

**Part B. Paleontology of the Neogene echinoid fossils from the  
northern part of Ibaraki Prefecture**

Brief remarks on 39 echinoid species from the Neogene of the northern part of Ibaraki Prefecture are made, among which two genera and six species are described as new to science.

Systematic classification and its manners are followed Nisiyama (1966, 1968) and Shigei (1986).

**1. Systematic description of echinoid fossils from the northern part  
of Ibaraki Prefecture**

**Systematic description**

Class ECHINOIDEA

Order Echinothurioida

Family Echinothuriidae

Echinothuriidae gen. et sp. indet.

(Pl. 8, figs. 8-9)

*Description:* Two imperfect specimens were examined.  
Tatsugami specimen (Pl. 8, fig. 8; IGUT. no.14517): aboral side

specimen, test very thin, large and hemispherical in marginal outline. Ambulacra area wide, ambulacral plates large and narrow, demipaltes rather large, and outer demiplates reached the ambulacra edge. Primary tubercle unconfirmed, secondary tubercles smaller than interambulacral secondary tubercles.

Interambulacral plates large more than ambulacral plates, with tubercles. Primary tubercles small and arranged randomly form. Boss very wide in small mamelon; secondary tubercles almost regularly arranged.

Yazawa specimen (Pl. 8, fig. 9; IGUT. no. 14518): oral side specimen, oral side with rather arranged primary tubercles. Boss wide, but areole narrowly. Primary spine shape rather long and pointed.

These features of the test and spine are suggesting it belongs to Echinothuriidae. However, it is difficult to identify the genus because of poor preservation.

*Remarks and affinities:* Two fossils Echinothuriidae, Mizuno (1992, 1993), *Phormosoma* cf. *bursarium* A. Agassiz and *Phormosoma* sp. were reported from the early middle Miocene Toyoma Formation in Aich Prefecture, central Japan.

Living Echinothuriidae is composed of thirteen genera (Fill,

1966), and inhabiting both in shallow and deep condition (Nisiyama, 1968; Shigei, 1974, 1986).

*Locality, formation and geologic age:* The present unnamed genus and species was collected from Loc. no. 06 and no. 11, early middle Miocene Naeshiroda Formation, Daigo-machi, Kuji-gun, Ibaraki Prefecture (Figs. 2, 5-8; Tables 1-2, 14).

*Occurrence and associated fauna:* The present specimen is collected from Loc. no. 06; imperfect, single occurred from fine grained sandstone of siltstone dominant alternating beds of sandstone and siltstone with molluscs of *Acilana tokunagai* (Yokoyama), *Portlandia kakimii* Uozumi and *Propeamussium tateiwai* Kanehara. Loc. no. 11; imperfect specimen occurred from fine grained tuffaceous sandstone of alternating beds of sandstone and siltstone, with such echinoid, holothurian, sponge and molluscs as *Brissopsis kajivarai* n. sp., *Brissopsis daigoensis* n. sp.; *Cucumaria igoi* Kikuchi and Nikaido, *Yipsilothuria bitentaculata* (Ludwig); *Portlandia* cf. *kakimii* Uozumi, *Propeamussium tateiwai* Kanehara and *Makiyama chitanii* (Makiyama)

Suborder Echinina Claus,

Family Echinometridae Gray, 1855

Genus *Anthocidaris* Lütken, 1864

*Anthocidaris* sp.

(Pl. 8, figs. 6-7)

*Description:* Two imperfect specimens were examined. Tokai specimen (Pl. 8, fig. 7; IGUT. no. 14519): lateral side, test medium in size. Poriferous zone with 6 or 7 pores pair. Primary ambulacra and interambulacral tubercles well developed; primary interambulacral larger than primary tubercle on the middle of arched part. Primary tubercle singled on aboral side.

Hitachi specimen (Pl. 8, fig. 6; IGUT. no. 14520): primary spine of the genus, rather long, stout and circular ship in cross section.

*Remarks and affinities:* These specimens can be identified *Anthocidaris* sp. which has characteristics of test and spine of the genus. Fossil record of *Anthocidaris* is only known to occur two species such as *Anthocidaris* ? sp. (Nisiyama, 1966) from the Miocene stratum of Guam Island and *Anthocidaris* sp. from the Pleistocene Nakoshi Formation of Okinawa Island. The living species of *Anthocidaris crassispis* (A. Agassiz) is known from the northern Honshu to Kyushu, Taiwan and southern China, and inhabiting depth

in littoral zone to 70 meters (Mortensen, 1943b; Nisiyama, 1968; Clark and Rowe, 1971; Shigei, 1974, 1986; and Saba et al., 1981).

Fossil *Anthocidaris* sp. interpreted it is indicating shallow-sea environment, on the basis of modern ecological analogy of the family.

*Locality, formation and geologic age:* The present specimens were collected from two localities: Loc. no. 31, Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14); Loc. no. 37, Pliocene Hatsuzaki Sandstone Member of the Hitachi Formation, Hitachi-shi, Ibaraki Prefecture (Figs. 2, 39-40, 42; Tables 1, 11, 14).

*Occurrence and associated fauna:* The present specimen was collected from Loc. no. 31, imperfect, single specimen occurred from gray to greenish gray, massive silty sandstone with echinoid of *Linthia tokunagai* Lambert, *Brisaster owstoni* Mortensen, *Nodaster watanabei* n. gen. et n. sp. and *Anametalia* sp. Loc. no. 37; imperfect, single specimen occurred from medium to coarse grained, massive sandstone, associated fossil absent.

*Geologic distribution:* Pliocene Muramatsu Formation, Tokai-mura, Naka-gun and the Pliocene Hatsuzaki Sandstone of the Hitachi Formation, Hitachi City in the Ibaraki Prefecture.

Suborder Temnopleuroina Mortensen, 1942

Family Temnopleuridae A. Agassiz, 1872

Genus *Temnotrema* A. Agassiz, 1863

*Temnotrema rubrum* (Döderlein, 1885)

(Pl. 8, figs. 5a-5c)

1885, *Pleurechinus ruber* Döderlein, p.92.

1903, *Pleurechinus ruber* Döderlein, Döderlein, p. 706, pl. 91, figs.  
3a-b.

1904, *Pleurechinus ruber* Döderlein, Mortensen, p. 84, pl. 6, fig.  
28, pl. 7, fig. 6.

1906, *Pleurechinus ruber* Döderlein, Tokunaga, pl. 8, figs. 8-10.  
(reproduced from Döderlein, 1903)

1912, *Temnotrema rubrum* (Döderlein), H. L. Clark, p.319.

1936, *Temnotrema rubrum* (Döderlein), Nisiyama, p. 125, pl. 11, figs.  
1-9.

1937, *Temnotrema rubrum* (Döderlein), Nisiyama, p. 54.

1943, *Temnotrema rubrum* (Döderlein), Mortensen, p. 252, pl. 19, text  
-figs. 133c-d, 135b.

1966, *Temnotrema rubrum* (Döderlein), Nisiyama, p. 228, text-figs.  
16a-f.

1968, *Temnotrema rubrum* (Döderlein), Nisiyama, p. 345.

*Description:* Test very small in size, thick and strong, rather high hemispherical in marginal outline. About 0.6 of horizontal diameter, beautifully rounded above and a little curved toward peristome. Oral side more or less depressed at peristomal edge, tubercle develops on oral side. Angular pit conspicuous, oblong, rather organized and arranged in aboral to lateral side pits shape; oral side pits a little smaller than aboral to lateral side pits.

Ambulacra part wide and width as about 0.7 of interambulacra on ambital area; medium area wide. Pores-pair small, arranged in a nearly straight line with groove formed. Primary tubercle develops, arranged in straight line; secondary tubercles arranged irregularly.

Interambulacra area wide, primary tubercles conspicuous and arranged in straight, secondary tubercles rather conspicuous, but arranged irregularly.

Peristome wide and with circular form, about 5 mm in diameter.

*Dimension*

Specimen	Horizontal diameter	Vertical diameter
IGUT. no. 14521	12.5 mm	8.2 mm

*Remarks and affinities:* In fossil record, *Temnotrema rubrum* (Döderlein) was only reported from the Pleistocene Namamugi Fossil Zone (= Tokyo Formation) in Yokohama City by Nisiyama (1936). The present fossil discovery suggested that geological range of the species go down to Pliocene in Japan. Nisiyama (1968) mentioned the recent species *Temnotrema rubrum* (Döderlein) is known only from the Tokyo Bay area in depth of 5–35 meters.

*Locality, formation and geologic age:* The present species, *Temnotrema rubrum* (Döderlein) was collected from Loc. no.39, Pliocene Hatsuzaki Sandstone Member of the Hitachi Formation, Hitachi-shi, Ibaraki Prefecture (Figs. 2, 39-40, 43; Tables 1, 11, 14).

*Occurrence and associated fauna:* The present fossil was single specimen occurred from coarse grained to pebbly, massive sandstone with echinoid of *Echinocyamus crispus* Mazzetti and *Scaphechinus cf. mirabilis* A. Agassiz and some molluscs (Watanabe,



1993 MS; Noda *et al.*, 1995).

*Geologic distribution:* Pleistocene Namamugi Fossil Zone (= Tokyo Formation) in Kanagawa Prefecture, the Pliocene Hatsuzaki Sandstone Member of the Hitachi Formation in Ibaraki Prefecture (Fig. 57).

*Geologic range:* Pliocene to Recent.

Order Clypeasteroida A. Agassiz, 1872

Suborder Laganoina Mortensen, 1948

Family Fibulariidae Gray, 1855

Genus *Echinocyamus* Van Phelsum, 1893

*Echinocyamus crispus* Mazzetti, 1893

(Pl. 8, figs. 1a-2c)

1893, *Echinocyamus crispus* Mazzetti, p. 239, pl. 13, figs. a-b.

1894, *Echinocyamus crispus* Mazzetti, Mazzetti, p. 215.

1904, *Echinocyamus crispus* Mazzetti, Meijer, p. 105, pl. 6, figs. 45-50, pl. 18, fig. 300.

1914, *Echinocyamus crispus* Mazzetti, H. L. Clark, p. 62.

1914, *Fabulina crispus* (Mazzetti), Lambert and Thiéry, p. 292.

1922, *Echinocyamus crispus* Mazzetti, Koehler, p. 137, pl. 12, fig.

- 16-17, 21.
- 1933, *Echinocyamus crispus* Mazzetti, Nisyama, p. 46, text-figs.  
57A-D.
- 1937, *Fabulina crispus* (Mazzetti), Jeannet and Martin, p. 239.
- 1948a, *Echinocyamus crispus* Mazzetti, Mortensen, p. 107.
- 1948b, *Echinocyamus crispus* Mazzetti, Mortensen, pl. 46, figs.  
46-47 55, text-fig. 112a.
- 1953a, *Echinocyamus crispus* Mazzetti, Morishita, p. 16, p. 6,  
fig. 1.
- 1954, *Echinocyamus crispus* Mazzetti, Utinomi, p.352.
- 1954, *Echinocyamus crispus* Mazzetti, Morishita, p. 225.
- 1960, *Echinocyamus crispus* Mazzetti, Morishita, p. 56.
- 1965, *Echinocyamus crispus* Mazzetti, Nisiyama, p. 78, 85.
- 1968, *Echinocyamus crispus* Mazzetti, Nisiyama, p. 48, text-figs. 30  
(5ab).
- 1971, *Echinocyamus crispus* Mazzetti, A.M. Clark and Rowe, p. 144,  
166.
- 1974, *Echinocyamus crispus* Mazzetti, Shigei, p. 313.
- 1974, *Echinocyamus crispus* Mazzetti, Morishita, p. 208, pl. 65, figs.  
1-3b.
- 1978, *Echinocyamus crispus* Mazzetti, Liao, p. 120, pl. 3, fig. 7.

1981, *Echinocyamus crispus* Mazzetti, Shigei, p. 202.

1982, *Echinocyamus crispus* Mazzetti, Shigei, p. 189.

1986, *Echinocyamus crispus* Mazzetti, Shigei, p. 115, pl. 92,  
figs. 1-3.

Description: Test very small in size, rather low and somewhat elongated pentagonal or oval in marginal outline. Anterior more constricted than posterior.

Aboral side slightly arched and flat. Highest point situated at the posterior part of apical system. Anterior slope almost equally to posterior one. Oral side concaved distinctively. Peristome deeply sunk. Apical system situated slightly anterior, with four genital pores. Petals well formed and widely open.

Peristome situated at the center; circular in marginal outline, about 1.5 mm in diameter. Periproct very small, transversely elongated, situated at about between the posterior and peristome. Tubercles size rather large.

*Dimensions*

Specimens	Longitudinal diameter	Transversal diameter	Height
IGUT. no. 14522	9.1 mm	7.9 mm	2.9 mm
IGUT. no. 14523	8.4 mm	6.5 mm	3.4 mm

*Remarks and affinities:* Fossil *Echinocyamus crispus* Mazzetti was reported from the early middle Miocene Oidawara Tuffaceous Mudstone (Morishita, 1956), early middle Miocene Akeyo Formation (Morishita, 1974) and the Pleistocene Ryukyu Limestone (Nisiyama, 1968; Fujiyama, 1982). The present species from the Hatsuzaki Sandstone Member is first record from the Pliocene. According to Shigei (1986) and others, distribution of the living species, *Echinocyamus crispus* Mazzetti is as follow; Japanese seas from Sagami Bay to Philippines, Indian Ocean to East African and the Red Sea to Kei Island, Guam and Hawaiian Island, 18–200 meters in depth.

The present species can be assigned to have the same this inhabiting depth both of fossil and living species, in particular the most deep depth of the species may be available to consider the sedimentation environment of Hatsuzaki Sandstone Member of the Hitachi Formation.

*Locality, formation and geologic age:* The present species, *Echinocyamus crispus* Mazzetti, was collected from the Pliocene Hatsuzaki Sandstone Member (Loc. no. 39) of the Hitachi Formation, Hitachi-shi, Ibaraki Prefecture (Figs. 2, 39–40, 43; Tables 1, 11, 14).

*Occurrence and associated fauna:* The present species was collected from Loc. no. 39, as a single specimen occurred from coarse grained to pebbly, massive sandstone with echinoid of *Temnotrema rubrum* (Döderlein) and *Scaphechinus* cf. *mirabilis* A. Agassiz and some molluscs (Watanabe, 1993MS; Noda et al., 1995).

*Geologic distribution:* The early middle Miocene Oidawara Tuffaceous Sandstone and Akeyo Formation in Gifu Prefecture, the Pliocene Hatsuzaki Sandstone Member of the Hitachi Formation in Hitachi City, Ibaraki Prefecture (Fig. 58).

*Geologic range:* Early middle Miocene to Recent.

Suborder Laganoina Mortensen, 1948

Family Sutellidae Gray, 1885

Genus *Scaphechinus* A. Agassiz, 1863

*Scaphechinus* cf. *mirabilis* A. Agassiz, 1863

(Pl. 8, figs. 3a–4b)

*Description:* Some imperfect specimens were examined. Test very small and low in size, inversed pentagonal marginal form. Petals not clear. Anterior margin very round and posterior margin somewhat wavy and broader than anterior.

Central part of aboral side concaved. Peristome circularly shaped, and situated at central, about 1.5 mm in diameter. Periproct circularly shaped, and situated at posterior end on aboral side, about 0.6 mm in diameter.

*Dimensions*

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Specimens	Longitudinal diameter	Transversal diameter	Height
IGUT. no. 14524	10.2 mm	10.0 mm	2.3 mm
IGUT, no. 14525	7.5 mm	7.1 mm	1.5 mm

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*Remarks and affinities:* Characteristics of these specimens that of the position of mouth and anus, and marginal shape of test can be compared with *Scaphechinus merabilis* A. Agassiz. One of these specimen exhibits young growth stage of the species. This species was known from the Pliocene to Pleistocene formations in Japan and Formosa (Nisiyama, 1968).

According to Shigei (1986) and others, distribution of the recent species *Scaphechinus mirabilis* A. Agassiz is as follow; Japanes sea from southern Hokkaido to southern Kyushu, Korea, north China, Kamchatca, Aleutian Island; littoral zone to 125 meters in depth.

*Locality, formation and geologic age:* The present species was collected from the Pliocene Hatsuzaki Sandstone Member (Loc. no. 39) of the Hitachi Formation, Hitachi City, Ibaraki Prefecture (Figs. 2, 39-40, 43; Tables 1, 11, 144).

*Occurrence and associated fauna:* The present species was collected from the Loc. no. 39, as a single specimen occurred from coarse grained to pebbly, massive sandstone with echinoids of *Temnotrema rubrum* (Döderlein) and *Echinocyamus crispus* Mazzetti and some molluscs (Watanabe, 1993 MS; Noda et al., 1995).

Order Spatangoida Claus, 1876

Suborder Urechinina H. L. Clark, 1925

Family Pourtalesiidae A. Agassiz, 1881

Genus *Pourtalesia* A. Agassiz, 1869

*Pourtalesia kusachii* n. sp.

(Pl. 10, figs. 1a-3; Pl. 12, fig. 9; Pl. 15, figs. 3a-4)

*Description:* Test very thin, very small in size, marginal outline bottle-like shape; highest point situate at near anterior part, and gradually slopes toward the posterior edge; lateral widest point being at near central part, becomes a little narrow toward the anterior edge, and gradually narrow toward the posterior edge, width of the posterior part relatively rapidly narrowed; with many spines. Oral side relatively flattened. Aboral side somewhat flattened, anterior edge, near the posterior end part deeply depressed forming a neck, neck forms a knob-like projection viz., in subanal rostrum.

Amblacra all simples, not petaloids; ambulacral petals large and wide, almost the same form with interambulacral ones on aboral side, and wider than the height, but a little smaller than inteambulacral plates size.

Rostrum small in size, keeled form with episternal plates, and extend toward the subanal rostrum. It's somewhat laterally swollen, and with a nodulously elevation on the aboral side. Subanal fasciole broadly developed, and surrounded subanal rostrum.

Apical system situated at near anterior edge on the aboral side with four genital pores. Preistome situated at near anterior edge on oral side. Periproct conspicuously situated at near vertical wall of the neck in posterior part on the aboral side.



Primary tubercles small, rather equal in size, and arranged irregularly on the each plates. Spines slender formed.

*Dimensions of test*

Specimens	Length	Width	Height
Holotype, IGUT. no. 14526	32.0 mm	—	16.0 mm
Paratype, IGUT. no. 14527	28.1 mm	15 mm+	—
IGUT. no. 14528	26.4 mm	—	11.5 mm
IGUT. no. 14529	25.5 mm	—	12.0 mm

*Comparisons:* The presented new species closely resembles *Pourtalesia laguncula* A. Agassiz, living species in having bottle-like shaped test, similar from to that of the species of the ambulacral plates and interambulacral plates, and also slender rostrum. However, *Pourtalesia laguncula* A. Agassiz has a rostrum with two nodulously elevations on both sides, while, the present fossil *Pourtalesia kisachii* has only nodulous elevation on the aboral side of rostrum.

The present new species also can be distinguished from *Pourtalesia laguncula beringiana* Branova, reported from 3,100 meters in depth of the Bering Sea by Branova (1955) in having shorter test.

However, detail features of *Pourtalesia laguncula beringiana* were not made. Therefore a more detail comparative study should be done between the present new species and allied living species of *Pourtalesia laguncula* A. Agassiz and *Pourtalesia laguncula beringiana* Branova.

*Etymology:* The present species name, *kusachii* is came from Mr. Iwao Kusachi, resident of the Tatsukuroiso, Suifu-mura, Kuji-gun, Ibaraki Prefecture.

*Remarks and affinities:* The first fossil record of the genus *Pourtalesia* was reported from the middle Miocene Tatsukuroiso Mudstone Member of the Higashikanasayama Formation by Kikuchi and Nikaido (1985).

The most allied living species, *Pourtalesia laguncula* A. Agassiz is recorded from 220–5,300 meters in depth of the Sagami Bay, Suruga Bay to Kyushu, Indonesia, New Guinea and the New Zealand regions (A. Agassiz, 1879, 1881, Lovén, 1883; Yoshiwara, 1900, 1906; H. L. Clark, 1917; Horikoshi et al., 1983; Shigei, 1986).

Therefore, from a ecological point of view, the present new species, *Pourtalesia kusachii* should be the indicator of deep condition as a more than 200 meters in depth.

*Types:* Holotype, IGUT. no. 14526, Paratype, IGUT. no. 14527.

*Locality, formation and geologic age:* The present new species, *Pourtalesia kusachii* was collected from the Loc. nos. 15 (type locality) and 16, of the middle Miocene Tatsukuroiso Mudstone Member of the Higashikanasayama Formation, Suifu-mura, Kuji-gun, Ibaraki Prefecture (Figs. 2, 16-18; Tables 2, 4, 14).

*Occurrence and associated fauna:* The present new species sporadically occurred from pale gray to light gray, massive tuffaceous mudstone with echinoids of *Aceste* sp, molluscs of *Solemya tokunagai* Yokoyama, *Delectopecten peckhami* (Gabb), *Bathyarca* sp., *Cavolina* sp., and sponge as *Makiyama chitanii* (Makiyama) (Loc. no. 15), and also with mollusca of *Solemya tokunagai* Yokoyama and sponge of *Makiyama chitanii* (Makiyama) (Loc. no. 16).

*Geologic distribution:* Middle Miocene Tatsukuroiso Mudstone Member of the Higashikanasayama Formation in Suifu-mura, Kuji-gun, Ibaraki Prefecture (Fig.59).

*Geologic range:* Middle Miocene.

Suborder Spatangoina Claus, 1876

Family Palaeonpneustidae A. Agassiz, 1904

Genus *Palaeopneustes* A. Agassiz, 1873

*Palaeopneustes psoidoperiodus* Nishio, 1961

(Pl. 9, figs. 1a-2b; Pl. 10, figs. 4-5)

1933, *Palaeopnesustes* sp., Aoki, p. 50, text-fig. 65a.

1953a. *Palaeopnesutes* aff. *cristatus* A. Agassiz, Moroshita, pl. 3,  
fig. 1.

1960, *Palaeopneustes cristatus* A. Agassiz, Hashimoto and Shibata,  
p. 337-338, pl. 39, figs. 1-2.

1961, *Palaeopneustes psoidoperiodus* Nishio, p. 130, pl. 1, figs.  
1-2.

1968, *Palaeopneustes psoidoperiodus* Nisiyama, Nisiyama, p 162,  
text-figs. 60a-c.

1968, *Palaeopneustes psoidoperiodus* Nisiyama, Matsuura and Hotsuta,  
p. 15, pl. 3(1), fig. 1.

*Description:* Test large in size, somewhat thin, ovoid in marginal outline; the transversely diameter longer than the longitudinal diameter; anterior part round and posterior part constrict; broadest point middle of test; edge of test flat. Ambulacra subpetaloid shaped. Oral side somewhat flat and aboral side arched. Apical system situated at near central part on aboral side.

Aboral side arched; gently rising from the toward the highest

point; highest point situated at near central, just on apical system. Ambulacra subpetaroid shaped; diverge flushed and open at a distal end.

Frontal ambulacrum (III) very long and wide, almost straight and shallow, with pores slightly small in size. Antero-lateral petals (II and IV) very long and wide, almost straight and broad form. Postero-lateral petals (I and V) almost straight and broad form. Pores-pairs remarkably oblong form with large in size; inner series of pores-pairs bigger than the outer sires of pores-pairs. Apical system small in size, situated in near center of aboral side; genital pores indistinct.

Oral side somewhat flatted, and rather concaved at peristomal part. Peristome very eccentric anteriorly depreessed, semilunal shaped in marginal outline. Labrum large and broad, following second plates in 5th interambulacrum. Plastron long and wide shape. Posterior ambulacra form rather long and wide. Periproct small in size, oval shaped in marginal outline and situated at a posterior edge of test.

Interambulacral plates wide and low on the aboral side; about 10 plates in a colume of postero-lateral interimbulacra (1 and 4),

Spines crowds on the interambulacral area, and sternal system

rather short, pointed and slender, size and form almost equal, but no crowd on ambulacra area.

*Dimensions*

Specimens	Length	width	Height
IGUT. no. 14532	110.3 mm	104.0 mm	40.2 mm
IGUT. no. 14533	107.0 mm	103 mm+	39.5 mm
IGUT. no. 14534	—	94.1 mm	51.5 mm
IGUT. no. 14535	94.6 mm	98.4 mm	40.3 mm

*Remarks and affinities:* The present fossil *Palaeopneustes psoidoperiodus* Nishio should be a valid name. Nishio (1961) reported one kind of species of *Palaeopneustes* from Chiba Prefecture as [*psoidoperodus* Nisiyama (MS), 1961] of new to science, with full description of the specimen and photograph. After that, Nisiyama (1968) described as *Palaeopneustes psoidoperiodus* from Fukushima Prefecture, which is synonymus with the Nishio's one. Therefore, present writer is judged that species described by Nishio (1961) to should be valid owing to the Zoological Nomenclature. Then present writer proposed here again [*Palaeopneustes psoidoperiodus* Nishio, 1961].

The present fossil species has been known from the Miocene Sakiyama Siltstone Member (Matsuura and Hotsuta, 1986), Pliocene Nakamura Formation (Aoki, 1933; Nisiyama, 1968), Pliocene Nadachi Formation (Morishita, 1953a), Pliocene Kanazawa Formation (Hashimoto and Shibata, 1960), Pliocene Muramatsu Formation (present paper), Pleistocene Umegase Formation (Nishio, 1961) and the Byubugaura Formation (present paper). In addition to the present species, three other species are included in genus *Palaeopneustes* that are known from the Miocene to Pleistocene age in Japan.

It is noteworthy that Henderson (1975) described as "*Palaeopneustes* is restricted to the Caribbean Sea area where it is only survivors presently persist but in Miocene time it passed through the Central American Seaway and crossed the Pacific Ocean area, presumably utilizing the North Pacific Equatorial Current, and colonized Japan".

*Locality, formation and geologic age:* The present species, *Palaeopneustes psoidoperiodus* Nishio was collected from the Loc. nos. 25 and 27, of the Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14).

*Occurrence and associated fauna:* The present species was collected from Loc. no. 25, as a single specimen occurred from the

gray to greenish gray, massive silty sandstone with mollusca of *Buccinum* sp. In loc. no. 27, aggregate specimens are occurred from the gray to greenish gray, massive silty sandstone with echinoids of *Brisaster owstoni* Mortensen, and mollusca of *Solemya tokunagai* Yokoyama.

*Geologic distribution:* Pliocene Nakamura Formation in Fukushima Prefecture, Sakiyama Siltstone Member in Ishikawa Prefecture, Nadachi Formation in Niigata Prefecture, Kanazawa Formation in Kanagawa Prefecture, Muramatsu Formation in Ibaraki Prefecture; Pleistocene Umegase Formation and the Byobugaura Formation in Chiba Prefecture (Fig. 60).

*Geologic range:* Pliocene to Pleistocene.

Suborder Spatangoina Claus, 1876

Family Aeropsidae Lambert, 1896

*Aceste* sp.

(Pl. 15, figs. 1-2b; fig. 51ab)

*Description:* Test very thin, very small in size, rather high, roundly cordiform in marginal outline; aboral side rising more or less distinctly to a posterior vertex; frontal amblacrum greatly



enlarged and deeply depressed a adaptically and with large and numerous pores; amblacral not petaloid; apical system situated at near posterior end.

*Dimension of test*

Specimens	Length	Width	Height
IGUT. no. 14536	10.6 mm	11.5 mm	6.6 mm
IGUT. no. 14537	9 0 mm	9.7 mm	—

*Remarks and affinities:* Family Aeropsidae is composed of genus *Aeropsis* and *Aceste*, and any kinds of fossil have been not known. Genus *Aeropsis* is characterized by cylinder form, and is distinguished easily from *Aceste* which has round form. Genus *Aceste* is composed of such three species as *Aceste weberi* Koehler, *Aceste ovata* A. Agassiz and H. L. Clark and *Aceste bellidifera* W. Thomson (Mortensen, 1954). Among these, *Aceste ovata* is known from the sea area of the Japanese Islands in the depth between 435 and 4,755 meters, and is known also from the Indian Ocean and the Hawaiian Islands (A. Agassiz and H. L. Clark, 1907; Koehler, 1914; H. L. Clark, 1917; Mortensen, 1954; Nisiyama, 1968).

The inhabiting environment of presented species can be

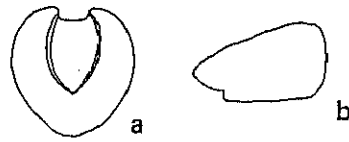


Fig. 51. Diagrammatic outline of the *Aceste* sp.  
(a. aboral side, b. lateral side).

implied to fossil record as to be a deeper place than continental slope under a warm-water surface condition. In the same way, *Aceste* sp. yielded together with *Pourtalesia kusachii* can be assigned a deep element. Then, time-range of *Aceste* species extends to middle Miocene to the present in the Japanese area.

*Locality, formation and geologic age:* The present species, *Aceste* sp. was collected from the middle Miocene Tatsukuroiso Mudstone Member (Loc. no. 15) of the Higashikanasayama Formation, Suifu-mura, Kuji-gun, Ibaraki Prefecture (Figs. 2, 16-18; Tables 1, 4, 14).

*Occurrence and associated fauna:* The present *Aceste* sp. was collected from Loc. no. 15, as sporadically occurred from pale gray to light gray, massive tuffaceous mudstone with echinoids of *Pourtalesia kusachii* n. sp., molluscs of *Solemya tokunagai* Yokoyama, *Delectopecten peckhami* (Gabb), *Bathyarca* sp., *Cavolina* sp., and siliceous sponge as *Makiyama chitanii* (Makiyama).

*Geologic distribution:* Middle Miocene Tatsukuroiso Mudstone Member of the Higashikanasayama Formation in Suifu-mura, Kuji-gun, Ibaraki Prefecture (Fig. 59).

*Geologic range:* Middle Miocene.

Family Schizasteridae Lambert, 1905

Genus *Linthia* Desor, 1853

*Linthia nipponica* Yoshiwara, 1899

(Pl. 16, figs. 1a-3; Pl. 18, fig. 3)

1899, *Linthia nipponica* Yoshiwara, p. 2.

1903, *Linthia nipponica* Yoshiwara, Yoshiwara, p. 18, p. 1, fig. 5.

1925, *Linthia nipponica* Yoshiwara, Lambert and Thiéry, p. 250.

1927, *Linthia nipponica* Yoshiwara, Tokunaga, p. 28, pl. 7, fig. 4,  
pl. 8, fig. 1.

1950, *Linthia nipponica* Yoshiwara, Mortensen, p. 2377.

1953a, *Linthia nipponica* Yoshiwara, Morishita, p. 222, pl. 1, fig.  
5-7.

1958, *Linthia nipponica* Yoshiwara, Tomizawa, p. 27, pl. 11, fig. 59.

1968, *Linthia nipponica* Yoshiwara, Nisiyama, p. 230, text-fig.  
69(44).

1982. *Linthia nipponica* Yoshiwara, Fujiyama, p. 384, pl. 192,  
fig. 1923.

1984, *Linthia nipponica* Yoshiwara, Matsuura et al., p. 21, pl. 5(1),  
fig. 2.

1989, *Linthia nipponica* Yoshiwara, Mizuno, p. 4, pl. 2, figs. 1a-2b.

*Description:* Test medium to large in size, thick, rather high, vary rounded cordiform in marginal outline, somewhat wider than long; the apical width being middle of test; anterior part of test widely rounded, frontal margin wide and very shallowly notched by a frontal groove; gradually elevated on aboral side, with concave curved from margin to the highest point; oral side nearly flat and slightly concaved.

Frontal ambulacrum (III) in very shallow groove, long and rather gradually converge proximally; pores very small and rounded, pores of a pair, more than 32 pore-pairs in each series and the pores in almost regular series. Ambulacral plates rather long and wide. Apical system placed subcentral, ethmoytic, the moderporite separating to postero-lateral plates (I and V), small, with four genital pores.

Antero-lateral petals (II and IV) long, straight, wide, and open at a distal end, somewhat depressed excepting proximal part, along between median line of petal (II) and petal (IV) being about  $115^\circ$ ; pores rather large and wide, pore-pairs situated in shallow groove, about 38 pairs on each series in petal; ambulacral plates low and rather wide.

Postero-lateral petals (I and V) short, straight, wide, and

open at a distal end, somewhat depress excepting proximal part, angle between median line of petal (I) and petal (V) being about  $85^{\circ}$  ; pores rather large and wide, pore-pairs situated in shallow groove; more than 25 pore-pairs in each series of petal; ambulacral plates low and rather wide. Ratio of length of antero-lateral petals and postero-lateral petals being about 1.0 : 0.75.

Peristome large, depressed, semilunar in marginal outline. Lubrum well develops with labiated form. Plastron long and wide, measamphisternous-form. Posterior ambulacra somewhat wide and long, each plates with single pore. Periproct elongate, situated on upper part of posterior extremity.

Interambulacral plates wide and low; more than 8 plates in the column of postero-lateral interambulacra (1 and 4), 11 or 12 plates in the column of antero-lateral interambulacra (2 and 3).

Peripetaleous fasciole narrow and sinuous. Latero-anal fasciole narrow and sinuous, and joins with peripetaleous fasciole.

*Dimension of test*

Specimens	Length	Width	Height
IGUT. no. 14538	63 mm+	62.3 mm	20.5 mm
IGUT. no. 14539	75 mm+	45 mm+	—

*Remarks and affinities:* The present fossil, *Linthia nipponica* Yoshiwara was occurred with *Linthia tokunagai* Lambert from the Pliocene Kume Formation and the Pliocene Muramatsu Formation. This co-occurrence of two species both of *Linthia nipponica* and *Linthia tokunagai* were the second record in Japan as followed the Pliocene Ogawa Formation in Nagano Prefecture (Yoshiwara, 1903; Lambert and Thiéry, 1925; Morishita, 1953).

The present fossil, *Linthia nipponica* has been reported from the Oligocene Asagai Formation (Tokunaga, 1927), Miocene stratum in Yamagata Prefecture (Fujiyama, 1982) and the Pliocene Ogawa Formation (Tokunaga, 1903; Lambert, 1925; Morishita, 1953a; Nisiyama, 1968).

*Linthia nipponica* reported by Matsuura and Hotsuta (1986; p. 15, pl. 3-1, fig. 2) from the Miocene Wajimazaki Sandstone of Ishikawa Prefecture is identified with *Cagaster recticanalis* Yoshiwara, which is characterized by postero-lateral petals being remarkably shorter than antero-lateral petals.

*Locality, formation and geologic age:* The present species, *Linthia nipponica* was collected from the following four localities; Loc. nos. 18-20, 28, Pliocene Kume Formation, Kanasago-machi, Kuji-gun, Ibaraki Prefecture (Figs. 2, 25-28; Tables 1, 7, 14); Loc.

no. 28, Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14).

*Occurrence and associated fauna:* The present species was collected from Loc. no. 18, as a single specimen occurred from gray to greenish gray, massive silty sandstone with molluscs of *Anadara amicula elongata* Noda and *Buccinum* sp. It is also yielded from the following localities; Loc. no. 19, as a single specimen occurred from gray to greenish gray, massive silty sandstone with mollusca of *Mizuhopecten ibaragiensis* (Masuda); Loc. no. 20, single specimen occurred from gray to greenish gray, massive silty sandstone with molluscs of *Acila* sp. and *Lucinoma* sp.; Loc. no. 28, single specimen occurred from gray to greenish gray sandy siltstone, in association with molluscs of *Solemya tokunagai* Yokoyama and *Conchocele bisecta* (Conrad).

*Geologic distribution:* Oligocene Asagai Formation? in Fukushima Prefecture; Miocene stratum in Yamagata Prefecture; Pliocene Ogawa Formation in Nagano Prefecture, Kume Formation and Muramatsu Formation in Ibaraki Prefecture (Fig.61).

*Geologic range:* Oligocene?, Late Miocene to Pliocene.

Genus *Linthia* Desor, 1853



*Linthia tokunagai* Lambert, 1925

(Pl. 15, figs. 7a-8; Pl. 18, figs. 2a-3c; Pl. 21, figs. 4a-b).

1925, *Linthia tokunagai* Lambert and Thiéry, p. 520.

1933, *Linthia tokunagai* Lambert, Aoki, p. 51, text-fig. P. 520.

1951, *Linthia tokunagai* Lambert, Mortensen, p. 237.

1965, *Linthia tokunagai* Lambert, Nisiyama, p. 80.

1968, *Linthia tokunagai* Lambert, Nisiyama, p. 234, pl. 24, figs. 3,  
6; pl. 25, figs. 1-3; pl. 26, figs. 1-3; text-fig. 70(54).

1974, *Linthia nipponica* Yoshiwara, Ishii et al., p. 116, pl. 21,  
fig. 11.

1982, *Linthia tokunagai* Lambert, Fujiyama, p. 384, pl. 192, figs,  
1922a-b.

1984, *Linthia tokunagai* Lambert, Matsuura et al., p. 21, pl. 5(1),  
fig. 2.

1987, *Linthia tokunagai* Lambert, Kikuchi and Nikaido, p. 87, figs.  
3, 4a-b.

*Description:* Test medium in size, thick, somewhat high, rounded cordiform in marginal outline, slightly wider than long; the grates width being middle of test; anterior part of test widely

rounded, frontal margin slightly wide and very shallowly notched by a frontal groove; gradually elevated on aboral side, with concave curved from margin to the highest point; oral side nearly flat and slightly concaved.

Frontal ambulacrum (III) in shallow groove, long and rather wide, gradually converged proximally; pores very small and rounded, more than 23 pore-pairs in each series and the pores in almost regular series. Ambulacral plates rather long and wide. Apical system situated in subcentral, ethmytic, the moderporite separating to postero-lateral plates (I and V), small, with four genital pores.

Antero-lateral petals (II and IV) long, straight, wide, and open at distal end, somewhat depressed excepting proximal part, along between median line of petal (II) and Petal (IV) being about  $110^{\circ}$  ; pores rather large and wide, Pore-pairs situated in shallow groove, more than 28 pore-pairs on each series in petal; ambulacral plates low and rather wide.

Postero-lateral petals (I and V) short, straight, wide, and open at distal ends, somewhat depress excepting proximal part, angle between median line of petal (I) and petal (V) being about  $80^{\circ}$  ; pores rather large and wide, pores-pairs in shallow groove, about 25 pores-pairs on each series in petal; ambulacral plates low and rather

wide. Ratio of length of antero-lateral petals (II and IV) and postero-lateral petals (I and V) being about 1.0 : 0.70.

Peristome large, depressed, semilunar in marginal outline. Lubrum well develops with labiated form. Plastron long and wide, measamhisternous form. Posterior ambulacra somewhat wide and long, each plates with single pore. Periproct roundly elongate, situated on upper part of posterior extremity.

Interambulacral plates wide and low; more than 8 plates in the column of postero-lateral interambulacra (1 and 4), 11 or 12 plates in the column of antero-lateral interambulacra (2 and 3).

Peripetaleous fasciole narrow and sinuous. Latero-anal fasciole narrow and sinuous, and joins with peripetaleous fasciole.

*Dimensions*

Specimens	Length	Width	Height
IGUT. no. 14541	50.4 mm	47.4 mm	21 mm+
IGUT. no. 14542	52 mm+	50.0 mm	—

*Remarks and affinities:* The present fossil, *Linthia tokunagai* Lambert has been recorded from the following strata; Miocene? Stratum in Hokkaido (Fujiyama, 1982) and Miocene Hosozaki

Mudstone (Hotsuta et al., 1984), Pliocene Sasaoka Formation (Nisiyama, 1968), Kazusawa Formation (Nisiyama, 1968), Ogawa Formation (Lambert and Thiéry, 1925; Tokunaga, 1927; Morishita, 1953a; Nisiyama, 1968) and the Kume Formation (Ishii et al., 1974; Kikuchi and Nikaido, 1987).

*Locality, formation and geologic age:* The present species was occurred from the following three localities; Loc. no. 21 of the Pliocene Kume Formation, Hitachiota City, Ibaraki Prefecture (Figs. 2, 25-26, 29; Tables 1, 7, 14); Loc. no. 31 of the Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14); Loc. no. 38 of the Pliocene Hatsuzaki Sandstone Member of the Hitachi Formation, Hitachi City, Ibaraki Prefecture (Figs. 2, 39-40, 42; Tables 1, 11, 14).

*Occurrence and associated fauna:* The present species was yielded from Loc. no. 21, as abundantly occurred from gray to greenish gray, massive silty sandstone, with many kinds of molluscan fossils (Watanabe, 1993MS; Noda et al., 1993). It is also occurred from the following localities; Loc. no. 31, as a single specimen occurred from gray to greenish gray sandy siltstone with echinoids of *Anthocardaris* sp., *Brisaster owstoni* Mortensen, *Nodaster watanabei* n. gen. et n. sp. and *Anametalia* sp., molluscs of *Portlandia lischkei* Smith and

*Limopsis tokaiensis* Yokoyama; Loc. no. 38, as a single specimen occurred from coarse grained to pebbly, massive sandstone, with many kinds of molluscan fossils (Watanabe, 1993 MS; Noda *et al.*, 1995).

*Geologic distribution:* Miocene? Stratum in Hokkaido and Miocene Hosozaki Mudstone in Ishikawa Prefecture; Pliocene Sasaoka Formation in Akita Prefecture, Kazusawa Formation in Yamagata Prefecture, Ogawa Formation in Nagano Prefecture, Kume Formation, Muramatsu Formation and Hatsuzaki Sandstone Member of the Hitachi Formation in Ibaraki Prefecture (Fig.62).

*Geologic range:* Late Miocene to Pliocene.

*Linthia* sp.

(Pl. 10, figs. 5-6)

*Remarks and affinities:* Imperfect specimens of *Linthia* species were collected from the following three formations. Kume specimen (Pl. 10, fig. 5; IGUT. no. 14544) was preserved of oral side part specimen from the Kume Formation (Loc. no. 19); Odaira specimen (Pl. 10, fig. 6; IGUT. no. 14545) was preserved of aboral side part specimen from the Kume Formation (Loc. no. 20); Tokai specimen was preserved oral side part from the Muramatsu Formation (Loc. no. 26).

*Locality, formation and geologic age:* The present specimens, *Linthia* sp. were collected from the three localities; Loc. nos. 19 and 20, Pliocene Kume Formation, Hitachiota City (Figs. 2, 25-28; Tables 1, 7, 14); Loc. no. 26, Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46, Tables 1, 12, 14).

*Occurrence and associated fauna:* The present species was occurred from the Loc. no. 19 as sporadically occurred from gray to greenish gray, massive silty sandstone with mollusca of *Mizuhopecten ibaragiensis* (Masuda). It is also occurred from the following localities; Loc. no. 20, as a single specimen occurred from the gray to greenish gray, massive silty sandstone with molluscs of *Acila* sp. and *Lucinoma* sp.; Loc. no. 26, as a single specimen occurred from the greenish gray sandy siltstone with mollusca of *Lucinoma* sp.

Genus *Lutetiaster* Lambert, 1920

*Lutetiaster ogasawarai* n. sp.

(Pl. 17, figs. 1a-f; Pl. 19, 1a-4d; Pl. 20, figs. 1a-6b; Pl. 22, fig. 3; Figs. 52a-c)

*Description:* Test slightly thin, medium in size, rather low,

very rounded cordiform in marginal outline, almost as wide as long; the greatest width being in middle of test; gradually elevated on aboral side, with concave curved from margin to the highest point; anterior part of test widely rounded, frontal margin wide and very shallowly notched by a frontal groove; posterior part more or less narrow, posterior end truncate; oral side nearly flat and slightly concave; peristomal region distinct to posterior margin; posterior almost vertically truncated, and slightly concave.

Frontal ambulacrum (III) in shallow groove, long and rather wide, both side almost straight and subparallel, rather gradually converge in proximal place; pore very small and round, pore of a pair; pore-pairs more or less oblique shaped, and placed in near adradial suture of plates; about 22 pore-pairs in each series, and the pores in almost regular series on each side; ambulacral plates somewhat low and wide; interporiferous zone rather wide.

Apical system subcentral, ethmoytic, madreporite separated from postero-lateral plates (I and V), small, with four genital pores.

Antero-lateral petals (II and IV) long, straight, and open at distal ends, somewhat depress excepting in proximal part, angle between median line of petal (II) and petal (IV) being about  $110^{\circ}$  ;

ambulacrum plate low and rather wide; Poriferous zone rather wide; pores somewhat large and wide, pores of a pair in groove, about 34 pore-pairs on each series in petals; interporiferous zone narrow.

Postero-lateral petals (I and V) short, straight, and open at distal ends, somewhat depress excepting in proximal part, angle between median line of petal (I) and petal (V) being about  $85^{\circ}$ ; ambulacrum plate low and rather wide; poriferous zone rather wide; pores somewhat large and wide, pores of a pair in a shallow groove; about 22 pore-pairs in each series in petals; interporiferous zone narrow. Ration of length of the antero-lateral petals and postero-lateral petals being about 1.0 : 0.7.

Peristome large in size, depressed adorally, semilunual in marginal outline. Lubrum well developed and labial shape, rather large and long, well arched anteriorly and pointed posteriorly. Plastron long and wide, mesamphisternous-form. Phyllodes rather broad, each plates with a large phyllode pore. Posterior ambulacra rather wide and long, each plates with a single pore.

Preiproct transversely elongate, rather straight upward and rounded downward, situated on upper portion of posterior extremity.

Interambulacra area wide; 10 or 11 plates in a column of postero-lateral interambulacra (1 and 4), and 11 or 12 plates in a



column of antero-lateral interambulacra (2 and 3).

Peripetalous fasciole narrow and sinuous. Peripetalous fasciole crosses the groove of frontal ambulacrum (III) slightly above ambitus, transverses antero-lateral interambulacra (2 and 3) with convex curve, almost parallel to and slightly above ambitus, passes distal end of antero-lateral petals (II and IV) on the extension of the same curve, then, bend right angle with a few downward curve running parallel to the course of petals to nearly middle of them, and again bend at a right angle at about center on 5<sup>th</sup> plate of anterior column of postero-lateral interambulacra (1 and 4), then, runs posteriorly, crossing 6<sup>th</sup> plate of the posterior column of the posterior area, with somewhat curve to distal end of postero-lateral petals (I and V) and passes there with rounded curve, and lastly it passes 6<sup>th</sup> plate posterior interambulacrum (5) with slightly convex curve.

Latero-anal fasciole narrow, joins with peripetalous fasciole at its extremity a short distance behind distal end of the antero-lateral petals (I and IV), crosses 8<sup>th</sup> or 9<sup>th</sup> plate in postero-lateral interambulacra with convex nearly parallel to and slightly above ambitus, continues with a curve to a short distance excavation to middle part of each column of posterior

interambulacrum (5), crossing postero-lateral amburacra, and lastly passing posteriorly under the periproct.

*Dimension of test*

Specimens	Length	Width	Height
Holotype, IGUT. no. 14546	42.6 mm	47.0 mm	12.0 mm
Paratype, IGUT. no. 14547	45.0 mm	46.6 mm	15.8 mm
IGUT. no. 14548-1	41.6 mm	41.4 mm	—
IGUT. no. 14548-2	35.7 mm	35.6 mm	8.5 mm
IGUT. no. 14548-3	54.5 mm	52.0 mm	18.0 mm
IGUT. no. 14548-4	34.6 mm	36.3 mm	10.0 mm

*Dimension of petals*

Specimens	I & V		II & IV	
	Length	Width	Length	Width
Holotype, IGUT. no.14546	15.5 mm	4.5 mm	22.4 mm	5.0 mm
Paratype, IGUT. no.14547	14.6 mm	4.5 mm	20.0 mm	—
IGUT. no.14548-1	13.0 mm	—	19.4 mm	4.2 mm
IGUT. no.14548-2	9.7 mm	3.0 mm	14.7 mm	3.4 mm
IGUT. no.14548-3	8.4 mm	3.2 mm	13.6 mm	3.8 mm
IGUT. no.14548-4	12.4 mm	3.0 mm	16.5 mm	4.4 mm

*Comparison and remarks:* This new species is characterized by



Fig. 52. Diagrammatic outline of the *Lutetiaster ogasawarai* n. sp. (a. aboral side, b. lateral side, c. posterior side).

small ratio of the length of postero-lateral petals (I and V) to antero-lateral petals (II and IV) and their angles. However the form of peripetalous fasciole and latero-anal fasciole very similar to *Linthia tokunagai* Lambert, the present new species can be easily distinguished from *Linthia tokunagai* in having transversely elongated periproct, large labrum and low test.

Genus *Lutetiaster* has been recorded three fossil species as, *Lutetiaster subglobosus* (Lamarck) from the Miocene strata of Europe and Africa, *Lutetiaster lamberti* Catex from the Eocene stratum of Europe (Cotteau, 1885-1889), and *Lutetiaster maccagnoi* Checchia-Rispoli from the Eocene stratum of Africa (Checchia-Rispoli, 1950). The present new species, *Lutetiaster ogasawarai* is the first record in Japan and the adjacent area.

*Etymology:* The present new species name, *ogasawarai* is come from Professor Kenshiro Ogasawara of the Institute of Geoscience, the University of Tsukuba.

*Types:* Holotype, IGUT. no. 14546, Paratype, IGUT. no. 14547.

*Locality, formation and geologic age:* The present new species, *Lutetiaster ogasawarai* was collected from the three localities; Loc. no. 23, Pliocene Kume Formation, Hitachiota City, Ibaraki Prefecture (Figs. 2, 33, 36-37; Tables 1, 9, 14); Loc. nos.

30 (type locality) and 34, Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14).

*Occurrence and associated fauna:* The present species was collected from Loc. no. 23, as abundantly occurred from gray to greenish yellow, massive silty sandstone with molluscs of *Acila divericata submirabilis* (Makiyama) and *Portlandia lischkei* Smith. It is also yielded as follows; Loc. no. 30, sporadically occurred from gray to greenish gray, massive silty sandstone with echinoid of *Brisaster owstoni* Mortensen and mollusca of *Solemen diaphana* (Dall); Loc. no. 34, sporadically occurred from gray to greenish gray, massive silty sandstone, in association with echinoids of *Brisaster owstoni* Mortensen and following molluscs of *Portlandia lischkei* Smith, *Liomopsis tokaiensis* Yokoyama, *Solemen diaphana* (Dall), *Turcricula sukegawaense* Noda and *Fulgoraria* sp.

*Geologic distribution:* Pliocene Kume Formation and Pliocene Muramatsu Formation in Ibaraki Prefecture (Fig. 63).

*Geologic range:* Pliocene.

Genus *Brisaster* Gray, 1905

*Brisaster owstoni* Mortensen, 1950

(Pl. 11, figs. 1a-11)

- 1881a, *Schizaster ventricosus* A. Agassiz, p. 204, pl. 36, figs. 1-3.
- 1900, *Schizaster ventricosus* A. Agassiz, Yoshiwara, p. 398.
- 1906, *Schizaster ventricosus* A. Agassiz, Tokunaga, pl. 17, figs.  
7-9.
- 1907, *Schizaster ventricosus* A. Agassiz, A. Agassiz and H. L.  
Clark, p. 137.
- 1917, *Brisaster latifrons* A. Agassiz and H. L. Clark, p. 180.
- 1925, *Brisaster latifrons* A. Agassiz and H. L. Clark, H. L. Clark,  
p. 207.
- 1950, *Brisaster owstoni* Mortensen, p. 160.
- 1951, *Brisaster owstoni* Mortensen, Mortensen, p. 291, pl. 23, figs.  
7-8, 11-15, pl.53, figs. 11, 14, 17-19.
- 1958, *Brisaster owstoni* Mortensen, Ozaki, p. 177, pl. 18, figs.  
15-16.
- 1968, *Brisaster owstoni* Mortensen, Nisiyama, p. 247, pl. 24,  
fig. 1.
- 1973, *Brisaster owstoni* Mortensen, Shigei, p. 321.
- 1974, *Brisaster owstoni* Mortensen, Shigei and Okutani, p. 439.
- 1980, *Brisaster owstoni* Mortensen, Shigei, p. 217, 249.
- 1982, *Brisaster owstoni* Mortensen, Saba et al., p. 39, pl. 31,  
fig. 4.

1982, *Brisaster owstoni* Mortensen, Fujiyama, p. 384, pl.

191, fig. 124.

1983, *Brisaster owstoni* Mortensen, Horikoshi et al., p. 3-6,

10-11, 16-18, 23, 30-33, 35, 38-39, 42-44, 46-48, 52,

58-60, 64, 67, 69, 72, 74-76, 144.

1983, *Brisaster owstoni* Mortensen, Ohta, p. 253.

*Description:* Test slightly thin, rather small to medium in size, somewhat oval in marginal outline; longer than wide in test, the greatest width being in middle of test; anterior part low, anterior end diverge and deeply notched by a frontal groove; posterior part high, posterior extremity almost vertically truncated, and slightly concave; gradually elevated aborally with convex curve from marginal to highest point; oral side nearly flat and slightly concave orally.

Frontal ambulacrum (III) very wide, long and deep groove, and rather suddenly converge proximally; pores large and regularly in groove, with about 39 pores in each series, ambulacrum plates low and wide.

Apical system distinctly posterior, situated at about 1/3 test of the length from the posterior end, ethmoytic, rather large,

with three genital pores.

Anterio-lateral petals (II and IV) very long, rather deep groove, and closed at distal ends, at first a little and then somewhat converge some distance from distal part and finally diverge outwardly near the middle of the petals; pores rather large, pores of a pair in a groove, about 31 pore-pairs on each series in petals: ambulacral plates rather low and wide.

Postero-lateral petals (I and V) very short, straight, rather deep groove, and closed at distal ends; pores of a pair in a groove, about 14 pore-pairs on each series in petals, pores size almost the same of the postero-lateral petals pores; ambulacral plates rather low and wide.

Peristome rather small, depressed orally, almost semilunar shape in outline; Labrum labiated form, small and short, arched anteriorly and pointed posteriorly. Plastron very long and wide, holamphisternous form, posterior ambulacra narrow and long.

Interambulacra (2 and 3) become very narrow from the proximal to middle part area; interambulacra (1 and 4) very wide; interambulacrum (5) short and narrow.

Peripetaleous fasciole well developed, rather wide and angular form, it runs cross to the petals end, and cross the frontal



ambulacrum edge. Primary spines rather short, distinct curved and spatula-shape.

*Dimensions*

Specimens	Length diameter	Transversal diameter	Height
IGUT. no. 14549	40.0 mm	32.3 mm	12.5 mm
IGUT. no. 14550	43.5 mm	42.2 mm	15.2 mm
IGUT. no. 14551	43.1 mm	39.3 mm	12.0 mm

*Remarks and affinities:* Fossil *Brisaster owstoni* Mortensen have been known only from the following three strata in Japan; Pliocene Iioka Formation (Ozaki, 1952), Pliocene Kakinokidai Formation (Fujiyama, 1982) and the Pleistocene Sanuki Formation (Nisiyama, 1968).

Living *Brisaster owstoni* is only recognized around the Sagami Bay and Suruga Bay in central Japan, in depth of 10 m to 600 m. Within this depth range, the most abundant individuals occurred from 300 m to 400 m (Nisiyama, 1968; Horikoshi et al., 1983; Shigei, 1986).

Very well-preserved fossil *Brisaster owstoni* occurred which many spines on test is suggested it is an autochthonous one. This fossil *Brisaster owstoni* is assigned the same environmental

condition to that of living species.

*Locality, formation and geologic age:* The present species were collected from eight localities of loc. nos. 27-35 of the Pliocene Muramatsu Formation, Tikai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14).

*Occurrence and associated fauna:* The present species was collected from Loc. no. 27 as the mode of sporadically occurred from gray to greenish gray, massive silty sandstone with echinoids of *Palaeonpneustes psoidoperiodus* Nishio and mollusca of *Solemya tokunagai* Yokoyama. It is occurred as followings; Loc. no. 28, sporadically occurred from gray to greenish gray, massive silty sandstone with echinoids of *Linthia nipponica* Yoshiwara, and molluscs of *Solemya tokunagai* Yokoyama, *Lucinoma acutilineata* (Conrad) and *Turritella nipponica nipponica* (Yokoyama); Loc. no. 29, sporadically occurred from gray to greenish gray, massive silty sandstone; Loc. no. 30, shows sporadically or abundantly occurred from gray to greenish gray, massive silty sandstone with echinoid of *Lutetiaster ogasawarai* n. sp., and such molluscs as *Portlandia lischkei* smith and *Solemen diaphana* (Dall); Loc. no. 31, abundantly occurred from gray to greenish gray, massive silty sandstone with echinoid of *Anthocidaris* sp., *Linthia tokunagai* Lambert, *Nodaster*

*watanabei* n. gen. et n. sp., *Anametalia* sp., and molluscs of *Portlandia lischkei* Smith and *Limopsis tokaiensis* Yokoyama; Loc. no. 32, abundantly occurred from gray to greenish gray, massive silty sandstone with such echinoid of *Nodaster watanabei* n. gen. et n. sp. and molluscs of *Portlandia lischkei* Smith, *Limopsis tokaiensis* Yokoyama, *Solemen diaphana* (Dall), *Turcicula sukegawaense* Noda and *Fulgoraria* sp.; Loc. no. 33, abundantly occurred from gray to greenish gray, massive silty sandstone with echinoid of *Brissopatagus* sp. and *Nikaidoster tokaiensis* n. gen. et n. sp. and molluscs of *Limopsis tokaiensis* Yokoyama; Loc. no. 34, abundantly occurred from gray to greenish gray, massive silty sandstone, with such echinoid of *Lutetiaster ogasawarai* n. sp. and molluscs of *Portlandia lischkei* Smith and *Lucinoma* sp.; Loc. no. 35, abundantly occurred from gray to greenish gray, massive silty sandstone with molluscs as *Portlandia lischekei* Smith and *Limopsis tokaiensis* Yokoyama.

*Geologic distribution:* Pleistocene Sanuki Formation, Pliocene Iioka Formation and Kakinokidai Formation in Chiba Prefecture, and Pliocene Muramatsu Formation in Ibaraki Prefecture (Fig. 64).

*Geologic range:* Pliocene to Recent

Family Schizasteridae Claus, 1986

Genus *Nikaidoster* n. gen.

*Type species: Nikaidoster tokaiensis* n. sp.

*Diagnosis:* Test small in size, swelled aborally, rectangular parallelepiped in marginal outline, ambulacra depress, posterior part conspicuously elevated. Frontal rather deeply notched. Frontal ambulacrum (III) slightly wide and rather grooved deeply. Antero-lateral petals long and rather widely; postero-lateral petals short and rather widely. Apical system ethmolytic form, and with four genital pores. Peripetalous fasciole and lateral-anal fasciole presents. Posterior end vertically truncated, periproct small in size with elongated shape.

*Comparison and remarks:* The genus is monotypic at present, but the peculiar feature of test is suggesting it be separated from the allied genus. It is clear that the present genus *Nikaidoster* belongs to family Schizasteridae on the basis of characters of peristome, peripetaleous fasciole, latero-anal fasciole and petals.

Present genus *Nikaidoster*, is characterized by the rectangular parallelepiped form with small size, high test, and elongated periproct. Therefore, these characteristics can be

obviously distinguished from other genera of family Shizasteridae.

*Nikaidoster tokaiensis* n. gen. et n. sp.

(Pl. 21, figs. 1a-3d; Figs. 53a-c)

*Description:* Test very thin, small in size, rather high, rectangular parallelepiped in marginal outline, almost as wide as long; most grate width being in center of test; anterior part rounded narrowly, frontal margin narrow, and rather deeply notched by a frontal groove; posterior part rather wide, conspicuously elevated; posterior extremity vertically concave orally.

Frontal ambulacrum (III) in a rather deep groove, long and slightly wide, both side nearly straight and subparallel, pores somewhat big, pore of a pair, about 16 pore-pairs in each side; ambulacrum plates very low and wide.

Apical system situated in slightly near anterior part, ethymotyctic, with four genital pores.

Antero-lateral petals (II and IV) straight, slightly depressed, narrow and long, and open at a distal end; angle between median line of petal(II) and petal(IV) being about  $130^{\circ}$  ; pores of a pair in a shallow groove, more than 24 pore-pairs on each series

in plates; ambulacrum plates very low and wide.

Postero-lateral petals (I and V) straight, slightly depressed, narrow and very short, and open at distal end, angle between median line of petal (I) and petal (V) being about  $60^\circ$ ; pore of a pairs in a shallow groove, about 17 pore-pairs on each series in petal; ambulacrum plates low and wide. Ratio of length of antero-lateral petals and postero-lateral petals being about 1.0 : 0.75. Interambulacral plates wide and long on aboral side, and with about 9 plates in a column of antero-lateral interambulacra (1 and 4).

Peristome rather large, strongly depressed orally, semilunar in outline. Lubrum developed and labiate shape, well arched anteriorly and pointed posteriorly. Plastron wide and long, with shaped of mesamphisternous. Phyllodes short and broad, deeply sunken; each plates longer than width, with more or less single pore.

Periproct small in size, elongated, pointed to upward and downward, situated on portion on posterior extremity.

Peripetaleous fascicle rather broad, being not suddenly curve at any point, and generously sinuous. It crosses the groove of a frontal ambulacrum (III) more above ambitus or frontal margin, transverses antero-lateral interambulacra with convex curve almost

parallel to and more ambitus, passes distal ends of antero-lateral petals and postero-lateral petals, and with slightly curve.

Latero-anal fasciole joins with peripetaleous fasciole at its extremity a short place behind distal ends of antero-lateral petals, crosses in postero-lateral interambulacra with subparallel to and more above ambitus, and passing posterior under periproct.

*Dimension of test*

Specimens	Lengthitudinal diameter	Transversal diameter	Height
Holotype, IGUT. no. 14560	24.5 mm	23.5 mm	12.9 mm
Paratype, IGUT. no. 14561	26.0 mm	27.6 mm	13.6 mm
IGUT. no. 14562	23.0 mm	—	13.3 mm

*Dimension of petals*

Specimens	I & V		II & IV	
	Length	width	Length	width
Holotype, IGUT. no. 14560	7.4 mm	3.2 mm	10.3 mm	3.7 mm
Paratype, IGUT. no. 14562	10.9 mm	3.4 mm	13.4 mm	3.4 mm
IGUT. no. 14563	6 mm+	3.0 mm	12.5 mm	3.3 mm



Fig. 53. Diagrammatic outline of the *Nikaidoster tokaiensis* n. gen. et n. sp. (a. aboral side, b. lateral side, c. posrerior side).



*Etymology:* The present new genus name, *Nikaidoster* is came from Mr. Akinobu Nikaido, the president of the Mito Agricultural High School, and also new species name, *tokaiensis* is taken from the fossil locality.

*Types:* Holotype, IGUT. no. 14560, Paratype, IGUT. no. 14561.

*Locality, formation and geologic age:* The present new genus and new species, *Nikaidoster tokaiensis* was collected from the Pliocene Muramatsu Formation (Loc. no. 33), Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14).

*Occurrence and associated fauna:* The present species were collected from Loc. no. 33, as the mode of sporadically occurred from gray to greenish gray, massive silty sandstone with echinoids of *Brisaster owstoni* Mortensen and *Brissopatagus* sp. and also molluscs of *Limopsis tokaiensis* Yokoyama.

*Geologic distribution:* Pliocene Muramatsu Formation in Ibaraki Prefecture (Fig. 65).

*Geologic range:* Pliocene.

Schizasteridae gen. et sp. indet.

*Materials:* Imperfect specimens that can be identified to family Shizasteridae were collected from four localities.

*Locality, formation and geologic age:* Imperfect specimens were collected from following four localities; Loc. no. 12, early middle Miocene Uchiono Formation, Daigo-machi, Kuji-gun, Ibaraki Prefecture (Figs. 2, 5, 7, 9; Tables 1-2, 14; IGUT. no. 14589); Loc. no. 17, early middle Miocene Tamagawa Formation, Omiya-machi, Naka-gun, Ibaraki Prefecture (Figs. 2, 19-21; Tables 1, 5, 14); Loc. no. 22, Pliocene Kume Formation, Hitachiota City, Ibaraki Prefecture (Figs. 2, 33-35; Tables 1, 9, 14), Loc. no. 40, middle Miocene Genjigawa Formation, Kanasago-machi, Kuji-gun, Ibaraki Prefecture (Fig. 2, 30-32; Tables 1, 8, 14).

*Occurrence and associated fauna:* Imperfect single fossil of the species was collected from fine grained sandstone of alternating beds of sandstone and siltstone with sponge of *Makiyama chitanii* (Makiyama) (Loc. no. 33). It is also occurred as follows; Loc. no. 17, single specimen occurred from the massive, tuffaceous sandy siltstone with molluscs of *Crassostrea gravitesta* (Yokoyama) and *Acila* sp.; Loc. no. 22, single specimen occurred from gray to greenish gray, massive siltstone with molluscs of *Acila* sp. and *Portlandia lischkei* Smith; Loc. no. 40, single specimen occurred from the greenish gray, massive sandy siltstone, and with molluscs of *Lucinoma* sp. and *Solemya cf. tokunagai* Yokoyama.

Family Pericosmidae Lambert, 1905

Genus *Nodaster* n. gen.

*Type species; Nodaster watanabei* n. sp.

*Diagnosis:* Elevated from of most angular heart shaped in marginal outline with somewhat depressed ambulacra. Frontal ambulacra (III) broad and terminating in a shallow notch; perforated by pore-pairs arranged in double series. Antero-lateral petals long and rather narrow shaped; postero-lateral petals short and rather narrow. Apical system ethemolytic form and with four genital pores. Peripetaleous fasciole presented, but latero-anal fasciole absent. Posterior end truncate vertically and vertically truncated wall almost triangle shape. Periproct elongate formed.

*Comparison and remarks:* Although the new genus is monotypic at present, the peculiar features of test of *Nodaster watanabei*, requires to be separated from allied genus. It is clear that present genus *Nodaster* belongs to family Pericosmidae and resembles to *Pericosmus* (in particular, *Pericosmus keiensis* Mortensen and/or *Pericosmus bidensu* Mortensen) forms in having similar to that periproct, peristome, petals, apical system and others.

The present new genus *Nodaster* is characterized by the test

of form elevated and very angular heart-shaped, triangle shape of the posterior end wall and lacking latero-anal fasciole. Therefore, these characteristics can be obviously distinguished from other genera of family Pericosmidae.

*Nodaster watanabei* n. gen. et n. sp.

(Pl. 17, figs. 2a-3g; Pl. 18, figs. 1a-d, 4; Figs. 54a-c)

*Description:* Test rather thick, medium in size, rather high, angular cordiform in marginal outline, almost as wide as long; the greatest width being in anterior of test; anterior part of test rounded widely, frontal margin very wide, and very shallowly notched by a frontal groove; posterior part narrowed from posterior half of postero-lateral interambulacra to posterior truncations; quickly elevated aborally and with steep slope from margin to the highest point; oral side slightly concave orally; posterior extremity vertically truncated, and slightly concave.

Frontal ambulacrum (III) in a slightly deep groove, long and rather wide, both side straight and almost parallel; pores very small in size, pore of a pair, pore-pairs almost oblique, and placed central

of plates, about 23 pore-pairs in each series and the pores in regular series on each side; ambulacrum plates somewhat low and wide.

Apical system slightly anteriorly, ethmoytic, medreporite separating by postero-lateral petals (I and V), genital pores rather large in size, with four genital pores.

Antero-lateral petals (II and IV) straight, narrow and long, both side almost straight, and open at distal end, slightly depressed excepting in proximal part; angle between median line of petal (II) and petal (IV) being about  $120^{\circ}$ ; Pores rather large in size, pore of a pair, pore-pairs placed shallow groove, about 31 pore-pairs on each series in petals; ambulacral plates low and wide.

Postero-lateral petals (I and V) straight, narrow and short, both side almost straight, and open at distal end, slightly depressed excepting proximal part, angle between median line of petal (I) and petal (V) being about  $80^{\circ}$ ; pores rather large in size, pore of a pair, placed shallow groove; ambulacral plates very low and wide. Ratio of length of antero-lateral petals (II and IV) and postero-lateral petals (I and V) being about 1.0 : 0.7.

Peristome large in size, rather deeply depressed orally, semilunar in outline, Lubrum well developed and labiated, well arched anteriorly and pointed posteriorly. Plastron somewhat wide and large

in size, mesampisternous form. Phyllodes broaden, each plate with a large phyllode-pore. Posterior ambulacra slightly narrow and long, each plate with a single pore.

Periproct elongated, and upward and downward rather pointed, situated on upper portion of posterior extremity.

Interambulacral plates on aboral side wide and low, and with 10 or 11 plates in a column of antero-lateral interambulacral (1 and 4), and 6 or 7 plates in a column of posterior interambulacrum (5).

Peripetalous fasciole very narrowed, with rather sinuous form. It crosses the groove of frontal ambulacrum (III) slightly above ambitus, transverses antero-lateral interambulacra (2 and 3) with almost parallel and slightly above ambitus, passes distal end of antero-lateral petals (II and IV) on the extension of the same curve, then bends right angle with a little downward curve running parallel to the course of petals to nearly middle of them, then again bends at a right angle at about center on 5th plate of anterior column of postero-lateral interambulacra (1 and 4), and runs posteriorly crossing 6th plate of the posterior column of area, with a slightly curve to distal end of the postero-lateral petals (I and V), and passes there with a rounded curve, and lastly it passes 6th plate in posterior interambulacrum (5) with almost straight. Latero-anal

fasciole absent.

*Dimension of test*

Specimens	Lengthitudinal diameter	Transversal diameter	Height
Holotype, IGUT. no. 14563	50.0 mm	50.3 mm	19.5 mm
Paratype, IGUT. no. 14564	58.3 mm	58.2 mm	18.0 mm
IGUT. no. 14565	42 mm+	36 mm+	18.5 mm

*Dimension of petals*

Specimens	I & V		II & IV	
	Length	width	Length	width
Holotype, IGUT. no. 14563	18.3 mm	4.2 mm	24.0 mm	4.9 mm
Paratype, IGUT. no. 14564	11.9 mm	3.8 mm	17.8 mm	4.8 mm
IGUT. no. 14565	14.5 mm	4.3 mm	23.4 mm	4.6 mm

*Etymology:* The present new genus name, *Nodaster* is come from Professor Emeritus Hiroshi Noda of the University of Tsukuba, and a new species, *watanabei* is come from former student Mr. Ryuichiro Watanabe of the Doctor Course Program of Geoscience, the University of Tsukuba.

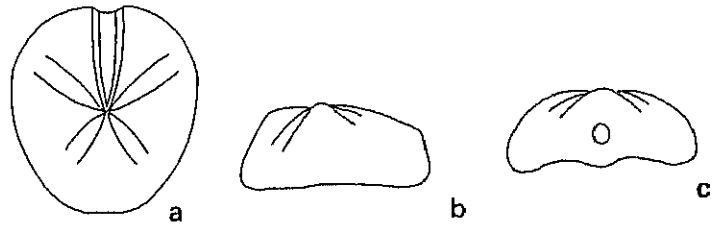


Fig. 54. Diagrammatic outline of the *Nodaster watanabei* n. gen. et n. sp. (a. aboral side, b. lateral side, c. posterior side).



*Types:* Holotype, IGUT. no. 14563, Paratype, IGUT. no. 14564.

*Locality, formation and geologic age:* Specimens were collected from following four localities; Loc. no.31 of the type locality and no. 32, Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46; Tables 1, 12, 14); Loc. nos. 36 and 38 of the Pliocene Hatsuzaki Sandstone Member of the Hitachi Formation, Hitachi City, Ibaraki Prefecture (Figs. 2, 38-42, Tables 1, 11,14).

*Occurrence and associated fauna:* A few specimens were collected from Loc. 31, as mode of sporadically occurred from gray to greenish gray, massive silty sandstone with such echinoid of *Anthocidaris* sp., *Linthia tokunagai* Lambert, *Lutetiaster ogasawarai* n. sp., *Brisaster owstoni* Mortensen, *Anametalia* sp. and also molluscs of *Portlandia lischekei* Smith and *Limopsis tokaiensis* Yokoyama; Loc. no. 32, sporadically occurred from gray to greenish gray, massive silty sandstone, with echinoid of *Brisaster owstoni* Mortensen, and such molluscs as *Portlandia lischekei* Smith, *Limopsis tokaiensis* Yokoyama, *Solemen diaphana* (Dall), *Turucicula sukegawaense* Noda and *Fulgoraria* sp.; Loc. no. 36, medium to coarse grained, massive sandstone; Loc. no. 38, medium to coarse grained, massive sandstone with echinoid of *Linthia tokunagai* Lambert, and mollusca of *Chlamys*

*cosibebsis* (Yokoyama).

*Geologic distribution:* Pliocene Muramatsu Formation in Tokai-mura, Naka-gun and the Pliocene Hatsuzaki Sandstone Member of the Hitachi Formation in Hitachi City, Ibaraki Prefecture (Fig. 66).

*Geologic range:* Pliocene.

Family Brissidae Gray, 1885

Genus *Brissopsis* A. Agassiz, 1847

*Brissopsis daigoensis* n. sp.

(Pl. 12, figs. 2-7b, pl. 13, figs. 1-6c, pl. 14,  
figs. 3a-b; Fig. 55)

1954, *Linthia nipponica* Yoshiwara, Morishita, p. 227, pl. 7, figs.  
4-8.

1967, *Linthia nipponica* Yoshiwara, Morishita, p. 109, pl. 19, figs.  
5-7.

1973, *Shizaster* sp., Hayashi and Miura, p. 140, pl. 2, fig. 33.

1976, *Linthia nipponica* Yoshiwara, Shikama and Kase, pl. 2, fig. 18.

1979, *Linthia tokunagai* Lambert, Yamana, p. 4, 28, pl. 1, fig. 1.

1986, *Linthia nipponica* Yoshiwara, Morishita and Itoigawa, pl. 141,  
text-fig. II (114).

1990, *Brissopsis makiyama* Morishita, Okamoto et al., pl. 11,  
figs. 1-3.

*Description:* Test thin, medium to large in size, rather high, rounded cordiform in marginal outline, almost long as wide; greatest width being middle of test; anterior part of test somewhat wide; frontal margin round and very shallowly notched by a frontal groove. Posterior part rather wide and rather flattened. Aboral side of test gradually elevated with steep slope from margin to highest point. Oral side of test rather flat and slightly concaved orally; sternal system rather wide; peristomial region rather narrow; posterior extremity gently inclined, and slightly concaved. Length of antero-lateral petals and postero-lateral petals nearly size.

Frontal ambulacrum (III) in a shallow groove, rather long and narrow shape. Both side almost straight. Pores very small and almost round and in a pair; pore-pairs in a regular series; more than 17 pore-pairs in each series and placed near outer margin of plates; ambulacrum plates low and wide.

Apical system rather small in size, situated at central part on aboral side, ethymoytic shape and with four genital pores.

Antero-lateral petals (II and IV) long and wide, slightly

depressed; outer marginal side more gradually concaved and arched anteriorly, and close to distal end; angle between median line of petal (II) and petal (IV) being about  $110^{\circ}$  ; pores somewhat large and wide, and in a pair; pore-pairs in a regular series; about 29 pore-pairs in each series; ambulacral plates low and wide.

Postero-lateral petals (I and V) long and wide, slightly depressed; outer marginal side more gradually convexed, and close to distal end; being about  $45^{\circ}$  ; pores somewhat large and wide, and in a pair; pore-pairs in a regular series; about 26 pore-pairs in each series; ambulacral plates low and wide. Ratio of length of antero-lateral petals (II and IV) and postero-lateral petals (I and V) being about 1.0 : 0.9.

Periostome small in size slightly depressed orally. Plastron very long and narrow, mesamphisternous shape. Posterior ambulacrum rather wide, each ambulacral plate long and wide. Periproct large in size, rounded, slightly concaved, and situated on upper portion of posterior extremity.

Interambulacral plate wide and rather low composed of 11 or 12 plates in a column of each interambulacral. Antero-lateral interambulacral area broad, and postero-lateral interambulacral area narrow.

Peripetaleous fasciole very narrow and conspicuously sinuous, surrounds petals, It crosses the groove of frontal ambulacrum (III) at slightly above of ambitus and it passes through near distal end of petal in the antero-lateral petals (II and IV) and postero-lateral petals (I and V). Latero-anal fasciole absented, and subanal fasciole indistinctness.

*Dimension of test*

Specimens	Lengitudinl diameter	Transversal diameter	Height
Holotype, IGUT. no. 14567	36.5 mm	37 mm+	—
Paratype, IGUT. no. 14568	42 mm+	41.0 mm	—
IGUT. no. 14569	38 mm+	34 mm+	—
IGUT. no. 14570	48.5 mm	40.5 mm	—
IGUT. no. 14571	42 mm+	36 mm+	—

*Dimension of petals*

Specimens	I & V		II & IV	
	Length	width	Length	width
Holotype, IGUT. no. 14567	12.2 mm	5.3 mm	12.4 mm	6.2 mm
Paratype, IGUT. no. 14568	14.7 mm	5.6 mm	17 mm+	5.5 mm
IGUT. no. 14569	13.9 mm	5.1 mm	14.3 mm	5.2 mm
IGUT. no. 14570	16 mm+	6.0 mm	13 mm+	6.3 mm
IGUT. no. 14571	15.5 mm	5.6 mm	16.4 mm	5.2 mm

*Comparison and remarks:* The present new species, *Brissopsis daigoensis* is allied to *Brissopsis makiyamai* Morishita, *Linthia nipponica* Yoshiwara and *Linthia tokunagai* Lambert in marginal outline. This new species have been confused with *Linthia nipponica* Yoshiwara, *Linthia tokunagai* Lambert and *Brissopsis makiyamai* Morishita.

However, present new species can be distinguished from *Linthia nipponica* Yoshiwara and *Linthia tokunagai* Lambert in lacking latero-anal fasciole and distal end of petals closing. Furthermore, this new species can be discriminated from *Brissopsis makiyamai* Morishita in having a little arched antero-lateral petals (II and IV).

Fossil specimens of *Linthia*, *Brissopsis* and *Shizaster*

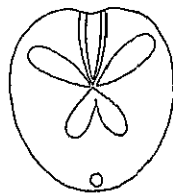


Fig. 55. Diagrammatic outline of the *Brissopsis daigoensis*  
n. sp.

species have been reported from Oligocene to Pliocene in Japan. Some of the followings are identified to the present new species on the basis of above-mentioned characters; *Linthia nipponica* Yoshiwara from the early middle Miocene Tajiri Formation in Mie Prefecture, the early middle Miocene Kadoya Formation and the early middle Miocene Morozakoi Formation in Aich Prefecture, the early middle Miocene Maki Formation in Gifu Prefecture (Morishita, 1954, p. 227, pl. 7, figs. 4-8); *Linthia nipponica* Yoshiwara from the early middle Miocene Morozaki Group in Aich Prefecture (Shikama and Kase, 1976, pl. 2, fig. 18); *Linthia nipponica* Yoshiwara from the early middle Miocene Morozaki Group in Aich Prefecture (Morishita and Itoigawa, 1986, p. 141, text-fig. II-114); *Linthia tokunagai* Lambert from the early middle Miocene Tottori Group and the early middle Miocene Tari Formation in Tottori Prefecture (Yamana, 1987, p. 23, 44, pl. 1, fig.); *Shizaster* sp. from the early middle Miocene Okazaki Formation in Aich Prefecture (Hayashi and Miura, 1973, p. 140, pl. 2, fig. 33); *Brissopsis makiyamai* Morishita from the early middle Miocene Bihoku Group in Hiroshima Prefecture (Okamoto et al., 1990, pl. 2, figs. 1-3); *Brissopsis* sp. from the early middle Miocene Morozaki Group in Aichi Prefecture (Mizuno et al., 1989, p. 11, pl. 3, fig. 2a (4), pl. 4, figs, 1a-2b; Mizuno, 1993a, p. 324, pl. 53, figs. 1a-2b;



Mizuno, 1993b, p. 150, pl. 3, fig. 2(4), pl. 4, fig. 1a(3). Echinoid fossil yielded from the early middle Miocene Tateya Formation in Tyokyo Prefecture is also identified to the present new species. The fossil occurrence of *Brissopsis daigoensis* of the present study is restricted in early middle Miocene in age and also in central portion of Japan in geography (Fig. 60). *Brissopsis daigoensis* can be regarded that it flourishes head in muddy bottom of water of continental slope under a warmer current on the basis of co-occured molluscan assemblage.

*Etymology:* The present new species name, *daigoensis* is come from locality name.

*Types:* Holotype, IGUT. no. 14567, Paratype, IGUT. no. 14568.

*Locality, formation and geologic age:* The specimens of new species, *Brissopsis daigoensis*, were collected from the following eleven localities; Loc. nos. 01-11 (type locality is no. 09), early middle Miocene Naeshiroda Formation, Daigo-machi, Kuji-gun, Ibaraki Prefecture (Figs. 2-8, Tables 1-2, 14).

*Occurrence and associated fauna:* Single specimen was collected from single occurred from dark gray, massive siltstone with molluscs of *Propeamssium tateiwai* Kanehara (Loc. no. 01); Loc. no. 02, sporadically occurred from dark gray, massive siltstone with

mollusca of *Acilana tokunagai* (Yokoyama) and plant of *Quercus* sp.;  
Loc. no. 03, single specimen occurred from dark gray, massive  
siltstone with molluscs of *Acilana tokunagai* (Yokoyama),  
*Propeamssium tateiwai* Kanehara and *Phanelorepida expansilabrum*  
(Kuroda); Loc. no. 04, single specimen occurred from dark gray,  
massive siltstone; Loc. no.05, sporadically occurred from dark gray,  
massive siltstone with molluscs of *Acilana tokunagai* (Yokoyama) and  
*Propeamussium tateiwai* Kanehara; Loc. no.06, single specimen  
occurred from dark gray, massive siltstone of alternating beds of  
sandstone and siltstone with echinoid of Echinothuriidae gen. et sp.  
indet., and molluscs of *Acilana tokunagai* (Yokoyama) and *Portlandia*  
*kakimii* Uozumi and plant of *Liquidamber* sp.; Loc. no. 07,  
sporadically occurred from dark gray, massive siltstone of  
alternating beds of sandstone and siltstone, with molluscs of  
*Lamellinucula* sp.; Loc. no. 08, abundantly occurred from dark gray,  
massive siltstone of alternating beds of sandstone and siltstone with  
molluscs of *Lamellinucula* sp., *Macoma* sp. and *Fissidentalium* sp.;  
Loc. no. 09, abundantly occurred from dark gray, massive siltstone  
of alternating beds of sandstone and siltstone, with following such  
fossils as, echinoid of *Brissopsis kajiwarai* n. sp., and molluscs  
of *Acilana tokunagai* (Yokoyama), *Lamellinucula* sp., *Bathymalletia*

sp., *Conchocele disjuncta* Gabb, *Periploma besshoense* (Yokoyama) and *Fissidentalium* sp., plant of *Comptonia naumanii* (Nathorst) Huzioka, and crustacea of *Callianassa titaensis* Nagao; Loc. no. 10, abundantly occurred from dark gray, massive siltstone of alternating beds of sandstone and siltstone, with mollusca of *Lamellinucula* sp.; Loc. no. 11, gregarious occurrence tuffaceous fine grained sandstone of alternating beds of sandstone and siltstone with echinoid of Echinothuriidae gen. et sp. indet. and *Brissopsis kajiiwarai* n. sp., echinothurian of *Cucumaria igoi* Kikuchi and Nikaido and *Ypsilothuria bitentaculata* (Ludwig), and such molluscs as *Portlandia kakimii* Uozumi, *Propeamussium tateiwai* Kanehara, and sponges of *Makiyama chitanii* (Makiyama).

*Geologic distribution:* Early middle Miocene Tottori Group and early middle Miocene Tari Formation in Tottori Prefecture; early middle Miocene Bihoku Group in Hiroshima Prefecture; early Miocene Tajiri Formation in Mie Prefecture; early middle Miocene Morozaki Group, early Miocene Morozaki Formation, early middle Miocene Kadoya Formation and early middle Miocene Okazaki Formation in Aich Prefecture; early middle Miocene Maki Formation in Gifu Prefecture; early middle Miocene Tateya Formation in Tokyo Prefecture; early middle Miocene Naeshiroda Formation in Ibaraki Prefecture (Fig. 67).

*Geologic range:* Early middle Miocene

*Brissopsis kajiwarai* n. sp.

(Pl. 12, figs. 1a-b, 8; Pl. 13, figs. 2a-b,

7a-b; Pl. 14, figs. 2a, 4; Fig. 56)

*Description:* Test thin, small to medium in size, low, elongated ovoid in marginal outline, very longer than width; greatest width being in middle of test; aboral side slightly convex, anterior part of test gradually narrows toward the anterior edge, frontal edge of test more or less wide and rather deeply depressed by a frontal groove, posterior part of test narrowly long and slightly convex, gradually narrows toward the anterior edge; aboral side rather flat and concaved orally, sternal system slightly distant.

Frontal ambulacrum (III) in a deep groove, rather short and narrow shape. Pores very small and in a pair. Ambulacrum plates low and wide.

Apical system situated at 1/3 of the length, small in size, with three genital pores.

Antero-lateral petals (II and IV) long and rather narrow, straight, slightly depressed and close to distal end; angle between

median line of petal (II) and petal (IV) being about  $130^{\circ}$  ; pores small in size, and in a pair; pore-pairs in a regular series; ambulacral plates small in size, low and wide.

Postero-lateral petals (I and V) short and rather narrow, slightly depressed; and close to distal end; angle between median line of petal (I) and petal (V) being about  $50^{\circ}$  ; pores somewhat large and wide, and in a pair; pore-pairs in a regular series; ambulacral plates low and wide. Ratio of length of antero-lateral petals (II and IV) and postero-lateral petals (I and V) being about 1.0 : 0.8

Periostome medium in size and with slightly depressed orally. Plastron very longed narrowly and slightly wide. Periproct large in size, rounded, concaved conspicuously, and situated on upper portion of posterior extremity.

Interambulacral plate on aboral side wide and rather low; anstero-lateral interambulacral area broad, and postero-lateral interambulacral area narrow. Peripetaleous fasciole very narrow and conspicuously sinuous, surrounds petals; and crosses the groove of frontal ambulacrum (III) at slightly above of ambitus and it passes through near distal end of petal in the antero-lateral petals (II and IV) and postero-lateral petals (I and V). Latero-anal and subanal fascioles indistinctness.

*Dimension of test*

Specimens	Lengthitudinal diameter	Transversal diameter	Height
Holotype, IGUT. no. 14574	48.5 mm	35.3 mm	10 mm+
Paratype, IGUT. no. 14575	40.5 mm	30.5 mm	11.5 mm
IGUT. no. 14576	45.0 mm	—	—
IGUT. no. 14577	21.5 mm	16.5 mm	4.0 mm

*Dimension of petals*

Specimens	I & V		II & IV	
	Length	width	Length	width
Holotype, IGUT. no. 14574	10.0 mm	2.5 mm	15.0 mm	—
Paratype, IGUT. no. 14575	11.7 mm	—	—	—
IGUT. no. 14576	15.0 mm	4.5 mm	12.4 mm	5.1 mm

*Comparison and remarks:* Although present new species, *Brissopsis kajiwarai*, is described based on some imperfect specimens, a more detail study should be needed in future. The marginal outline of test of the species is closely allied *Brissopsis makiyamai* Morishita that yielded from the early middle Miocene. However, the new species is distinguished from *Brissopsis makiyamai* in having

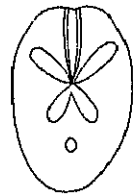


Fig. 56. Diagrammatic outline of the *Brissopsis kajiwarai*  
n. sp.

rather well arched antero-lateral petals and situated at more frontal part of apical system.

*Etymology:* The present new species name, *kajiwarai* is come from Professor Yoshimichi Kajiwara of the Institute of Geoscience, the University of Tsukuba.

*Types:* Holotype, IGUT. no. 14575, Paratype, IGUT. no. 14576.

*Locality, formation and geologic age:* A few specimens of *Brissopsis kajiwarai* were collected from next two localities; Loc. no. 09 (type locality) and 11, early middle Miocene Naeshiroda Formation, Daigo-machi, Kuji-gun, Ibaraki Prefecture (Figs. 2, 5, 7-8, Tables 1-2, 14).

*Occurrence and associated fauna:* The present species was collected from Loc. no. 09 in the mode of abundantly occurred from dark gray, massive siltstone of alternating beds of sandstone and siltstone with echinoid of *Brissopsis daigoensis* n. sp., and such molluscs as *Acilana tokunagai* (Yokoyama), *Lamellinucula* sp., *Bathymalletia* sp., *Conchocele juncta* Gabb, *Periploma besshoense* (Yokoyama) and *Fissidentalium* sp., plant of *Comptonia naumanii* (Nathorst) Huzioka, and crustacea of *Callianassa titaensis* Nagao. It is also occurred from loc. no. 11, as sporadically occurred tuffaceous fine grained sandstone of alternating beds of sandstone



and siltstone with such echinoid as Echinothuriidae gen. et sp. indet. and *Brissopsis daigoensis* n. sp., echinothurian of *Cucumaria igoi* Kikuchi and Nikaido and *Ypsilothuria bitentaculata* (Ludwig), molluscs of *Portlandia kakimii* Uozumi, *Propeamussium tateiwai* Kanehara and sponge of *Makiyama chitani* (Makiyama).

*Geologic distribution:* Early middle Miocene Naeshiroda Formation in Daigo-machi, Kuji-gun, Ibaraki Prefecture (Fig. 68).

*Geologic range:* Early middle Miocene.

*Brissopsis* sp.

(Pl. 14, figs. 1a-1b, 5)

*Description and remarks:* Imperfect specimens of *Brissopsis* sp. were collected from following two localities. Their features are as followings; Takikura specimen (Pl. 14, 1a-1b; IGUT. no. 1): Oral side specimen, test of medium in size, thin, elongated oval in marginal outline, very longer than width. Plastron mesamphisternous-form; Kegano specimen (Pl. 14, fig. 5; IGUT. no. 11108): Oral side specimen, test of medium in size, thin, elongated oval in marginal outline, very longer than width. Plastron mesamphisternous-form long and narrow, and with many tubercles.

Although the present specimens are imperfect, it can be identified to *Brissopsis* sp. on the basis the characteristics of general form and test.

*Locality, formation and geologic age:* The present species, *Brissopsis* sp. was collected from two localities as Loc. no. 13 of the early middle Miocene Daienji siltstone Member of the Asakawa Formation, Daigo-machi, (Figs. 2, 10-12, Tables 1-3, 14), and the early middle Miocene Oginokubo Siltstone Member of the Nishizome Formation (Figs. 2, 13-15, Tables 1-3, 14) in Suifu-mura, Kuji-gun, Ibaraki Prefecture.

*Occurrence and association fauna:* Single specimen *Brissopsi* sp. collected from dark gray, massive siltstone (Loc. no. 09) of alternating beds of sandstone and siltstone with molluscs of *Acila* sp., *Lamellinucula* sp. and *Portlandia watasei* (Kanehara), and crustacean of *Munidea* sp., Single specimen also occurred from dark gray, massive siltstone (Loc. no. 14), with such molluscs as *Lamellinucula* sp., *Portlandia kakimii* Uozumi, *Acilana tokunagai* (Yokoyama) and *Preopeamussium tateiwai* Kanehara.

*Brissopatagus* sp.

(Pl. 22, figs. 1a-2c)

*Description and remarks:* Test very thin, small in size, rather low, rounded cordiform in marginal outline, anterior part narrowly round. Frontal ambulacrum (III) very wide and deep groove, with a large primary tubercles. Antero-lateral petals form wide and long. Postero-lateral petals short and wide.

The present specimens can be identified to species of genus *Brissopatagus*. However, it is difficult to determine specific level because of imperfect specimens (Pl. 22, figs. 1a-c, IGUT. no. 14586; Pl. 22, figs. 2a-c IGUT no. 14587).

There are few reports on the *Brissopatagus* fossil in the world. It is known such strata ranging from Oligocene to Pleistocene as; *Brissopatagus venzoi* Checchia-Rispoli from the Upper Oligocene/Lower Miocene Formation in North Africa and *Eupatagus (Brissopatagus) avilensis* Sanchez Roig from the Oligocene in Cuba (Kier and Lawson, 1987), and *Brissopatagus* sp. from the Pleistocene Chinen Formation in Okinawa Island, Japan (Kikuchi, 2000).

Living species, *Brissopatagus relictus* Shigei is known only from Sagami Bay (Shigei, 1975) in the water of 80 to 117 meters in depth.

Fragmental occurrences of the specimens suggested that *Brissopatagus* sp. occurred from the Pliocene Muramatsu Formation

might be come from shallow sea to a more deep condition as transported by turbidity current and/or debris flow.

*Locality, formation and geologic age:* The present species, *Brissopatagus* sp. was collected from only one locality of loc. no. 33 of the Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46, Tables 1, 12, 14).

*Occurrence and associated fauna:* Two imperfect specimens were collected from gray to greenish gray, massive silty sandstone (Loc. no. 33) associated with such echinoids as *Brisaster owstoni* Mortensen and *Nikaidoster tokaiensis* n. gen. et n. sp., and mollusca of *Limopsis tokaiensis* Yokoyama.

*Geologic distribution:* Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture.

*Anametalia* sp.

(Pl. 21, figs. 5a-c)

*Description and remarks:* Imperfect single specimen is at hand (IGUT. no. 14588). Their characteristics are as follows: test low, medium in size, ovoidal in marginal outline; posterior end of test not vertical; front of test rounded and broad; antero-lateral petal

somewhat wide, straight and not depressed; plastron extending posterior.

Their feature closely resembles to living species of *Anametalia stemaloides* (Bolau). However, the detailed argument is difficult because of an imperfect specimen. Living species, *Anametalia stemaloides* is known from Hog Kong and Gulf of Shame in the depth of 24 to 27 meters (Mortensen, 1954; Nisiyama, 1968; Shigei, 1974). This data on depth range may be available to that of the Muramatsu Formation.

*Locality, formation and geologic age:* The present fossil *Anametalia* sp. was collected only from one locality of loc. no. 31 of the Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture (Figs. 2, 44-46, Tables 1, 12, 14).

*Occurrence and associated fauna:* One specimen of the present species was collected from gray to greenish gray, massive silty sandstone (Loc. no.31) with echinoid of *Anthocidaris* sp., *Linthia tokunagai* Lambert, *Lutetiaster ogasawarai* n. sp., *Brisaster owstoni* Mortensen and *Nodaster watanabei* n. sp.; and also molluscs of *Portlandia lischei* Smith and *Limopsis tokaiensis* Yokoyama

*Geologic distribution:* Pliocene Muramatsu Formation, Tokai-mura, Naka-gun, Ibaraki Prefecture.

