CBM-PI 3447, SHM-1. Scale bars = 1, 2, 5, 6: 10 mm; 3, 4: 5 mm.

and 4 with broad meri and carpi with a row of granules on anterior margin; propodi with two rows of granules and a single groove along upper margin.

Remarks: Based on characteristic shape of the orbit and general morphology of the carapace, the present specimens are assigned to *Xenophthalmus*. However, species identification is difficult because of the incompleteness of several diagnostic characters such as the frontal region and posterolateral and posterior margins of the carapace. This is the first fossil record for the genus from Japan. The only fossil record of the genus is *X. subitus* Morris and Collins, 1991 from the Pliocene of Indonesia (Morris and Collins, 1991; Collins et al., 2003). Living species of the genus comprises *X. pinnotheroides* White, 1846 and *X. wolffi* Takeda and Miyake, 1970. The former is widely

known from the muddy bottom in the Indo-West Pacific (Griffin and Campbell, 1969) and the latter is recorded from the Persian Gulf to northern Arabian Sea (Ghani and Tirmizi, 1995) and India (Padate et al., 2018).

Occurrence: SHM-1.

Concluding remarks

The decapod fossils obtained in the present study are dominated by three species, *Raphidopus ciliates*, *Asthenognathus inaequipis* and *Mariaplax* sp. Of approximately 70 total specimens, these species account for 55 specimens. The former two species are known as the muddy bottom inhabitants (Ng and Nakasone, 1994; Sakai, 1976) in a shallow marine, inner bay environment. The genus *Mariaplax* is also considered to

be the inhabitant of the muddy bottom (Rahayu and Ng, 2014) or the very fine sand (Naruse et al., 2017) in the littoral to shallow water. Most of the associated species are consistent with the same or similar environment.

Interestingly, these dominant three species are not appeared in the list of the extant decapod crustaceans living in the Hamana-ko (Hamanako Branch, Shizuoka Prefectural Research Institute of Fishery, 2019). None of *Raphidopus* and *Asthenognathus* as well as hexapodid crabs are documented in the total approximately 110 species of anomuran and brachyuran decapods from the Hamana-ko. This inconsistency may reflect the differences of environmental conditions between the Recent Hamana-ko and “Paleo-Hamana Bay” (e.g. Irizuki and Seto, 2004).

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