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Original Article  
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## *Ophiura sarsii sarsii* (Echinodermata, Ophiuroidea) from the latest Middle Miocene to earliest Late Miocene Itahana Formation, Gunma Prefecture, central Japan

ISHIDA Yoshiaki<sup>1</sup>, TAKAKUWA Yuji<sup>2</sup> and KAMIMURA Hideo<sup>3</sup>

<sup>1</sup>*Chitosegaoka Senior High School: 3-18-1, Funabashi, Setagaya-ku, Tokyo 156-0055, Japan*

<sup>2</sup>*Gunma Museum of Natural History: 1674-1, Kamikuroiwa, Tomioka, Gunma, 370-2345, Japan*

<sup>3</sup>*585-2, Nishiakiya, Misato, Gunma, 370-3105, Japan*

**Abstract:** Specimens of the extant species *Ophiura sarsii sarsii* Lütken, collected from the latest Middle Miocene to earliest Late Miocene Itahana Formation in Annaka City, Gunma Prefecture, central Japan, are described systematically herein. The Itahana specimens, in addition to specimens from the Wakkanai formation, represent the oldest fossil record of this species. The geographical variation of the body size of extant specimens of *Ophiura sarsii sarsii*, larger in the northern area, may have already existed until the earliest Late Miocene.

**Key Words :** *Ophiura sarsii sarsii*, Ophiuroidea, Miocene, Itahana Formation, Gunma Prefecture

### Introduction

*Ophiura sarsii sarsii* Lütken is an extant ophiuroid species which is an epifaunal inhabitant of soft sediment bottoms. This species is widespread in the northern hemisphere, forming high-density populations especially in the upper bathyal zone surrounding northern Japan (Fujita and Ohta, 1989, 1990). Fossils of *Ophiura sarsii sarsii* have been found from the Late Pleistocene of Norway (Bjørlykke, 1898; Jensen and Thomsen, 1987), and from the late Middle Miocene to Middle Pleistocene of central and northernmost Japan (Ishida and Inoue, 1993, 1995; Ishida et al., 1996, 1998a, b, 1999, 2002; Ishida and Kurita, 1998; Ishida, 1999; Ishida and Fujita, 2001) (Fig. 1). In all these fossils from Japan, ophiuroids occurred in dense aggregations.

Recently, new accumulations of fossil ophiuroids were discovered in the latest Middle to earliest Late Miocene Itahana Formation, Gunma Prefecture (Suto et al., 2002), which proved to be assignable to *Ophiura sarsii sarsii*, based on a detailed morphological analysis. The present specimens were some of the oldest fossils of this species recorded in addition to *Ophiura sarsii sarsii* from the Wakkanai Formation, Hokkaido reported by Ishida and Fujita (2001). In this paper, we describe the new specimens systematically, and discuss the geographical variation in body size of *Ophiura sarsii sarsii* through geologic time.

### Locality and age

Five specimens and 13 isolated arms were collected from the bank of Usui River of Annaka City, Gunma Prefecture, about 3 km southwest of JR Annaka Station on the Syinetsu Line in the district of Annaka City (Fig. 1). The Lower to Middle Miocene Tomioka Group in this area comprises, the Haratajino, Niwaya, Haraichi and Itahana Formations in ascending order (Oishi and Takahashi, 1990). The strata exposed at this locality are mainly

composed of massive very fine sandstone assigned to the lowest part of the Itahana Formation. The age of the fossil horizon in the Itahana Formation is inferred to be latest Middle Miocene to earliest Late Miocene from the following study. The radiometric age (<sup>40</sup>Ar-<sup>39</sup>Ar) and diatom biostratigraphical age have been determined as 11.28 Ma for the Baba tuff at the upper part of the Haraichi Formation (Suto et al., 2002).

### Systematic description

Family Ophiuridae Lyman, 1865

Subfamily Ophiurinae Lyman, 1865

Genus *Ophiura* Lamarck, 1816

*Ophiura sarsii sarsii* Lütken, 1855

Figures 2-3

*Ophiura sarsii*, Lütken, 1855, p. 101; Clark, 1911, pp. 37-44; Matsumoto, 1917, p. 272, fig. 74; Berry, 1934, pp. 98-124, Pls. 5-6; Chang, 1948, pp. 65-66, fig. 17; Ishida and Inoue, 1993, p. 104, pls. 1-3\*; Ishida et al., 1996, pp. 67-69, fig. 3\*.

*Ophiura sarsi*, Mortensen, 1927, p. 238, figs. 128-1, 2; D'yakonov, 1954, p. 98, fig. 35; Irimura, 1990, p. 98.

*Ophiura sarsii sarsii*, Ishida and Kurita, 1998, pp. 138-142, figs. 2-6\*; Ishida et al., 1998a, pp. 10-12, figs. 3-4\*; Ishida and Fujita, 2001, pp. 784-789, figs. 2-4, Plates 1-2\*; Ishida et al., 2002, pp. 127-130, figs. 2-3, plates 1-2\*.

*Ophioglypha sarsii*, Lyman, 1865, pp. 41-44, figs. 2-3; Koehler, 1914, p. 23, pls. 1-5, 6.

*Ophioglypha sarsi*, Koehler, 1909, pp. 155-156, Pl. 7-3.

\*fossil specimens

**Materials** Five specimens with disc and arms (GMNH-PI-1511-1515), and 13 isolated broken arms (GMNH-PI-1516-1528) from the Itahana Formation are housed at the Gunma Museum of Natural History, Gunma Prefecture. Five of these speci-

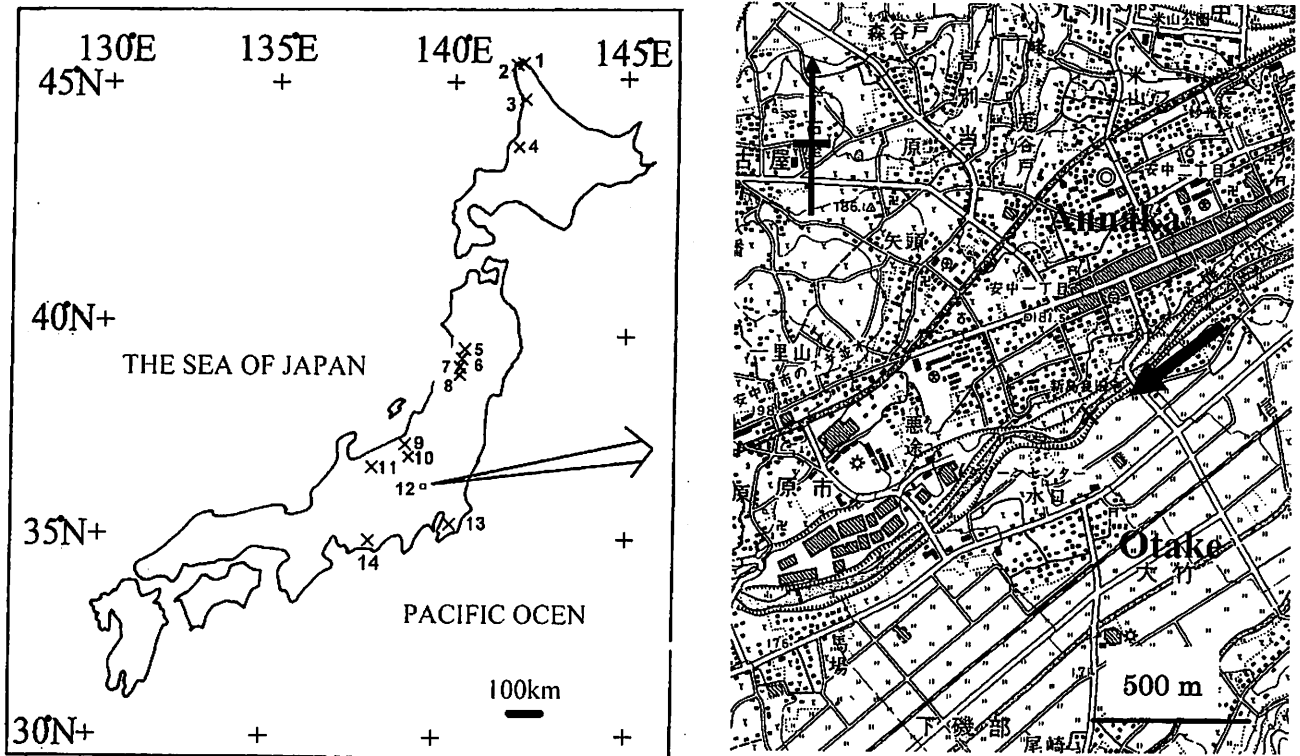


Fig. 1 Localities of fossil *Ophiura sarsii sarsii* in Japan. Right figure showing sampling locality from the Itahana Formation, Gunma Prefecture. Part of the "Tomioka" 1 : 25,000 topographic map by the Geographical Survey Institute. ×: Sampling localities. 1, Koetoi Formation; 2, Wakkanai Formation; 3, Enbetsu Formation; 4, Mashike Formation; 5, Noguchi Formation; 6, Furu-kuchi Formation; 7, Nakawatari Formation; 8, Hongo Formation; 9, Hachioji Formation; 10, Higashigawa Formation; 11, Ogawa Formation; 12, Itahana Formation; 13, Ichijuku Formation; 14, Hijikata Formation. References: 1-3, 5-9, 11, 13-14, see Ishida and Fujita, 1999; 4, Ishida unpublished data; 10, Ishida, 2004; 12, this paper.

mens (GMNH-PI-1511-1513, 1515, 1525) are illustrated here.

**Measurements** Disc diameter ranges from 9.4 to 10.7 mm (mean, 10.1 mm, N=5). Ratio of proximal arm width to disc diameter ranges from 0.19 to 0.21 (mean, 0.20, N=3).

**Description** Disc circular in outline, low and flat, covered with small, flat and imbricated scales. Primary scales are fairly large and circular; marginal scales large and rectangular; radial shields oval, separated from each other, about twice as long as disc radius, and about twice as long as wide. Arm comb plates are elliptical; oral shields pentagonal; adoral plates slender, rectangular, and in contact with each other at adoral margin. Oral plates are fairly long, rectangular, and in contact with each other at adoral margin. The first 3 or 4 arm segments insert laterally into the disc. Arms are bent gradually on the bedding plane, and are about three times as long as disc diameter. The arms are flattened, much wider than high, rather wide at the base, and taper gradually. Dorsal arm plates are well developed, rectangular, wider than long proximally, longer than wide distally, with a median keel, and in contact over their whole breadth. First dorsal arm plates are triangular; ventral arm plates triangular, about two times as wide as long. First ventral arm plates are trapezoidal. Lateral arm plates are well developed, separated by dorsal arm plates, but in contact ventrally. Arm spines are three in number, almost equal in length to arm segment at mid-arm, and are adpressed or somewhat detached. Vertebral ossicles are dorsally triangular, with a pointed distal corner.

**Remarks** Morphologically the Itahana specimens have much

in common with Recent *Ophiura sarsii sarsii*, which is related to *Ophiura sarsii vadicola*, *Ophiura kinbergi* and *Ophiura leptoctenia*. These four (sub) species can be distinguished mainly on the basis of the shape of arm comb papillae, disc size, ratio of proximal arm width to disc diameter, and ratio of length of radial shields to disc radius and ratio of length to width of radial shields (Ishida and Kurita, 1998). Although the arm comb papillae were not discernible in the Itahana specimens, they have been identified as *Ophiura sarsii sarsii* because such morphological ratios are similar to those of the previously described *Ophiura sarsii sarsii*.

## Discussion

The specimens of *Ophiura sarsii sarsii* from the latest Middle Miocene to the earliest Late Miocene Itahana Formation are the oldest fossils recorded for this taxon, in addition to the previously oldest record of the species, late Middle Miocene to early Late Miocene Wakkanai Formation (Ishida and Fujita, 2001).

The fossil ophiuroids obtained in the present study had their arms and discs attached, and the arms of the present material were not disarticulated to ossicle pieces. It is well known that ophiuroids become disarticulated quickly within one day to two weeks after death (Brett et al., 1997). So these specimens were probably autochthonous or semi-autochthonous. Extant *Ophiura sarsii sarsii* forms a dense bed covering the sea floor around Japan (Fujita and Ohta, 1989, 1990). The present fossil *Ophiura*

*sarsii sarsii* might also have formed dense aggregates.

Recent *Ophiura sarsii* are found at 153-550m depth in cold water (Fujita and Ohta, 1990, Ishida and Fujita, 2001). The molluscan fauna from the lower part of the Itahana Formation belong to the Shiobara type, indicating upper to lower sublittoral (Iwasaki, 1970; Kurihara, 1998, 2000). Foraminiferal analysis indicates upper bathyal depth for the lower part of the Itahana Formation near the study area (Kaneko and Nomura, 1998). From this data, these specimens are inferred to have lived in the lower sublittoral to upper bathyal zone in cold water.

Fossil aggregations of *Ophiura sarsii sarsii* have been found from the fourteen formations of northern to central Japan (Fig. 1). The body size tends to increase from south to north, being largest in Hokkaido (Ishida and Fujita, 1999). The body size of extant specimens in Japan also tends to be larger in the northern area (Fujita and Ohta, 1990; Ishida and Fujita, 2001). The disc

diameter of the Itahana specimens is within the range of the body size of fossil and living *Ophiura sarsii* (Table 1). So the geographical variation of the body size may have already existed until the earliest Late Miocene.

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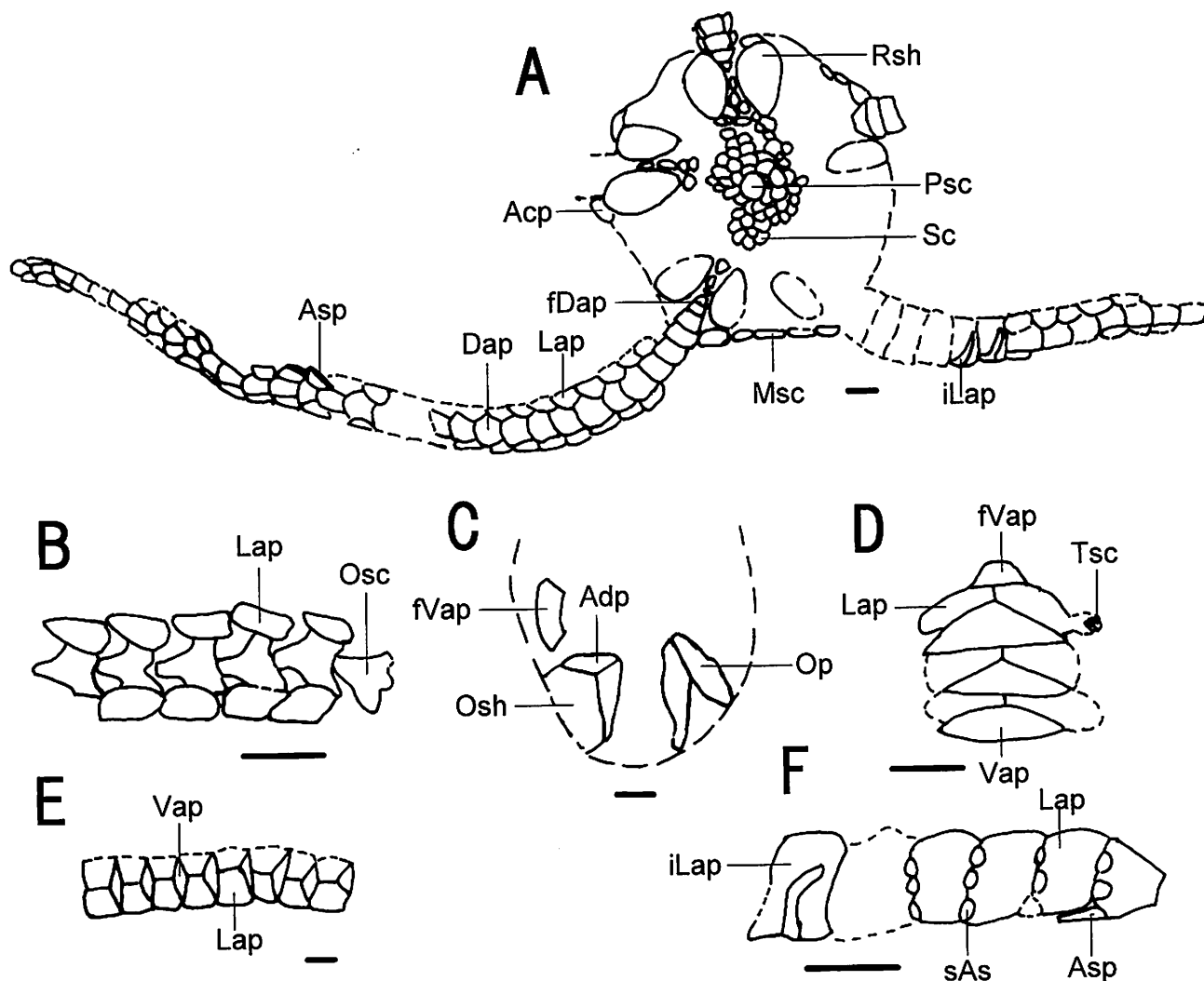


Fig.2 Camera lucida drawings of the figured specimens of *Ophiura sarsii sarsii* from the Itahana Formation. A, Dorsal view of disc and arms (GMNH-PI-1515); B, Dorsal view of mid arm (GMNH-PI-1511); C, Partial ventral view of Jaw (GMNH-PI-1512); D, Ventral view of proximal arm (GMNH-PI-1513); E, Ventral view of mid arm (GMNH-PI-1525); F, Lateral view of mid arm (GMNH-PI-1525). Abbreviation: Acp, Arm comb papilla; Adp, Adoral plate; Asp, Arm spine; Dap, Dorsal arm plate; fDap, first dorsal arm plate; fVap, first ventral arm plate; iLap, inside of lateral arm plate; Lap, Lateral arm plate; Msc, Marginal scale; Op, Oral plate; Osc, Ossicle; Osh, Oral shield; Psc, Primary scale; Rsh, Radial shield; sAs, Socket of arm spine; Sc, Scale; Tsc, Tentacle scale; Vap, Ventral arm plate.

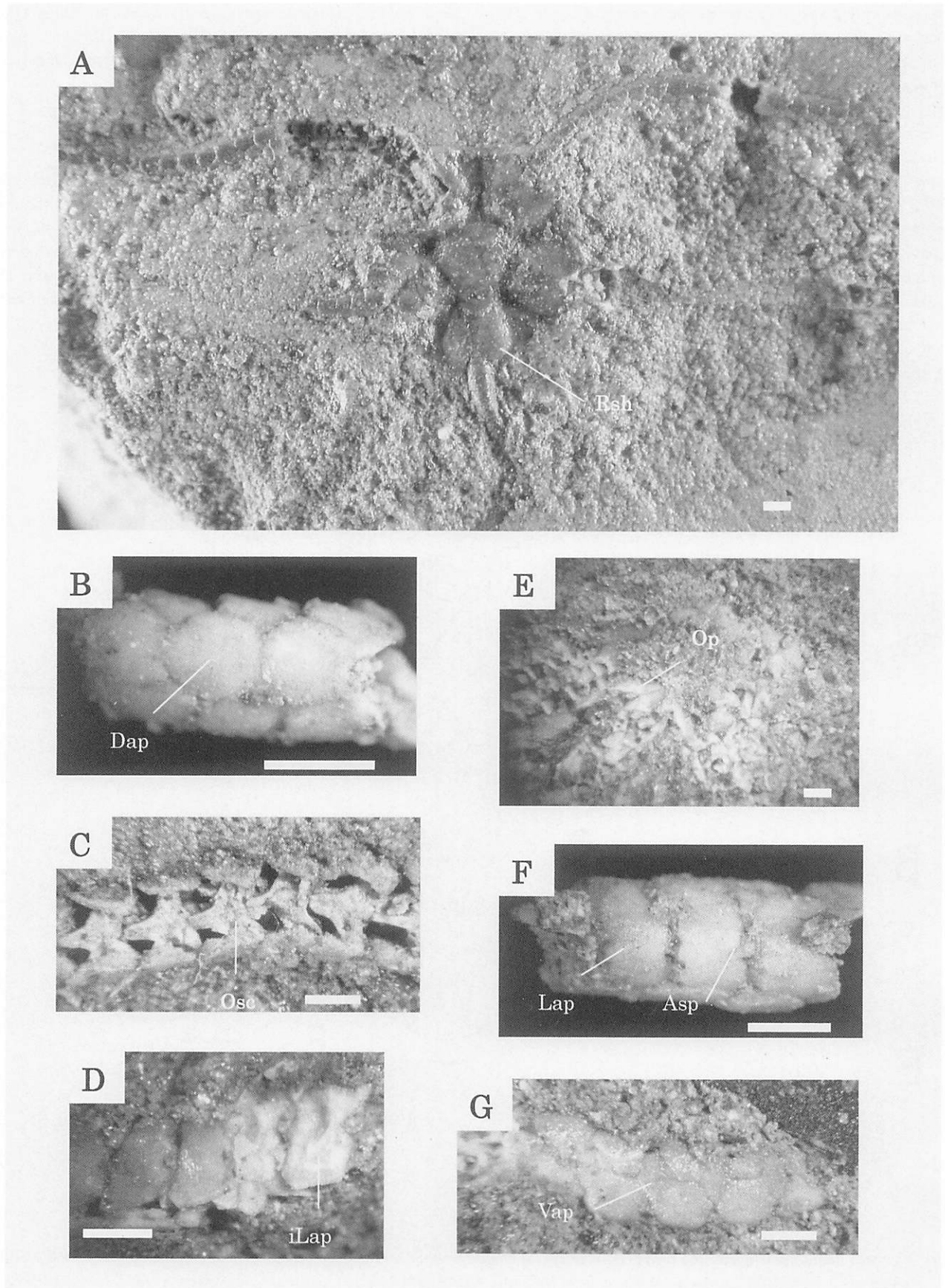


Fig.3 *Ophiura sarsii sarsii* from the Itahana Formation in Annaka City. A, Whole dorsal view (GMNH-PI-1515); B, Dorsal view of mid arm (GMNH-PI-1525); C, Dorsal view of mid arm (GMNH-PI-1511); D, Lateral view of mid arm (GMNH-PI-1525); E, Ventral view of jaw apparatus; F, Lateral view of mid arm (GMNH-PI-1525); G, Ventral view of mid arm (GMNH-PI-1512). For abbreviations see Fig. 2. Scale bars denote 1 mm.

**Table 1** Disc diameter and geological age of fossil *Ophiura sarsii sarsii* from Japan. Locality numbers correspond to those in Fig. 1, respectively.

Locality No.	Formation	Age	Number of specimens	Mean (mm)	Maximam (mm)	Reference
1	Koetoi F.	Late Mio - Early Plio	46	14.9	26.3	Ishida and Fujita, 2001
2	Wakkanai F.	late Middle Mioearly Late Mio	132	15.7	37.4	Ishida and Fujita, 2001
3	Enbetsu F.	Late Mio-Early Plio	108	12.8	31.8	Ishida and Fujita, 1999
4	Mashike F.	Late Mio	arm	-	-	Ishida unpubl.
5	Noguchi F.	Early Plio	4	13.7	17.1	Ishida et al., 1999, 2002
6	Furukuchi F.	Late Mio	33	11.8	14.9	Ishida et al., 1999
7	Nakawatari F.	Lower Plio	11	12.1	16.8	Ishida et al., 2002
8	Hongo F.	Late Mio	10	8.0	13.4	Ishida et al., 1999
9	Hachioji F.	Late Plio	31	9.7	14.1	Ishida and Kurita, 1998
10	Higashigawa F.	Pliocene	3	13.7	14.4	Ishida, 2004
11	Ogawa F.	Late Mio	37	11.2	19.2	Ishida et al., 1998
<b>12</b>	<b>Itahana F.</b>	<b>latest Middle Mio-earliest Late Mio</b>	<b>5</b>	<b>10.1</b>	<b>10.7</b>	<b>present study</b>
13	Ichijuku F.	Middle Pleist	342	9.6	19.0	Ishida and Inoue, 1993
14	Hijikata F.	Plio-Pleist	376	8.2	20.0	Ishida et al., 1996

**References cited**

Berry, C. T. (1934) : Miocene and Recent *Ophiura* skeletons. *Johns Hopkins Univ. Stud. Geol.*, 11: 9-135.

Bjørlykke, K. (1898) : Geologisk Kart med beskrivelse over Kristiania by. *Norges Geologiske Undersøgelse*, 25: 1-86.

Brett, C. E., Moffat, H. A. and Taylor, W. L. (1997) : Echinoderm taphonomy, taphofacies, and lagerstätten. *Palaeont. Soc. Papers*, 3: 147-190.

Chang, F.Y. (1948) : Echinoderms of Tsingtao. *Contr. Inst. Zool. Acad. Peiping*, 4: 33-104.

Clark, H. L. (1911) : North Pacific ophiurans in the collection of the United States National Museum. *Bull. United States Natn. Mus., Smithsonian Inst.*, 75: 1-302.

D'yakonov, A. M. (1954) : Ophiuroids of the USSR seas. *Zool. Inst. Acad. Sci. USSR*, 55: 1-123. (in Russian, translated, 1967: Israel Program for Scientific Translations)

Fujita, T. and Ohta, S. (1989) : Spatial structure within a dense bed of the brittle star *Ophiura sarsi* (Ophiuroidea: Echinodermata) in the bathyal zone off Otsuchi, northeastern Japan. *J. Oceanogr. Soc. Japan*, 45: 289-300.

Fujita, T. and Ohta, S. (1990) : Size structure of dense populations of the brittle star *Ophiura sarsii* (Ophiuroidea: Echinodermata) in the bathyal zone around Japan. *Mar. Ecol. Prog. Ser.*, 64: 113-122.

Irimura, S. (1990) : Ophiuroidea; *Echinoderms from Continental Shelf and Slope around Japan, Vol 1*. p. 65-100. Japan Fisheries Resource Conservation Association, Tokyo.

Ishida, Y. (1999) : Escape behavior and postures of epifaunal ophiuroids from burial: Extant and Late Miocene *Ophiura sarsii sarsii* as an example. *Mem. Geol. Soc. Japan*, 54: 161-173.

Ishida, Y. (2004) : *Ophiura sarsii sarsii* (Echinodermata, ophiuroidea) from the Upper Pliocene Higashigawa Formation in Niigata Prefecture, central Japan. *Bull. Fossa Magna. Mus.*, 3 (in contribution)

Ishida, Y. and Fujita, T. (1999) : Dense populations of fossil and extant *Ophiura sarsii* (Echinodermata, Ophiuroidea) in Japan. P. 293-298. In: Carnevali, M. D. C. and Bonasoro, F. eds., *Echinoderm Research 1998*. Balkema, Rotterdam/ Brookfield.

Ishida, Y. and Fujita, T. (2001) : *Ophiura sarsii sarsii* (Echinodermata, Ophiuroidea) from the late Middle Miocene to Early Pliocene formations of North Hokkaido, Japan. *J. Geol. Soc. Japan*, 107: 782-791.

Ishida, Y. and Inoue, K. (1993) : Fossil ophiuroids (*Ophiura sarsii*, Lütken, 1854) from the Pleistocene Ichijuku Formation (Kazusa Group), Chiba Prefecture, Central Japan. *Nat. Hist. Res.*, 2: 103-112.

Ishida, Y. and Inoue, K. (1995) : Mode of occurrence and paleoecology of *Ophiura sarsii* Lütken, 1854—Fossil ophiuroids from the Pleistocene Ichijuku Formation (Kazusa Group), Chiba Prefecture, Central Japan—. *Earth Sci.*, 49: 32-44.

Ishida, Y. and Kurita, Y. (1998) : *Ophiura sarsii sarsii* (Echinodermata, Ophiuroidea) from the Late Pliocene Hachioji Formation in Niigata Prefecture, Central Japan. *Palaeont. Res.*, 2: 137-144.

Ishida, Y., Nagamori, H. and Narita, K. (1998a) : *Ophiura sarsii sarsii* (Echinodermata, Ophiuroidea) from the Late Miocene Ogawa Formation, Shinshushinmachi, Nagano Prefecture, Central Japan. *Res. Rep. Shinshushinmachi Fossil Mus.*, 1: 9-16.

Ishida, Y., Nagasawa, K. and Abe, H. (2002) : *Ophiura sarsii sarsii* (Echinodermata, Ophiuroidea) from the Early Pliocene Noguchi and Nakawatari Formations in Yamagata Prefecture, northern Japan. P. 125-136. *Research report on the fossil sperm whale from*

- Mamurogawa-machi in Yamagata Prefecture, March 2002*, Yamagata Prefectural Museum.
- Ishida, Y., Nagasawa, K. and Tokairin, H. (1999) : *Ophiura sarsii sarsii* (Echinodermata, Ophiuroidea) from the Late Miocene to Early Pliocene formations of Yamagata Prefecture, northern Japan. *Earth Sci.*, **53**: 223-232.
- Ishida, Y., Tanabe, T., Ito, T. and Hachiya, K. (1996) : Fossil ophiuroids from the Plio-Pleistocene Hijikata Formation of the Kakegawa Group, Shizuoka, Central Japan. *Bull. Natn. Sci. Mus., Tokyo, Ser. C*, **22**: 63-89.
- Ishida, Y., Tanabe, T., Ito, T. and Hachiya, K. (1998b) : Paleoenvironment of fossil ophiuroids from the Plio-Pleistocene Hijikata Formation of the Kakegawa Group, Shizuoka Prefecture, Central Japan. p. 365-370. In: Mooi, R. and Telford, M. eds., *Echinoderms*: San Francisco, Balkema, Rotterdam/ Brookfield.
- Iwasaki, Y. (1970) : The Shiobara-type molluscan fauna. An ecological analysis of fossil molluscs. *Jour. Fac. Sci. Univ. Tokyo, Sec. 2*, **17**: 351-444.
- Jensen, M. and Thomsen, E. (1987) : Ultrastructure, dissolution and "pyritization" of Late Quaternary and Recent echinoderms. *Bull. Geol. Soc. Denmark*, **36**: 275-287.
- Kaneko, M. and Nomura, M. (1998) : Fossil foraminifera and Paleoenvironment of Haraichi formation and lowest part of Itahana formation in Tomioka and Annaka area, Gunma Prefecture, Japan. *Bull. Gunma Mus. Natu. Hist.*, **2**: 57-66. (in Japanese with English abstract)
- Koehler, R. (1909) : Échinoderms provenant des campagnes du yacht Princesse-Alice. *Rés. Sci. Campagnes Prince Monaco*, **34**: 1-317, pls. 1-32.
- Koehler, R. (1914) : A contribution to the study of the ophiurans of the United States National Museum. *Bull. U. S. Natl. Mus.*, **84**: 1-146, pls. 1-18.
- Kurihara, Y. (1998) : Molluscan fossils were found from Tomioka Group. p. 40-41. In: Kimura, T., Ito, O. and Takakuwa, Y. eds., The guidebook of 4<sup>th</sup> temporal exhibition "Will you look at treasure of nature that I dig?"; Gunma Museum of Nat. Hist. (Tomioka). (in Japanese)
- Kurihara, Y. (2000) : Faunal change of Miocene Molluscan fossils in Annaka-Tomioka area. P. 6-7. *Palaeont. Soc. Japan, 2000, Annual Meeting, Abstracts with Programs*. (in Japanese)
- Lütken, C. F. (1855) : Bidrag til Kundskab om Slangestjerne. I. Forelobig Oversigt over Gronlandshavets Ophiurer. *Vidensk. Medd. Dansk. Naturh. Foren. Kjobenhavn*, **1854**: 95-104.
- Lyman, T. (1865) : Ophiuridae and Astrophytidae. *Illust. Cat. Mus. Comp. Zool. Harvard*, **1**: 1-200, 2 pls.
- Matsumoto, H. (1917) : A monograph of Japanese Ophiuroidea, arranged according to a new classification. *J. Coll. Sci. Imp. Univ. Tokyo*, **38**: 1-408, 52 pls.
- Mortensen, H. (1927) : *Handbook of the echinoderms of the British Isles*. London Oxford Univ Press, 471pp.
- Oishi, M. and Takahashi, M. (1990) : Miocene formations in the Takasaki district, central Japan—With special reference to the developmental process of the Niwaya Unconformity—. *Sci. Rep. Tohoku Univ., 2nd Ser. (Geol.)*, **92**: 1-17. (in Japanese with English abstract)
- Suto, I., Takahashi, M. and Yanagisawa, Y. (2002) : Diatom biostratigraphy of the Middle Miocene marine sequence of the Ayukawa section in the Fujioka area, Gunma Prefecture, central Japan, with special reference to the correlation between the diatom biohorizon D55 and an <sup>40</sup>Ar-<sup>39</sup>Ar age. *Jour. Geol. Soc. Japan*, **108**: 746-760. (in Japanese with English abstract)

## 群馬県下部板鼻層（中部中新統最上部—上部中新統最下部）から産出したキタクシノハクモヒトデ

石田吉明<sup>1</sup>・高乗祐司<sup>2</sup>・上村秀雄<sup>3</sup>

<sup>1</sup>東京都立千歳丘高校：〒156-0055 東京都世田谷区船橋3-18-1 E-mail:y-ishida@msi.biglobe.ne.jp

<sup>2</sup>群馬県立自然史博物館：〒370-2345 群馬県富岡市上黒岩1674-1 E-mail:BXJ04105@nifty.ne.jp

<sup>3</sup>群馬県群馬郡箕郷町西明屋585-2

**要旨**：群馬県安中市の下部板鼻層（中部中新統最上部～上部中新統最下部）からクモヒトデ化石が発見され、その形態から現生種のキタクシノハクモヒトデ (*Ophiura sarsii sarsii* Lütken) と同定された。化石は密集して産出し、現生個体群と同様に下部浅海帯～上部漸深海帯に密集して棲息していたと推定された。

これまで本種の化石は中部中新統上部～上部中新統下部の稚内層産個体が最も古い時代を示していたが、板鼻層産化石はこれと並んで最古の化石記録となる。

本種の現生個体は北方に産する個体ほど大きくなる傾向がある。本種の化石は日本の北部～中部地域にわたる中部中新統上部～中部更新統（14地層）から知られているが、化石個体においても同様の傾向が認められる。板鼻層産化石もこの傾向が当てはまることから、すでに中期中新世後期～後期中新世最前期にはキタクシノハクモヒトデの体の大きさに地域差が生じていたことが推定される。

キーワード：キタクシノハクモヒトデ、棘皮動物、中新世、板鼻層、群馬県