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New varunids (Decapoda: Brachyura) from the Miocene Bihoku Group, Japan, with descriptions of one new genus and two new species

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Abstract

Two new species of varunid crabs (Brachyura, Grapsoidea) are described from the Bihoku Group (early to middle Miocene), southwest Japan. *Sakakurapus*, a new monotypic genus from Niimi City in Okayama Prefecture is proposed for *Sakakurapus kogisorum*, new species. The new genus is related to members of Asthenognathinae and Gaeticinae. *Asthenognathus sakumotoi*, a new species of Asthenognathinae from Miyoshi City in Hiroshima Prefecture is the second record for the genus from the Miocene of Japan.

Key wards: Decapoda, Brachyura, Varunidae, Miocene, Bihoku Group, Japan

Introduction

The Miocene Bihoku Group (Imamura *et al*., 1953) is distributed in the western part of Okayama Prefecture and the eastern part of Hiroshima Prefecture, southwest Honshu, Japan. This formation contains rich decapod fossils (Karasawa and Nishikawa, 1991; Karasawa, 1993; Karasawa, 1997; Sakumoto, 1997; Sakumoto, 2001). Sakumoto (2001) reported 13 species of decapods and recognized five types of tropical-subtropical, shallow, marine decapod assemblages.

The purpose of this paper is to describe one new genus and two species of varunid crabs (Brachyura, Grapsoidea) from the Bihoku Group. The specimens representing a new genus and new species were collected from the Lower Sandstone Member of the Bihoku Group in Nishikata, Niimi City, Okayama Prefecture [=Loc. BIH-3 of Karasawa (1993)]. *Callianassa nishikawai* Karasawa, 1993 (Axiidea: Callianassidae) is the predominant decapod at the present locality; therefore, Sakumoto (2001) suggested a depositional environment within an intertidal zone of muddy bottom based upon the decapod assemblage. The type specimens of a new asthenognathine species occurred from Kamifuno, Funo-cho, Miyoshi City, Hiroshima Prefecture [=Loc. 2, Funo, of Sakumoto (2001)]. Sakumoto (2001) recognized a *Miosesarma japonicum*-dominated assemblage at the locality and considered that the sediments containing decapods were deposited within an upper sublittoral to a lower sublittoral zone of muddy bottom. The geologic age of the Lower Sandstone Member of the Bihoku Group was the early to middle Miocene (17–14.9 Ma) based upon planktonic microfossils (Goto *et al*., 2013).

The described specimens are housed in the Mizunami Fossil Museum (MFM).

Systematics

Family Varunidae H. Milne Edwards, 1853

Remarks: Since Ng *et al*. (2008) and De Grave *et al*. (2009) classified Varunidae into five subfamilies, Asthenognathinae Stimpson, 1858, Cyclograpsinae H. Milne Edwards, 1853, Gaeticinae Davie and N. K. Ng, 2007, Thalassograpsinae Davie and N. K. Ng, 2007, and Varuninae, most subsequent workers have accepted their subdivisions to the family. Števčić (2013) alone used a different scheme to Varunidae and treated Varunidae as a grapsid subfamily together with Gaeticinae and Cyclograpsinae. He elevated Asthenognathinae to full family status. Kitaura *et al*. (2010) questioned the monophyly of varunid subfamilies, Cyclograpsinae, Gaeticinae, Thalassograpsinae, and Varuninae, based upon the molecular analysis. Within the other works using molecular analyes the subfamilies were not monophyletic (Kitaura *et al*,, 2002; Schubart *et al*., 2002; Schubart *et al*., 2006; N. K. Ng *et al*., 2007; Tang *et al*., 2017). Karasawa and Kato (2001) suggested the monophyly of Varuninae and Cyclograpsinae under their Grapsidae using a morphology-based cladistic analysis.

Komai and Konishi (2012) transferred *Pseudopinnixa* Ortmann, 1894, from Pinnotheridae de Haan, 1833, to Gaeticinae within Varunidae, while Naruse (2015) did not refer the genus to his gaeticine revision. Palacios Theil *et al*. (2009) and Palacios Theil *et al*. (2016) showed, using a

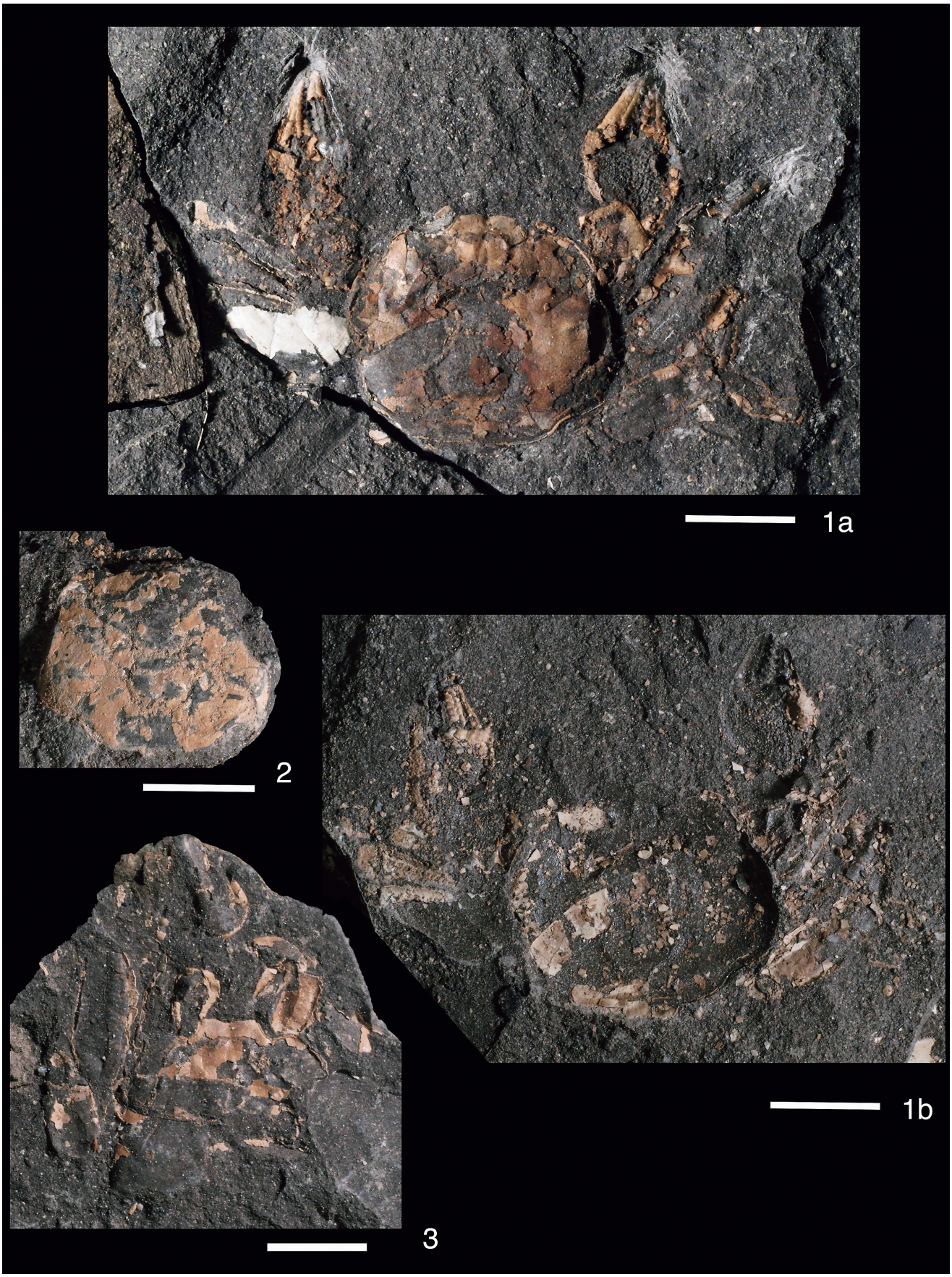


Fig. 1. **1–3. *Sakakurapsus kogisorum*, new genus and species.** ***1a,*** holotype (MFM39021), carapace and pereiopods, dorsal view; ***1b,*** reversal image of cast of holotype; ***2,*** paratype (MFM39022), carapace, dorsal view; ***3,*** paratype (MFM39023), carapace and pereiopods, dorsal view. Scale bar = 5 mm.

molecular analysis, that the monophyletic Asthenognathinae containing only one genus *Asthenognathus*, was the derived sister to Varunidae. However, *Pseudopinnixa* occupied the most basal position within Pinnotheroidea de Haan, 1833 (Palacios Theil *et al*., 2009; Palacios Theil *et al*., 2016). Thus, the subfamilial divisions within Varunidae are confused and a phylogenetic analysis must be conducted including representatives from all recognized extant genera of the family. At this time, the currently known five subfamilies are treated as valid taxa.

Genus *Sakakurapsus*, new genus

Type species: *Sakakurapsus kogisorum*, new species, by monotypy; neuter gender.

Diagnosis: Small-sized varunid. Carapace trapezoidal in outline, widening posteriorly, length about 90% maximum carapace width. Fronto-orbital margin about 55% maximum carapace width, weakly rimmed; front narrow, projected forward, with shallow median sulcus; frontal margin composed of gently arched lobes, medially interrupted by shallow V-shaped sulcus; anterior margin divided from lateral margins by subtle notch; orbits small; upper orbital margin entire, slightly concave, continuing to straight, divergent lateral margin of front. Anterolateral margins gently arched, diverging posteriorly, weakly rimmed; posterolateral margins not confluent with anterolateral margins, strongly sinuous, converging posteriorly. Posterior margin slightly wider than fronto-orbital margin, nearly straight, weakly rimmed. Dorsal surface smooth, gently convex; regions poorly defined; anterior epigastric regions weakly raised transversely; mesogastric and cardiac regions defined by shallow grooves; other regions not well differentiated; subtle oblique ridge extending to lateral margin forming posterolateral facet. Chelipeds equal, similar in shape; both occlusal surfaces of fingers with broadly triangular teeth regularly arranged.

Etymology: The name is dedicated to F. Sakakura (Nagoya, Aichi) who is one of my colleagues.

Discussion: The new genus is similar to *Asthenognathus*, a sole included genus of Asthenognathinae in the general shape of the carapace, but it differs in the occlusal margins of both chelipeds with clearly defined broadly triangular teeth arranged regularly. The carapace in the new genus is much longer than that of *Asthenognathus*. *Asthenognathus* has a moderately vaulted dorsal carapace, not seen in *Sakakurapsus*. The new genus resembles two gaeticine genera, *Proexotelson* Naruse, 2015, from the Ryukyu Islands, Japan (Maenosono and Naruse, 2016) and *Sestrostoma* Davie and P. K. Ng, 2007, from Japan, Taiwan, and China (Davie and P. K. Ng, 2007). However, the new genus has a trapezoidal carapace with rather well defined mesogastric and cardiac regions and has the anterior margin of the front, separated from the lateral margin by a subtle notch. *Sakakurapus* also bears resemblance with *Pseudopinnixa* from Japan, a gaeticine genus *fide* Komai and Konishi (2012), but it differs in that the anterior margin of the front is separated from the lateral margin by a subtle notch and the occlusal margins of both chelipeds bear well-defined triangular teeth.

The genera of Varuninae and Thalassograpsinae have well-defined anterolateral teeth of the carapace, but the anterolateral margins of *Sakakurapus* are entire. Although some members of *Cyclograpsus* H. Milne Edwards, 1837 (Cyclograpsinae) have a trapezoidal carapace, these have a carapace with a wide front and with weak anterolateral teeth, lacking in the new genus.

Thus, *Sakakurapus* might be included in Asthenognathinae or Gaeticinae; however, the ventral aspects, which are important characters to identification of the subfamilial divisions, are not preserved. Therefore, the new genus cannot be assigned to any subfamily with certainly.

Sakakurapsus kogisorum, new species

(Figs. 1.1–1.3)

Diagnosis: As for the genus.

Etymology: This species is named for the family of Futamu Kogiso and his wife Akiko, who kindly helped me and my family for last five years.

Description: Small-sized varunid. Carapace trapezoidal in outline, widening posteriorly, wider than long, length about 90% maximum carapace width, widest at about 68% the distance from front. Fronto-orbital margin about 55% maximum carapace width, weakly rimmed. Front narrow, about 20% maximum carapace width, projected forward, slightly downturned, with shallow median sulcus; frontal margin bilobed, consists of gently convex lobes, medially interrupted by shallow V-shaped sulcus; anterior margin divided from lateral margins by subtle notch. Orbits small; upper orbital margin entire, slightly concave, continuing to straight, divergent lateral margin of front, with bluntly angular outer-orbital angle. Anterolateral margins gently arched, diverging posteriorly, weakly rimmed. Posterolateral margins not confluent with anterolateral margins, strongly sinuous, converging posteriorly. Posterior margin slightly wider than fronto-orbital margin, about 60% maximum carapace width, nearly straight, weakly rimmed, with gently convex lateral corner. Dorsal surface smooth, gently vaulted; regions poorly defined; anterior epigastric regions weakly raised transversely; mesogastric region pyriform, separated from protogastric regions by shallow grooves; cardiac region transversely hexagonal, wider than long, defined by shallow grooves; other regions not well differentiated; subtle oblique ridge extending to lateral margin forming posterolateral facet.

Chelipeds equal, similar in shape. Propodus about 0.7 times as long as high, smooth on surfaces; dorsal and ventral margins unarmed. Fixed finger slightly shorter than palm with shallow grooves parallel to occlusal and ventral margins; occlusal surface with broadly triangular teeth regularly arranged. Dactylus slightly longer than fixed finger with shallow groove parallel to occlusal margin; dorsal margin unarmed; occlusal margin bearing broadly triangular teeth arranged regularly. Carpus short, about as long as high, about 33% propodus length, smooth laterally. Merus much longer than high.

Pereiopods long, flattened in lateral view.

Remarks: Karasawa (1997) identified the present species with Chasmocarcininae gen. et sp. indet (Karasawa, 1997; p. 62, pl. 23, fig. 11). However, re-examination of his material with additional material moves it to Varunidae, as discussed above.

Material examined: Holotype (MFM39021), paratypes (MFM39022, MFM39023).

Occurrence: Nishikata, Niimi City, Okayama Prefecture [=Loc. BIH-3 of Karasawa (1993)]; Lower Sandstone Member of the Bihoku Group [early to middle Miocene, 17–14.9 Ma by Goto *et al*. (2013)].

Subfamily Asthenognathinae Stimpson, 1858

Genus *Asthenognathus* Stimpson, 1858

Type Species: *Asthenognathus inaequipes* Stimpson, 1858, by monotypy.

Included Species: *Asthenognathus alleronensis* Pasini, Garassino, and De Angeli, 2017 (Pleistocene); *A. atlanticus* Monod, 1933 (extant); *A. australensis* Feldmann, Schweitzer, Casadío, and Griffin, 2011 (Miocene); *A. cornishorum* Schweitzer and Feldmann, 1999 (Oligocene–Miocene); *A. globosum* (Karasawa, 1990) (Miocene); *A. inaequipes* Stimpson, 1858 (extant); *A.* sp. cfr. *A. inaequipes* Stimpson, 1858 (Pleistocene) (Karasawa *et al*., 2014); *A. laverdensis* De Angeli and Garassino, 2006 (Oligocene); *A. microspinus* Casadío, De Angeli, Feldmann, Garassino, Hetler, Parras, and Schweitzer, 2004 (Oligocene); *A. urretae* Schweitzer and Feldmann, 2001 (Oligocene–Miocene).

***Asthenognathus sakumotoi*, new species**

(Figs. 2.1–5, 3.1–3)

Diagnosis: Large-sized *Asthenognathus*, Carapace trapezoidal in outline, widening posteriorly, length about 80% maximum carapace width. Fronto-orbital margin about 55% maximum carapace width, weakly rimmed; front narrow, projected forward, downturned, with shallow median depression; frontal margin composed of slightly convex lobes divided by shallow median notch; orbit small, upper orbital margin entire, nearly straight, continuing to straight, divergent lateral margin of front. Infraorbital ridge present, unarmed. Anterolateral margins gently arched, diverging posteriorly, weakly rimmed; subtle cervical notch present; posterolateral margins not confluent with anterolateral margins, strongly convex, converging posteriorly. Posterior margin narrower than fronto-orbital margin, about half length of maximum carapace width, nearly straight, weakly rimmed. Dorsal surface smooth, moderately vaulted longitudinally and transversely; regions poorly defined; epigastric regions weakly raised transversely; mesogastric and cardiac regions defined by shallow grooves; other regions not well differentiated; small hole present at anterior junction of protogastric and hepatic regions behind upper orbital margin; subtle ridge extending from cardiac region anterolaterally to lateral margin; feeble oblique ridge extending to lateral margin forming posterolateral facet. Chelae of chelipeds unequal in size; occlusal surfaces minutely dentate with median triangular tooth.

Etymology: In honor of T. Sakumoto, a senior researcher who studied decapods from the Bihoku Group.

Description: Carapace large-sized for *Asthenognathus*, trapezoidal in outline, widening posteriorly, wider than long, length about 80% maximum carapace width, widest at about 72% the distance from front. Fronto-orbital margin about 55% maximum carapace width, weakly rimmed. Front narrow, about 23% maximum carapace width, projected forward, downturned, with shallow median depression; frontal margin bilobed, composed of slightly convex lobes divided by shallow median notch. Orbit smalls, shallow; upper orbital margin entire, nearly straight dorsally, gently convex anteriorly, continuing to straight, divergent lateral margin of front, with bluntly angular outer-orbital angle. Infraorbital ridge present, unarmed. Anterolateral margins gently arched, diverging posteriorly, weakly rimmed; subtle cervical notch present at about 30% the distance from front. Posterolateral margins not confluent with anterolateral margins, strongly convex, converging posteriorly. Posterior margin narrower than fronto-orbital margin, about half length of maximum carapace width, nearly straight, weakly rimmed. Dorsal surface smooth, moderately vaulted longitudinally and transversely; regions poorly defined; epigastric regions weakly raised transversely; mesogastric region separated from protogastric regions by shallow grooves; small hole present at anterior junction of protogastric and hepatic regions behind upper orbital margin; cardiac region transversely hexagonal, slightly wider than long, defined by shallow grooves; other regions not well differentiated; subtle ridge extending from cardiac region anterolaterally to lateral margin at about half the distance from front; feeble oblique ridge extending to lateral margin forming posterolateral facet.

Thoracic sternum partly preserved; therefore, detailed characters unknown.

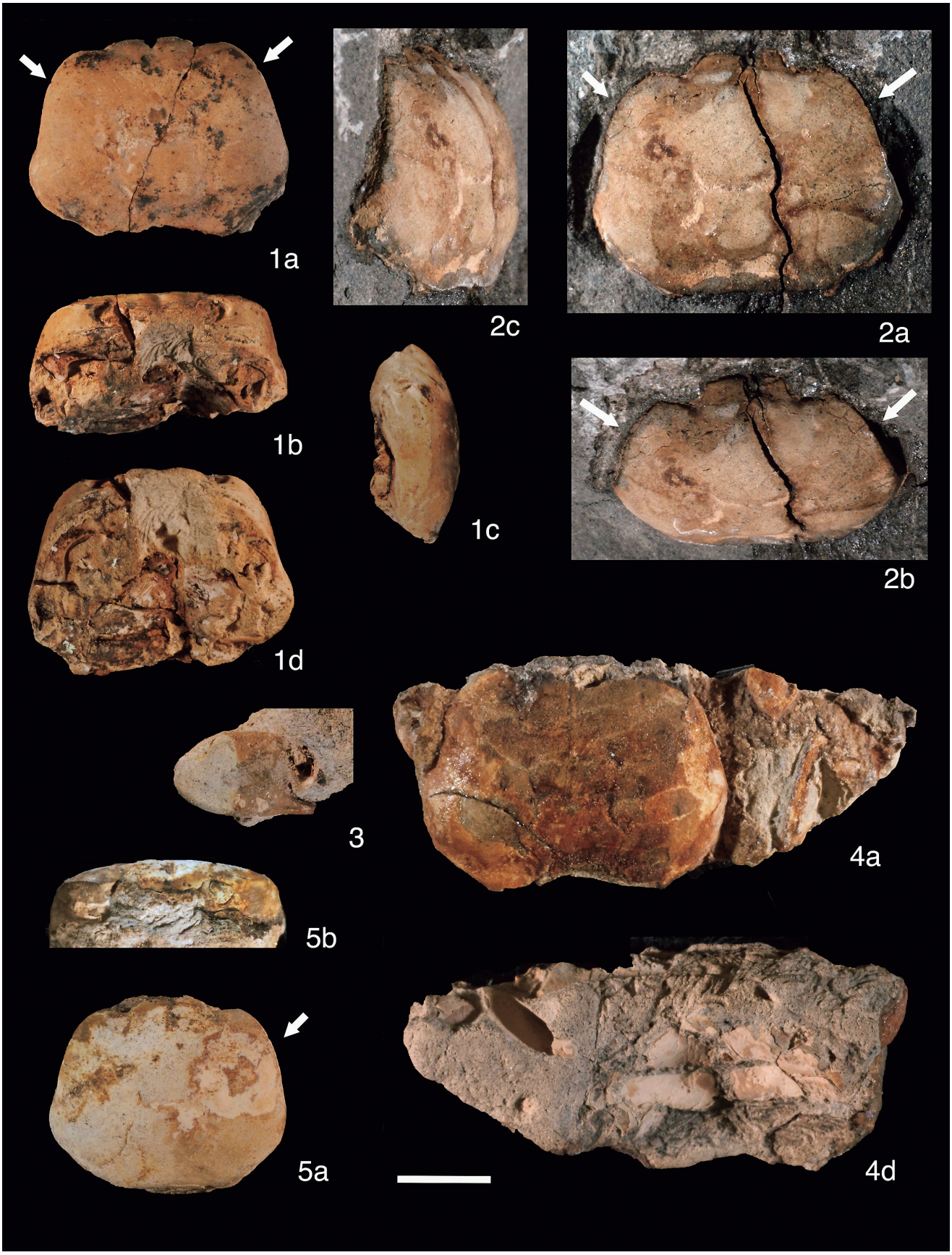


Fig. 2. **1a–5b.** ***Asthenognathus sakumotoi,*** **new species.** ***1,*** holotype (MFM39024), carapace and thoracic sternum; ***2,*** paratype (MFM39025), carapace; ***3,*** paratype (MFM39027), right cheliped, lateral view; ***4,*** paratype (MFM39026), carapace, thoracic sternum, and pereiopods; ***5,*** paratype (MFM39028), carapace. a, dorsal; b, frontal; c, lateral; d, ventral view. Scale bar = 5 mm. Allows indicate a cervical notch of the anterolateral margin of carapace.

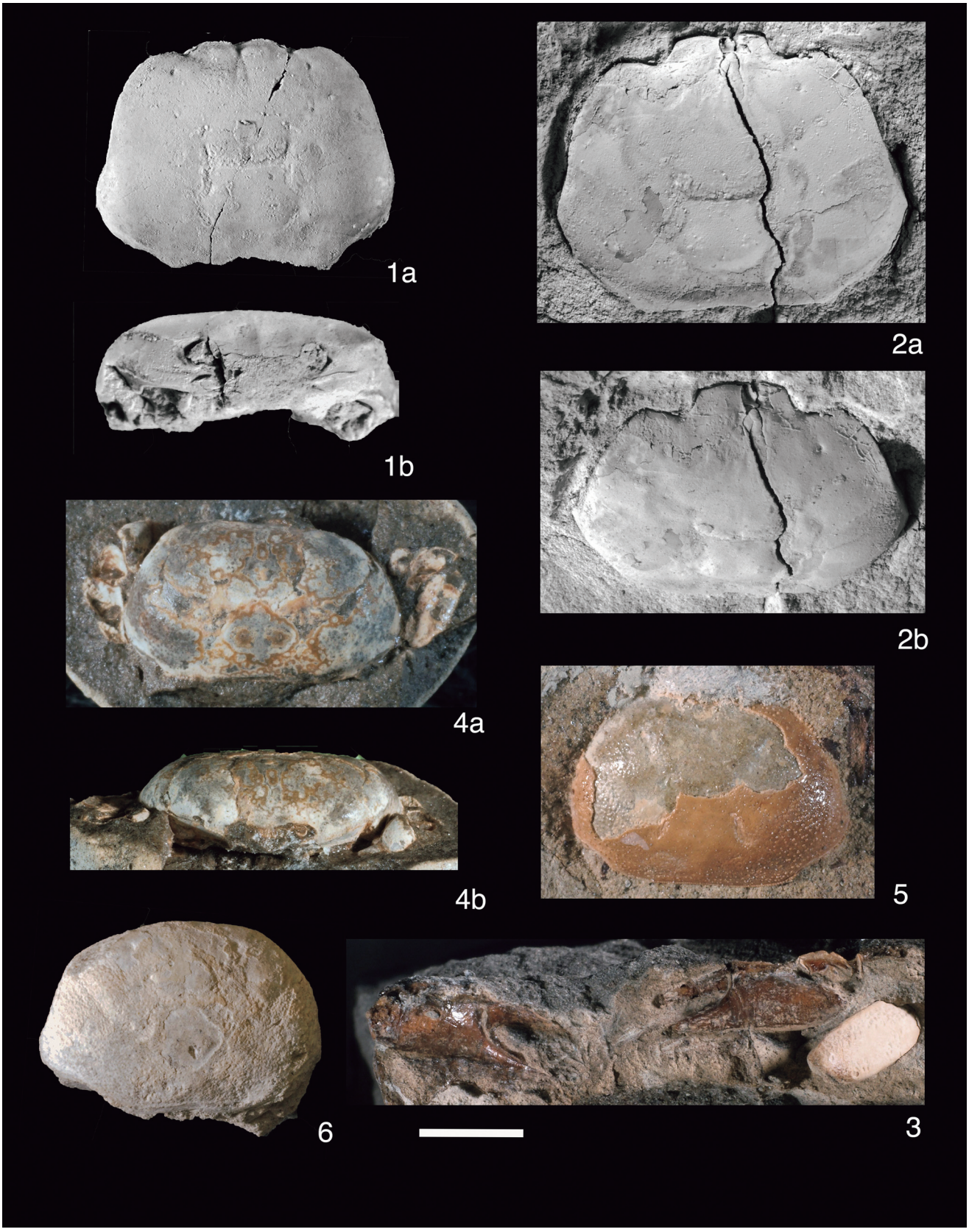


Fig. 3. **1a–3.** ***Asthenognathus sakumotoi,*** **new species.** ***1,*** holotype (MFM39024), carapace and thoracic sternum coated with ammonium chloride sublimate; ***2,*** paratype (MFM39025), carapace coated with ammonium chloride sublimate; ***3,*** paratype (MFM39026), both chelipeds, mesial view. **4a–6.** ***Asthenognathus globosum*** **(Karasawa, 1990),** carapace. ***4,*** MFM9121 from the lower to middle Miocene Mizunami Group; ***5,*** MFM83205 from the lower middle Miocene Yatsuo Group; ***6,*** MFM9033 (holotype) from the lower-middle Miocene Mizunami Group. a, dorsal; b, frontal view. Scale bar = 5 mm.

Chelae of chelipeds poorly preserved, unequal in size, much longer than high; fingers shorter than palm; occlusal surfaces minutely dentate with median triangular tooth; lateral surface of propodus with weak ridge parallel to ventral margin; mesial surface of propodus keeled along ventral margin. Unidentified pereiopods poorly preserved, flattened.

Remarks: The new species possesses the general shape of the carapace most like those of *Asthenognathus australensis* from the Carmen Silva Formation (middle Miocene) of Argentina (Feldmann *et al*., 2011), *A. laverdensis* from the lower Oligocene marls of Italy (De Angeli and Garassino, 2006), and *A. urretae* from the Centinela Formation (now Estancia 25 de Mayo Formation by Feldmann, per. com., July 2017) (late Oligocene–early Miocene) of Argentina (Schweitzer and Feldmann, 2001). However, it differs from those species in that a subtle notch is present on the anterolateral margin, a small hole is present at about anterior junction of the protogastric and hepatic regions on the dorsal surface, and the granular ornamentation of the dorsal carapace lacks. Although *Asthenognathus globosum* (Figs. 3.4a–6) has been known from the early to middle Miocene deposits of Japan (Karasawa, 1993), its carapace is much wider than long and strongly inflated. These carapace characters are not seen in the new species. Sakumoto (1997; pl. 1, fig. 10) referred the present species from the Korematsu Formation of the Bihoku Group to an unidentified species of *Cyclograpsus*, but the species cannot be assigned to *Cyclograpsus* in that the carapace is trapezoidal in outline, the anterolateral margin bears only one subtle notch, and the infraorbital ridge is unarmed.

Material examined: Holotype (MFM39024), paratypes (MFM39025–MFM39028).

Occurrence: Kamifuno (type locality), Funo-cho, Miyoshi City, Hiroshima Prefecture [=Loc. 2, Funo, of Sakumoto (2001)]; Lower Sandstone Member of the Bihoku Group [early to middle Miocene, 17–14.9 Ma by Goto *et al*. (2013)]. Nakabara, Shobara City, Hiroshima Prefecture [=Loc. 2 of Sakumoto (1997)]; Korematsu Formation of the Bihoku Group [early to middle Miocene, 17–14.9 Ma by Goto *et al*. (2013)].

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