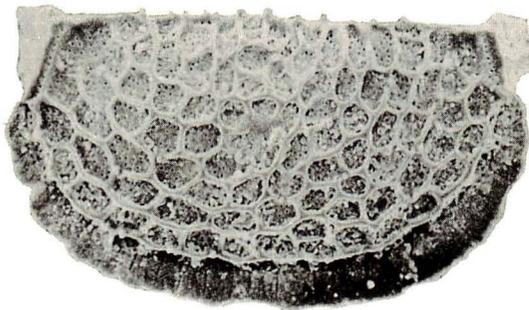


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The ostracod carapace on the cover is an adult specimen of *Manawa konishii* NOHARA (Suborder Palaeocopina, Family Punciidae) from the East China Sea. (photo by K. ABE, ×190)

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786. ECHINOIDS FROM THE CRETACEOUS HAIDATEYAMA GROUP,  
EASTERN KYUSHU\*

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**Abstract.** In this paper four species of spatangoid echinoids are described which came from the Upper Formation of the Haidateyama Group in Oita Prefecture. They are three species of *Heteraster*, of which one is new, and one species assigned to *Pseudowashitaster*. For the description of a new species, material from the Lower Cretaceous Arida Formation in Wakayama Prefecture also is complementally dealt with here. Three of the echinoid species occur in common in the Lower Barremian of several areas in the Chichibu Terrane, Southwest Japan. Therefore, this combined with already reported ammonites strongly suggests an Early Barremian age for the Upper Formation of the Haidateyama Group.

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**Introduction**

The Lower Cretaceous Haidateyama Group in the Chichibu Terrane of eastern Kyushu has hitherto been investigated from the standpoint of stratigraphy by Fujii (1954), Teraoka (1970), Tanaka and Ohta (1980) and Tashiro *et al.* (1983). Nevertheless, palaeontological works have not yet been completed, except for the description of an ammonite species by Noda (1977) and that of trigonian species by Tashiro and Matsuda (1983).

Recently, numerous specimens of fossil

echinoids have been obtained from the Haidateyama Group, some of which have been preliminarily reported by Noda (1977) without palaeontological descriptions. This is a useful piece of information about the Lower Cretaceous echinoid faunas of Japan which are very inferior to the molluscan faunas. The echinoid specimens available for the present study were collected by Seiji Kohi, a former pupil of one of us (M. N.) and by another of us (H. T.), but their specific identification has been done by the senior author (K. T.) in cooperation with M. N. Thus, four species belonging to two genera have been distinguished; two of them are identified with

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\* Received August 15, 1983

hitherto known species and another is new. In this paper the four echinoid species are described and their biostratigraphic implications are discussed. Furthermore, the specimens from the Barremian Arida Formation of the Yuasa area, Wakayama Prefecture are also dealt with here as complementary material for a new species.

The specimens described here are kept at the Geological Survey of Japan, Tsukuba (GSJ) and the Institute of Geology and Mineralogy, Hiroshima University, Hiroshima (IGH), with their respective abbreviations in parentheses.

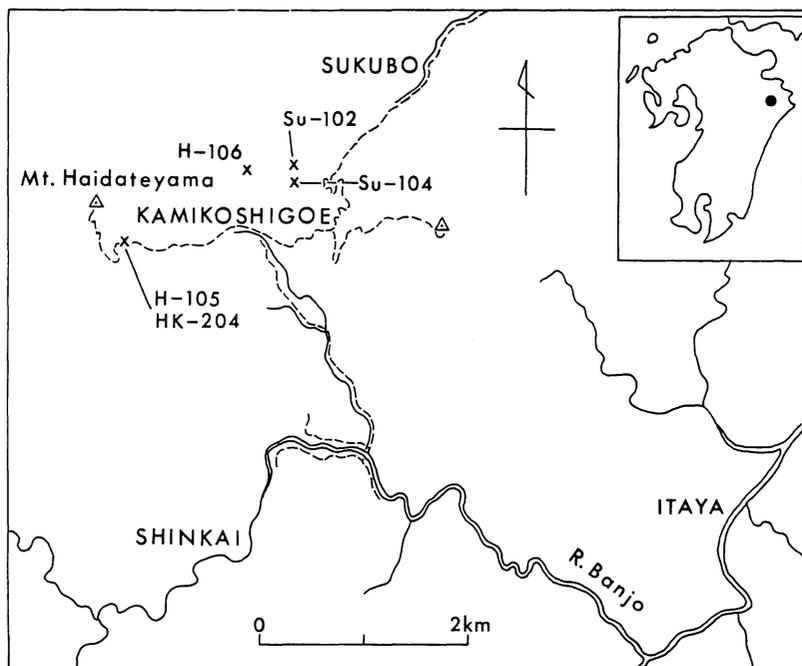
Before going further, we wish to express our sincere gratitude to Professor Emeritus Tatsuro Matsumoto of Kyushu University for his valuable suggestions and kindness in critical reading of the first draft. We also thank Mr. Seiji Kohi for supplying the material for this study, and Mr. Yoshio Masai of the Geological Survey of Japan for photographing some of the specimens.

### Geological Setting

The Haidateyama area represents one of the Cretaceous outcrop belts in the Chichibu Terrane of eastern Kyushu. The most recent stratigraphic context of the Haidateyama Lower Cretaceous has been described by Tashiro *et al.* (1983).

The Lower Cretaceous clastic sequence rests on pre-Cretaceous strata with an angular unconformity, forming an east-plunging syncline. It is collectively called the Haidateyama Group. According to Tashiro *et al.* (1983), this group is stratigraphically divided into four units, provisionally named I (nonmarine), II (mostly brackish water), III (marine) and IV (marine) in ascending order, totalling more than 900 m thick. These four units are here termed the Lower, Middle, Upper and Uppermost Formations. The lower three formations (Hauterivian? – Barremian) are in conformable sequence and the Uppermost Formation (Upper Albian) is faulted against them.

The Upper Formation from which the echi-



Text-fig. 1. Localities of echinoid specimens from the Haidateyama Group. Inset is a map of Kyushu, showing location of the studied area (solid circle).

noid specimens examined came, consists chiefly of thickly alternating beds of sandstone and mudstone and is about 200 m thick. It yields abundant shallow marine molluscan fossils.

The echinoid specimens for the present study were obtained from locs. HK-204, H-105, H-106, Su-102 and Su-104 of the Upper Formation (Lower Barremian) of the Haidateyama Group (Text-fig. 1). Of these localities, Noda's locality is indicated by prefix HK and H. Tanaka's ones by H and Su.

Locs. HK-204, H-105 (much the same as the preceding one) and H-106 are situated at Honjura, Minamiama-gun, Oita Prefecture. Loc. HK-204 is occupied by siltstone with subsidiary mudstone, and locs. H-105 and H-106 by siltstone to fine sandy siltstone. Locs. Su-102 and Su-104 are situated at Notsu-machi, Ono-gun, Oita Prefecture. The former is occupied by fine sandy siltstone and the latter by siltstone. Especially locs. HK-204, H-105 and H-106 yield a number of echinoid fossils.

At all the echinoid localities various molluscan species also occur abundantly. The occurrence of *Ancyloceras* (*Ancyloceras*) sp. aff. *A. (A.) vandenheckii* Astier at loc. HK-204 (Noda, 1977) and *Crioceratites* (*Crioceratites*) sp. aff. *C. (C.) koechlini* (Astier) at loc. H-105 (Matsumoto et al., 1982), among others, is worthy of mention.

### Systematic Descriptions

(by Keisaku Tanaka and Masayuki Noda)

Order Spatangoida Claus, 1876

Suborder Toxasterina Fischer, 1966

Family Toxasteridae Lambert, 1920

Genus *Heteraster* d'Orbigny, 1853

*Heteraster macroholcus* (Nisiyama)

Pl. 82, Figs. 1, 2

1950. *Washitaster* (?) *macroholcus* Nisiyama, *Inst. Geol. Palaeont. Tohoku Univ., Short Papers*, no. 1, p. 44, text-figs. 4-6.  
 1965. *Heteraster macroholcus*, Tanaka, *Trans. Proc. Palaeont. Soc. Japan*, N. S., no. 59,

p. 133, pl. 16, figs. 3, 4, text-fig. 4.

1968. *Paraheteraster macroholcus*, Nisiyama, *Palaeont. Soc. Japan, Special Papers*, no. 13, p. 190, pl. 21, fig. 3; *ibid.*, no. 11 (1966), pl. 18, figs. 3, 12, 13.  
 1982. *Heteraster macroholcus*, Tanaka and Kozai, *Trans. Proc. Palaeont. Soc. Japan*, N. S., no. 126, p. 344, pl. 55, fig. 2, text-fig. 2.

*Material*:—GSJ. F6024 and 6025, from loc. HK-204 (coll. Kohi); IGH:Hi-a-001 and 002, from loc. H-105 (coll. H. Tanaka); IGH:Hi-b-001 and 002 from loc. H-106 (coll. H. Tanaka). Ten comparable specimens from loc. HK-204, two from loc. H-105, one from loc. H-106 and one from loc. Su-102 were also examined.

*Descriptive Remarks*:—The specimens available are secondarily deformed. They are characterized by the deep and very long frontal sinus, distinct anterior notch, very posteriorly placed apical system, superficial paired ambulacra, and deeply sunken peristome. Moreover, the frontal ambulacrum shows an irregular alternation of two to eight longer slit-shaped pores and one shorter slit-shaped pore in the outer row and somewhat inward disposition of pores (slightly smaller or shorter than the normal round to oval pores), opposite to shorter outer pores, in the inner row (see Tanaka, 1965, text-fig. 4), thus the pore pairs lining up in three (or better to say rather four) files. The number of longer pores alternating with a shorter pore varies from place to place in one specimen and also differs between individuals, ranging from two to eight with the commonest occurrence of two to five. Furthermore, in a specimen (IGH:Hi-a-002) represented by an external mould of the aboral surface, a broad, diffuse peripetalous granular band or pseudo-fasciole is seen which is covered with streaks of granules very slightly smaller than those covering the rest of the aboral surface and decorated with tubercles.

*Occurrence*:—Locs. HK-204 (siltstone to mudstone), H-105 (siltstone to fine sandy siltstone) and H-106 (siltstone to fine sandy siltstone); Upper Formation of the Haidateyama Group, Lower Barremian. One specimen probably re-

ferable to this species is found in the fine sandy siltstone of the same formation at loc. Su-102.

*Heteraster bungoensis* Tanaka et Noda, sp. nov.

Pl. 82, Figs. 3–6; Pl. 83, Fig. 4; Text-figs. 2, 3

*Material*:—Holotype, GSJ. F6013, represented by an internal mould, from loc. HK-204 (see p. 447), (coll. Kohi); paratypes, GSJ. F6014 and 6036, represented by an internal mould, respectively, from the same locality (coll. Kohi). Designated as paratypes are also GSJ. F6033A, B (A, internal mould; B, imperfect external mould of aboral surface) and GSJ. F6039A, B (A, internal mould; B, imperfect external mould of aboral surface), from loc. K-613 (= loc. 1 in Tanaka and Okubo, 1954), west of Kumai, Yuasa-cho, Arida-gun, Wakayama Prefecture, Upper Member of the Arida Formation, Lower Barremian (coll. K. Tanaka). Three comparable specimens from locs. H-106 and Su-104 (coll. H. Tanaka) are also available.

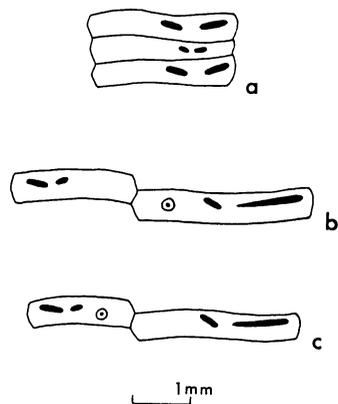
*Diagnosis*:—Test medium-sized, heart-shaped in outline, somewhat rounded polygonal, weakly emarginate in front, more or less longer than wide, evenly rounded at the antero-lateral margins, rather straight at the postero-lateral margins, widest slightly in front of the midpoint, contracted behind, relatively low; frontal sinus rather short, somewhat broad, shallow, not sharply limited, expanding towards the ambitus with constant depth, extending to the peristome; anterior notch shallow, moderately broad.



Text-fig. 2. Apical system of *Heteraster bungoensis* Tanaka et Noda, sp. nov., GSJ. F6039A, paratype.

Aboral surface gently arched with steeper anterior slope, highest slightly behind the apical system, abruptly truncated behind; posterior truncated surface slightly concave; posterior margin very shallowly emarginate. Oral surface more or less inflated in the plastral region and antero-lateral regions, depressed around the peristome. Apical system small, slightly posterior, ethmophract, with four gonopores arranged in a quadrate form; posterior genital plates mutually contiguous.

Frontal ambulacrum rather short, shallowly sunken throughout its length, subpetaloid; petaloid part extending about four-fifths the way to the anterior margin; poriferous zones about half as wide as the interporiferous zone at the middle; near the middle part double pairs of longer pores alternating with a pair of shorter pores; near the proximal part and also near the distal part a pair of longer pores alternating with a pair of shorter pores; longer pore pairs slit-shaped, somewhat longer in the outer row than in the inner row, somewhat circumflexed, widely set; shorter pore pairs small, elongate oval to oval, more or less longer in the outer row than in the inner row, close together; pore pairs lining up in four files.



Text-fig. 3. *Heteraster bungoensis* Tanaka et Noda, sp. nov., GSJ. F6039B, paratype. a, Frontal ambulacrum. b, Right anterior ambulacrum. c, Right posterior ambulacrum.

Paired ambulacra flexuous, superficial, sub-petaloid. Anterior paired ambulacra nearly as long and wide as the frontal ambulacrum; petaloid parts rather long, extending about two-thirds the way to the ambitus, open distally; poriferous zones unequal, widest near the middle, tapering towards the ambitus and the apical system; anterior poriferous zones much narrower than the posterior zones which are narrower than the interporiferous near the middle; pores in the anterior poriferous zones oval in the inner row, short slit-shaped in the outer row, close together; pores in the posterior poriferous zones short slit-shaped in the inner row, very long slit-shaped and acuminate inwards in the outer row, rather close together; pores of each pair somewhat circumflexed, nonconjugate.

Posterior paired ambulacra somewhat shorter, narrower, less flexuous and diverging at a smaller angle than the anterior; petaloid parts short, extending about halfway to the margin, nearly two-thirds as long as those of the anterior paired ambulacra, open distally; poriferous zones unequal, widest near the middle, tapering towards the ambitus and the apical system; anterior poriferous zones much narrower than the posterior zones which are somewhat narrower than the interporiferous near the middle; pores in the anterior poriferous zones oval in the inner row, short slit-shaped in the outer row, closely set; pores in the posterior poriferous zones of slit shape, much longer in the outer row than in the inner row, rather close together; pores of each pair more or less circumflexed, nonconjugate.

Peristome near the anterior fourth, small, moderately deep, subpentagonal, wider than long. Plastron mesamphisternous. Periproct rather large, transversely oval, high up on the posterior truncated surface, at half the height of the test, partly visible from above. Tubercles small, perforate, crenulate, scrobiculate; closely spaced on the plastron, widely scattered elsewhere; interporiferous zones of the paired ambulacra dotted with smaller tubercles; numerous granules between tubercles. No fascioles.

*Measurements*:—The specimens available are deformed by the subsequent distortion. The

holotype represented by the least deformed specimen is 23.4 mm long, 22.2 mm wide, and 9.2 mm high.

*Remarks*:—The holotype and other specimens available from the Haidateyama Group are small (probably young) individuals. Accordingly, two specimens (GSJ. F6033 and 6039; coll. K. Tanaka), one of which is a much larger individual, and a comparable specimen (GSJ. F6008; coll. K. Tanaka) represented by a relatively large individual, from the Barremian Arida Formation in Wakayama Prefecture are also dealt with here. The largest of the Arida specimens, though incomplete and secondarily depressed, probably attains about 47 mm in length.

*Comparison*:—This new species resembles *Heteraster nexilis* Nisiyama (1950, p. 42, text-figs. 1–3) from the Barremian of several areas in the Chichibu Terrane, Southwest Japan, but differs from that species in having a test of cordate outline, an apical system which is slightly behind the centre, a rather short and shallow frontal sinus, a shallow anterior notch and a subpentagonal peristome.

The present species is easily distinguishable from the other two Japanese contemporary species, *Heteraster macroholcus* (Nisiyama) (1950, p. 44, text-figs. 4–6; Tanaka, 1965, p. 133, pl. 16, figs. 3, 4, text-fig. 4) and *H. yuasensis* (Tanaka et Okubo) (1954, p. 223, pl. 7, fig. 6, text-fig. 7; Tanaka, 1965, p. 136, pl. 16, figs. 6, 7, text-fig. 6), in many respects. The apical system is much less posterior and the frontal sinus is much shorter and much shallower in the new species with a test of cordate outline than in *Heteraster macroholcus* with a test of ovate outline. *Heteraster bungoensis* sp. nov. has superficial paired ambulacra as against sunken in *H. yuasensis*. The frontal sinus extends towards the anterior margin with constant depth, forming a shallow but distinct anterior notch in the present species, whereas in *Heteraster yuasensis* it becomes much shallower and indistinct near the ambitus, thus the anterior notch, if any, being very indistinct. The new species has a subpentagonal peristome, and both *Heteraster macroholcus* and *H. yuasensis* have a transversely

oval peristome. As to the mode of arrangement of pore pairs in the frontal ambulacrum, *Heteraster bungoensis* as well as *H. yuasensis* shows the *Enallaster* type (four files) of Devriès (1955), whereas *H. macroholcus* does show the *Heteraster* type (three files).

This species is similar to *Heteraster lepidus* (de Loriol) (1887–88, p. 91, pl. 15, fig. 4) from the Lower Barremian (Rey, 1972) of Portugal, in the cordate outline of test, the shallow frontal sinus and the shallow anterior notch. However, it differs from that species in that the frontal ambulacrum shows *Enallaster*-type arrangement of pore pairs, the anterior paired ambulacra have longer petaloid parts, and in that both the anterior and the posterior paired ambulacra have wider posterior poriferous zones whose outer pores are much longer than those of the anterior zones.

The present species also resembles *Heteraster couloni* (Agassiz) (d'Orbigny, 1853, p. 179, pl. 848) from the Barremian of France and Switzerland, but is separated from that species by its lower test, shallower frontal sinus, somewhat shorter petaloid parts of the paired ambulacra, less divergent posterior paired ambulacra, and by its features of pore pairs in all the ambulacra. Particularly, the new species shows *Enallaster*-type arrangement of pore pairs in the frontal ambulacrum as against *Heteraster*-type in *Heteraster couloni*.

*Heteraster bungoensis* is also akin to *H. pomeli* (Ficheur) (1900, p. 592, pl. 10, figs. 5–8) from the Lower Aptian of Algeria, in the outline of the test, position of the apical system and features of the pore pairs in all the ambulacra. However, it differs from that species in that the test is relatively low, the frontal sinus is shallow and not constricted immediately behind the anterior margin, and in that the anterior notch is shallow.

*Occurrence*:—Loc. HK-204; Upper Formation of the Haidateyama Group, Lower Barremian; siltstone. This species occurs also in the siltstone of the Upper Member (Lower Barremian) of the Arida Formation in the Yuasa area, Wakayama Prefecture. Moreover, several specimens probably

identical with this species are found in the siltstone of the Upper Formation of the Haidateyama Group at locs. H-106 and Su-104.

*Heteraster* sp.

Pl. 83, Fig. 5

*Material*:—GSJ. F6027, represented by an internal mould, from loc. Su-104 (coll. H. Tanaka).

*Description*:—The specimen is poorly preserved and longitudinally compressed secondarily. Nevertheless, it measures about 12.5 mm in length.

The test seems to have a rather heart-shaped outline. The frontal sinus is rather shallow, becoming much shallower towards the ambitus, thus the anterior notch, if any, is probably indistinct. The apical system is somewhat posterior and has four gonopores.

The frontal ambulacrum is rather shallowly sunken and subpetaloid. Each poriferous zone consists of about twenty pore pairs. A pair of slit-shaped pores widely spaced regularly alternates with a pair of elongate oval pores close together, the pore pairs lining up in four files. However, at least in the left poriferous zone a double pair of longer pores is placed at the middle.

The paired ambulacra are somewhat flexuous, slightly sunken and subpetaloid. The anterior paired ambulacra consist of anterior poriferous zones with oval to elongate oval pores close together and much wider posterior poriferous zones with slit-shaped pores widely set. The posterior paired ambulacra have much shorter petaloid parts than do the anterior paired ambulacra. They consist of similar poriferous zones with rather slit-shaped pore pairs.

*Remarks*:—The present specimen is so poorly preserved and very small (probably young) that the specific identification is impossible. However, it is very closely similar in many respects to and probably the same species as certain echinoid specimens that have been referred to as *Heteraster* sp. (Tanaka and Kozai, 1982, p. 345, pl.

55, fig. 4), from the Yunoki Formation (Upper Barremian) of the Monobe area, Kochi Prefecture. It may also be noted that the present form shows some resemblance to a *Heteraster* species, from the Upper Member (Lower Barremian) of the Arida Formation of the Yuasa area, Wakayama Prefecture (Tanaka and Okubo, 1954, p. 224, pl. 7, fig. 7, text-fig. 7), which has been compared with *Heteraster böhmi* (de Loriol) (presumably synonymous with *H. bravoensis* (Böse) according to Cooke, 1955), as is the case with the above Monobe specimens (Tanaka and Kozai, 1982). Anyhow, we refrain from further taxonomic discussion of the present form, because of the very small size and poor preservation of the material available.

*Occurrence*:—Loc. Su-104; Upper Formation of the Haidateyama Group, Lower Barremian; siltstone.

Suborder Hemiasterina Fischer, 1966

Family Hemiasteridae Clark, 1917

Genus *Pseudowashitaster* Tanaka, 1982

*Pseudowashitaster mysticus* Tanaka

Pl. 83, Figs. 1–3

1982. *Pseudowashitaster mysticus* Tanaka in Tanaka and Kozai, *Trans. Proc. Palaeont. Soc. Japan*, N. S., no. 126, p. 348, pl. 55, figs 5–7; pl. 56, figs. 1, 2, text-figs. 3, 4.

*Material*:—GSJ. F6021, 6022 and 6023, from loc. HK-204 (coll. Kohi); GSJ. F6026A, B (A, internal mould; B, imperfect external mould of aboral surface), from loc. H-105 (coll. H. Tanaka); IGH: Hi-b-003A, B (A, internal mould; B, external mould of aboral surface), from loc. H-106 (coll. H. Tanaka).

*Descriptive Remarks*:—The test, though incomplete and secondarily deformed, appears to have an oval outline. The frontal sinus is very long and deep, forming a conspicuous notch in the anterior edge of the test. The apical system is very eccentric behind and ethmophract, with four gonopores. The frontal ambulacrum is very long, deeply sunken and composed of oval inner

pores and slit-shaped outer pores which are scarcely or occasionally set more or less inwards. The paired ambulacra are very unequal in length and width, flexuous, subpetaloid and open distally. The anterior paired ambulacra are very long, considerably narrow almost throughout the way but rapidly widened near the ambitus and are very slightly sunken. The posterior paired ambulacra are short, broad and flush. All the paired ambulacra consist of anterior poriferous zones with minute, round pore pairs and much wider posterior poriferous zones with longer and elongated pore pairs. The peristome is far anterior. The periproct is oval, vertically elongate and high up on the posterior truncated surface. The plastron is mesamphisternous. The peripetalous fasciole is distinct, narrow and continuous.

The largest one (GSJ. F6022) of the specimens, though transversely compressed secondarily, probably attains a little more than 70 mm in length.

It has been pointed out by Tanaka and Kozai (1982) that *Pseudowashitaster mysticus* shows intraspecific variation in arrangement of outer pores in the frontal ambulacrum. In one (GSJ. F6021) of the specimens, for example, a shorter pore is placed somewhat inwards three times at intervals of 12 to 14 longer pores within a series of 52 pores in the middle part of the right poriferous zone, and also three times at intervals of 9 to 15 longer pores within a series of 33 pores in the middle to distal parts of the left poriferous zone. In GSJ. F6026 one shorter pore is set more or less inwards every 7 to 11 longer pores in the middle part of the right poriferous zone. On the other hand, IGH: Hi-b-003 has only two shorter pores within a series of about 50 pores in the middle part of the right poriferous zone.

*Occurrence*:—Locs. HK-204 (siltstone to mudstone), H-105 (siltstone) and H-106 (siltstone); Upper Formation of the Haidateyama Group, Lower Barremian.

#### Concluding Remarks

Among the echinoid specimens examined

from the Upper Formation of the Haidateyama Group, the following four species are described in this paper:

*Heteraster macroholcus* (Nisiyama)

*Heteraster bungoensis* Tanaka *et Noda*, sp. nov.

*Heteraster* sp.

*Pseudowashitaster mysticus* Tanaka

Of the above four, *Heteraster macroholcus* is numerically dominant. This species is known to occur in the Middle to Upper Members (= Am to Au in Obata and Ogawa, 1976) of the Arida Formation of the Yuasa area, Wakayama Prefecture (Nisiyama, 1950; Tanaka and Okubo, 1954), in the lower part of the Ishido Formation of the Sanchu Graben, Saitama — Gumma Prefecture (Tanaka, 1965), and also in the Monobe Formation of the Monobe area, Kochi Prefecture (Tanaka and Kozai, 1982). These three echinoid horizons are assigned to the Barremian, strictly speaking, to the Lower Barremian respectively (Obata and Ogawa, 1976; Obata *et al.*, 1976; Tashiro *et al.*, 1980).

*Pseudowashitaster mysticus* was reported from the Yunoki Formation of the Monobe area (Tanaka and Kozai, 1982), the lower part of the Ishido Formation (Tanaka, 1965), and also from the Upper Member of the Arida Formation (Tanaka and Kozai, 1982). The first of these formations is correlated with the Upper Bar-

remian (Tashiro *et al.*, 1980).

*Heteraster bungoensis* sp. nov. is found not only in the Haidateyama Group but also in the Upper Member (Lower Barremian) of the Arida Formation.

To sum up, so far as the material available is concerned, it is evident that all the three species mentioned above are restricted to the Barremian and moreover, occur in common in the Lower Barremian.

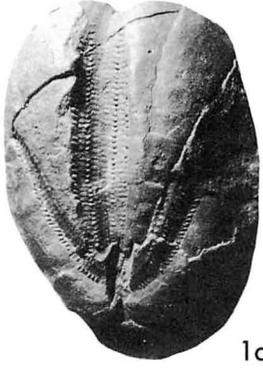
Various molluscan species occur abundantly at the echinoid localities in the Upper Formation of the Haidateyama Group. Among them, *Ancyloceras* (*Ancyloceras*) sp. aff. *A. (A.) vandenheckii* Astier, though somewhat imperfect, was considered as suggestive of the uppermost Barremian or the lowermost Aptian (Noda, 1977), but is not convincing. Very recently another diagnostic ammonite, *Crioceratites* (*Crioceratites*) sp. aff. *C. (C.) koechlini* (Astier), was obtained from about the same locality as the above ammonite, and it suggests an Early Barremian age (Matsumoto *et al.*, 1982). Thus, the Haidateyama echinoid faunule is compatible with the ammonoid-based correlation. It is also not inconsistent with the bivalve-based age assignment by Tashiro *et al.* (1983). In short, it is reasonable to correlate the Upper Formation of the Haidateyama Group with the Lower Barremian.

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#### Explanation of Plate 82

- Figs. 1,2. *Heteraster macroholcus* (Nisiyama) . . . . . Page 447
1. GSJ. F6024 from loc. HK-204, Haidateyama area, aboral (a) and left lateral (b) views, ×1.3.
  2. GSJ. F6025 from loc. HK-204, aboral (a) and oral (b) views, ×1.1.
- Figs. 3—6. *Heteraster bungoensis* Tanaka *et Noda*, sp. nov. . . . . Page 448
3. GSJ. F6013, holotype, from loc. HK-204, Haidateyama area, aboral (a), oral (b), left lateral (c), anterior (d) and posterior (e) views, ×1.4.
  4. GSJ. F6036, paratype, from loc. HK-204, aboral (a) and oral (b) views, ×1.6.
  5. GSJ. F6033, paratype, from loc. K-613, Yuasa area, aboral (a), oral (b) and left lateral (c) views, ×1.7.
  6. GSJ. F6039A, paratype, from loc. K-613, aboral view, ×1.

All specimens illustrated here are internal moulds.



1a



2a



3a



1b



3c



3b



4a



4b



3d



5c



5a



3e



2b



5b



6

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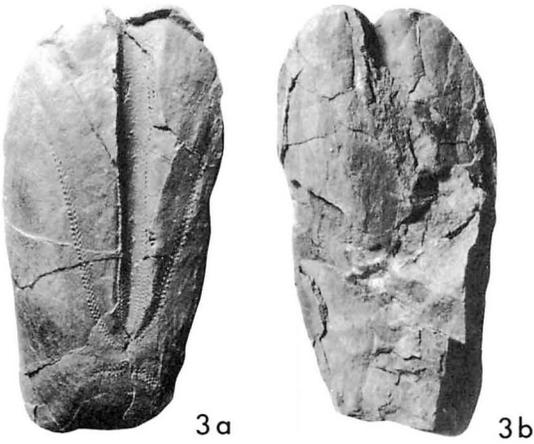
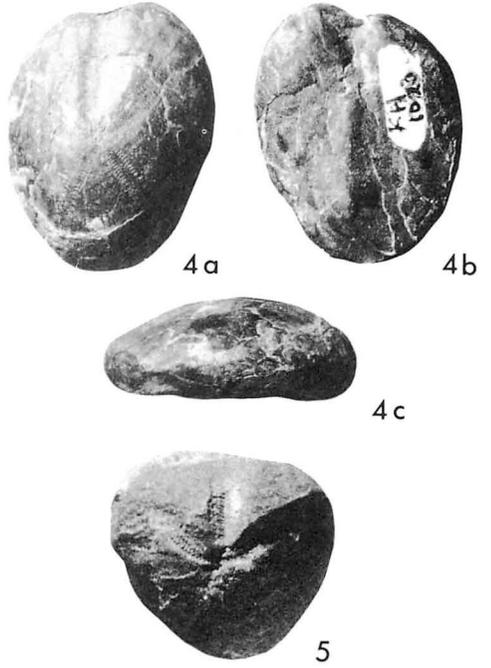
Arida 有田, Banjo 番匠, Haidateyama 佩楯山, Honjo 本匠, Ishido 石堂, Itaya 板屋, Kamikoshigoe  
上腰越, Koshigoe 腰越, Monobe 物部, Minamiyamabe 南海部, Notsu 野津, Ono 大野, Sanchu 山中,  
Shinkai 新開, Sukubo 須久保, Yuasa 湯浅, Yunoki 柚ノ木

九州東部の下部白亜系佩楯山層群から産したウニ化石：大分県の秩父帯に分布する下部白  
亜系佩楯山層群の上部層から産したウニ化石について、*Heteraster* の3種（既知種・新種・  
同定不能種）及び *Pseudowashitaster* の1種（既知種）を識別し、古生物学的記載を行った。  
*Heteraster* の新種は和歌山県湯浅地域の有田層の上部層（下部バレミアン）からも産する。  
*Heteraster* の既知種は秩父帯の他地域の下部バレミアンから、*Pseudowashitaster* の1種も  
同じく下部・上部バレミアンから知られている。佩楯山層群の上部層はアンモナイトによって  
下部バレミアンに対比されており、ウニ化石の層位はこの対比論と矛盾しない。

田中啓策・野田雅之・田中 均

### Explanation of Plate 83

- Figs. 1—3. *Pseudowashitaster mysticus* Tanaka . . . . . Page 451
1. GSJ. F6022 from loc. HK-204, Haidateyama area, external cast, aboral (a) and oral (b) views,  $\times 1.2$ .
  2. GSJ. F6026 from loc. H-105, Haidateyama area. 2a, Aboral view of an internal mould (A),  $\times 1$ . 2b, Aboral view of an external mould (B),  $\times 3$ . A peripetalous fasciole is seen between two arrows.
  3. GSJ. F6021 from loc. HK-204, aboral (a) and oral (b) views,  $\times 1.1$ .
- Fig. 4. *Heteraster bungoensis* Tanaka et Noda, sp. nov. . . . . Page 448
- GSJ. F6014, paratype, from loc. HK-204, Haidateyama area, aboral (a), oral (b) and left lateral (c) views,  $\times 1.4$ .
- Fig. 5. *Heteraster* sp. . . . . Page 450
- GSJ. F6027 from loc. Su-104, Haidateyama area, aboral view,  $\times 2.2$ .
- All specimens illustrated here are internal moulds, unless otherwise stated.



787. NOTES ON *MYTILOIDES INCERTUS* (CRETACEOUS BIVALVIA) FROM THE UPPER TURONIAN OF THE POMBETS AREA, CENTRAL HOKKAIDO\*

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**Abstract.** In this paper, *Inoceramus incertus* Jimbo, 1894 is restudied biometrically as well as taxonomically and biostratigraphically. At first normal distribution of various characters is evaluated for each sample from Pombets of Hokkaido by the method of chi-square test, and the specific diagnosis is revised. Then the extent of variation for selected characters are numerically shown. Finally the biostratigraphic significance of the species is discussed.

The results obtained are as follows: (1) *Inoceramus incertus* Jimbo should be assigned to *Mytiloides*. Almost all the specimens of so-called *I. incertus* from Pombets are assigned to *M. incertus* which shows a considerable extent of variation in shell form and surface ornamentation. The extent of variation tends to expand in ascending the stratigraphic sequence. (2) A few specimens from loc. Ik2014 are distinctly outside the variation of *M. incertus* and should be called *Mytiloides* sp. aff. *M. mytiloidiformis* (Tröger). (3) *M. fiegei* (Tröger) from the Upper Turonian of various regions of the world is probably regarded as a junior synonym of *M. incertus*. Thus, *M. incertus* can be evaluated as one of the widespread indices of the Upper Turonian.

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### Introduction

*Inoceramus incertus* was established by Jimbo (1894) on the basis of three incomplete specimens from a single calcareous nodule. According to the original description, the nodule was obtained in the pebbles of the River Pombets. As pointed out by Matsumoto (1963), Jimbo's original figure (pl. 8, fig. 7) was synthetically reconstructed based on these specimens. Jimbo mentioned that the complete outline was exactly unknown, but that it was distinguished from *Inoceramus* sp. (Yokoyama, 1890) in the crowded minor concentric ornamentations. The geological age was not precisely known at that

date.

About 45 years later, Nagao and Matsumoto (1940) redescribed *Inoceramus incertus* Jimbo on a number of specimens, including the syntypes and some subsequent collections from the mudstone of particular exposures on the river side of the Pombets, and ascribed the stratigraphic position of this species to the lowest part of the Upper Ammonite Beds.

Subsequently, Matsumoto (1959) referred the species to the lineage of *I. labiatus* — *I. latus* and ascribed its range probably to the Upper Gyliakian in the Japanese scale which is approximately correlated with the Upper Turonian in the international scale on the ground of the associated ammonoids.

Since 1975, I have investigated the exposure

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with Matsumoto with assistance of a number of co-operaters. On the large samples in these and previous collections, I examined statistically the variation and the ontogenetic change of selected characters. In this paper, I described the result of this statistical study, giving remarks on the relations with previously known species. The stratigraphic implication of this and related species is discussed.

Incidentally, a part of the result of this study has been preliminarily reported in a short paper by Matsumoto and Noda (1983), with emphasis on biostratigraphic aspects. This paper gives a full account for the palaeontological aspects.

Before going further, I thank Emeritus Professor Tatsuro Matsumoto of Kyushu University for his cordial help throughout the present study including comments on manuscript and supply of a large number of specimens registered at Kyushu University (GK) for this study. I am indebted to Professor Itaru Hayami of University of Tokyo for his kindness in giving facilities for the access to the syntypes of Jimbo and useful advice, and also to Professor Masayuki Tashiro of Kochi University for his generosity to let me quote his unpublished data. My gratitude is extended to Messrs. Kikuo Muramoto of Mikasa Museum, Takemi Takahashi of Mikasa and Shigehiro Uchida of Horomui for their help in the field work. I express my sincere gratitude to Professor Karl-Armin Tröger of Bergakademie Freiberg for his kindness in offering the replica of certain specimens from the Upper Turonian of East Germany. Furthermore, I am much obliged to Mr. Yoshihiro Matsubara, the Chief of Iwamizawa Forestry Office and other staff members for giving facilities in the field work.

A part of this study was supported by scientific research subsidy of the Shimonaka Commemorative Foundation (1978, 1980).

#### Locality

The outcrops of localities Ik2012-2014 are on the right bank of the River Pombets, about 3 km upstream from Ikushumbets, central Hokkaido, as shown in Text-fig. 1. They

are in Ikushumbets Quad. (1:25000); Long.  $141^{\circ}58'46''\text{N}-50''\text{N}$ , Lat.  $43^{\circ}16'20''\text{E}-23''\text{E}$ . The main part of Ik2011 is on the opposite bank of Ik2012, the cliff of a forest road along the left side of the River Pombets. The sequence of strata exposed on the cliff is shown in Text-fig. 2 (see also Matsumoto, 1965; Matsumoto et al., 1981). The stratigraphy and the geological age of this area have already been reported by several researchers (Matsumoto, 1959; Matsumoto, 1965; Matsumoto, 1971; Matsumoto et al., 1981; Matsumoto and Noda, 1983). The whole sequence of the fine-sandy siltstone exposed from loc. Ik2012b to Ik2014, below the 5 m bed of green sandstone at loc. Ik2012a and above the massive or thickbedded pebbly coarse-grained sandstone at loc. Ik2015, is referred to Unit IIIa', the lower part of the Upper Yezo Group. Considering the lithology and the mode of preservation, Jimbo's type specimens must have been derived from somewhere in the cliff of Ik2012-2014.

The associated species of ammonoid and other megafossils are listed with their frequency by Matsumoto et al. (1981).

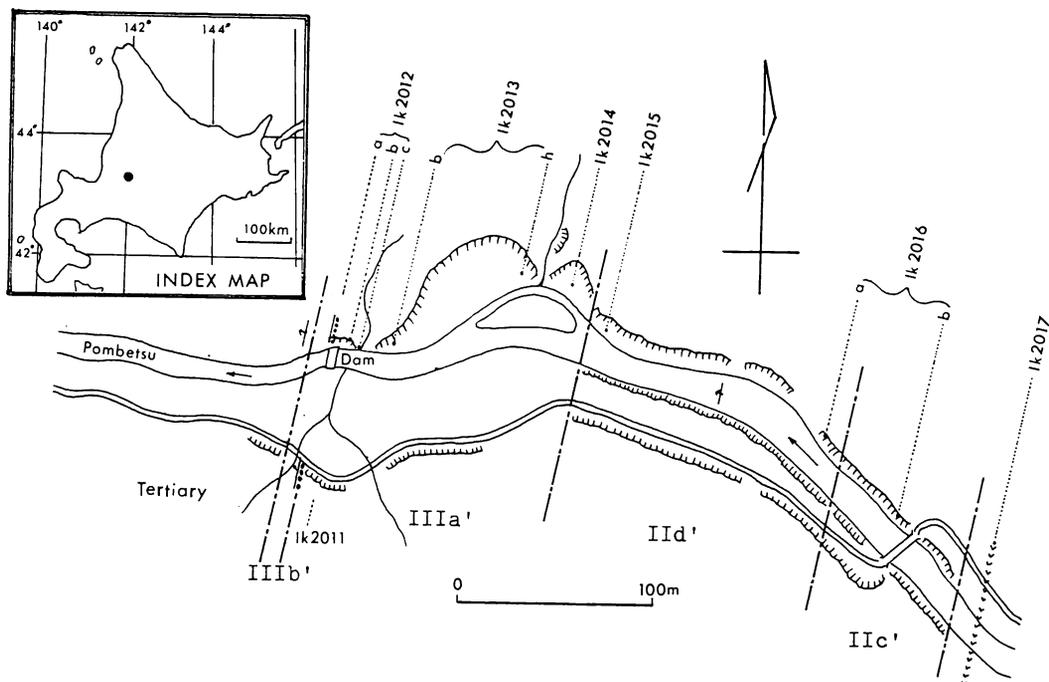
#### Material and Method

The sample size and the stratigraphic positions are shown in Table 1. The repositories of the examined specimens are as follows: GK: Kyushu University; HK: Hokkaido University; JG: Jonan Geological Association, Oita; IGPS: Tohoku University; TTC: Takemi Takahashi Collection, Mikasa; UMUT: University Museum, University of Tokyo.

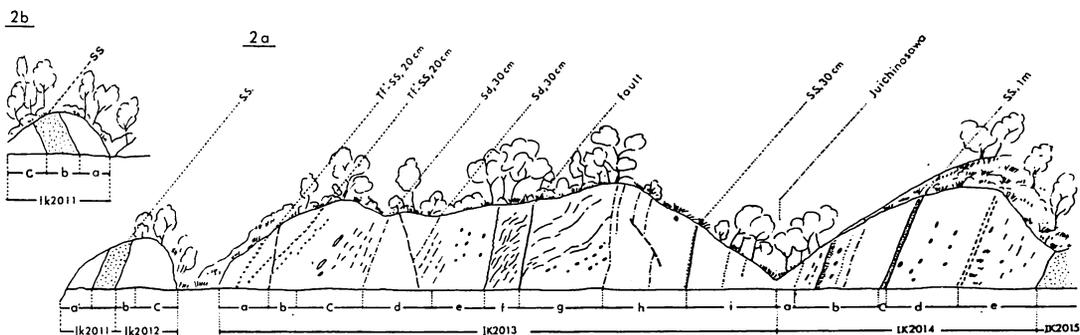
In this paper, at first, the specific characters are examined by means of traditional method, in addition to the numerical analyses of variation and relative growth, and then compared with allied species.

At first, several well preserved specimens of *Mytiloides incertus* are selected, and their linear dimensions and angles are measured as shown in Text-fig. 3.

Based on the measurements, (1) the mean value, standard deviation and Pearson's coeffi-



Text-fig. 1. Route map along the River Pombets (after Matsumoto, 1965).

Text-fig. 2. Sketch of the outcrops where *Mytiloides incertus* occurs (after Matsumoto et al. 1981).

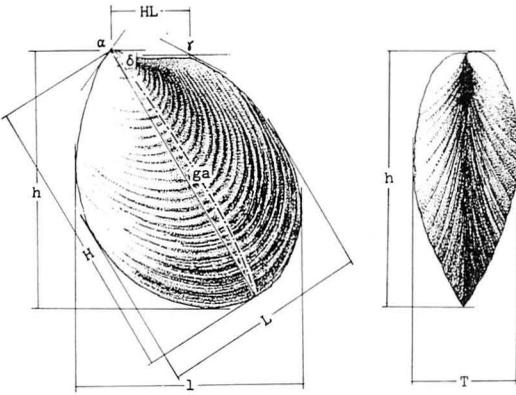
cient of variation of the selected biometrical characters are obtained for each sample, and the normal distribution for each character is evaluated by means of chi-square test, (2) the difference between the mean values of each character is evaluated by Student's *t*-test, (3) for the samples of which the *t*-value is not significant, the two samples are combined and the mean value, standard deviation and Pearson's

coefficient of variation are obtained, (4) the significant difference from some samples of allied species is examined by *t*-test for each biometrical character, (5) the two variables, shell height (*h*) and shell length (*l*), and *H* and *L* for each specimen are concerned with examination of relative growth, plotting *h*, (*H*) in abscissa and *l* (*L*) in ordinate on logarithmic graph paper, and the striking features of the reduced major

Table 1. Sample size of each outcropping unit.

exposure	Ik2011	Ik2012	Ik2013				Ik2014			total
subdivision	c		d	e	g	h	b	d	f	
number	9		2	1	6	15	2	4	2	41
	(2)	(1)	(10)							(13)
total	11	1	34				8			54

( ) : not allocated to a subdivided unit.



Text-fig. 3. Basic morphology for measurements.

axes and the coefficients of correlation are calculated.

For the method of measurements and the procedure of statistics and their analyses, refer to Hayami (1969), Hayami and Matsukuma (1971) and Noda (1975).

And also, for the comparison with the allied species described by Tröger (1967), the relative growth between  $\delta$  and  $h$ , and that between  $1/h$  and  $h$  are shown in the same way as Tröger's.

#### Palaeontological Description

Family Inoceramidae Giebel, 1852

Genus *Mytiloides* Brongniart, 1822

#### *Mytiloides incertus* (Jimbo)

Pl. 84; Pl. 85; Pl. 86, Figs. 1–8.

1894. *Inoceramus incertus* Jimbo. *Palaeont.*

*Abhandl., Neue Folge*, vol. 2, no. 3, p. 189 [43], pl. 24 [8], fig. 7.

1930. *Inoceramus inconstans* Woods; Fiege, *Palaeontographica*, vol. 73, p. 38, pl. 5, figs. 16, 17, pl. 6, fig. 18.

1940. *Inoceramus incertus* Jimbo; Nagao and Matsumoto, *Jour. Fac. Sci., Hokkaido Imp. Univ.*, ser. 4, vol. 6, no. 1, p. 10–13, pl. 3, figs. 1–3, 5, pl. 10, fig. 2.

non 1940. *Inoceramus incertus* Jimbo; Nagao and Matsumoto, *op. cit.*, ser. 4, vol. 6, no. 1, pl. 3, fig. 4.

non 1940. *Inoceramus incertus* var. *yubarensis* Nagao and Matsumoto, *op. cit.*, ser. 4, vol. 6, no. 1, p. 11, 12, pl. 6, fig. 1.

1959. *Inoceramus incertus* Jimbo; Matsumoto, *Mem. Fac. Sci., Kyushu Univ.*, ser. D, vol. 9, no. 2, p. 85.

1963. *Inoceramus incertus* Jimbo; Matsumoto, *A survey of the fossils from Japan illustrated in classical monographs*. Part 10, p. 45, pl. 67, fig. 7.

non 1966. *Inoceramus* sp. cf. *incertus*; Tamura and Tashiro, *Mem. Fac. Educ., Kumamoto Univ.*, no. 14, sec. 1, pl. 1, figs. 11–13.

1967. *Inoceramus fiegei fiegei* Tröger. *Abh. Staatl. Mus. Mineral-Geol.*, vol. 12, p. 105–108, pl. 11, fig. 3, pl. 13, figs. 14, 15, 17, 20.

1976. *Inoceramus incertus* Jimbo; Noda and Matsumoto, *Atlas of Japanese fossils*. no. 45, sheet 270, fig. 7.

1977. *Mytiloides* (=“*Inoceramus*”) *incertus* (Jimbo); Kauffman, *Palaeont. Soc. Japan, Special Papers*. no. 21, p. 179, 180.

1978. *Mytiloides fiegei fiegei* (Tröger); Kaufman, *Ann. Mus. Nat. d'Hist. Nice*, vol. 4, no. 23, p. 9, pl. 15, fig. 1, pl. 16,

fig. 4.

1982. *Inoceramus fiegei fiegei* Tröger; Keller, *Geol. Jahrb.*, A, no. 64, p. 110, pl. 7, fig. 5.
1983. *Mytiloides incertus* (Jimbo); Matsumoto and Noda, *Proc. Japan. Acad.*, vol. 59, ser. B, no. 5, p. 111, figs. 2-4.

*Lectotype*.—UMUT.MM7535. One of the syntypes (designated by Matsumoto and Noda, 1983, p. 111). Pebble of the River Pombets, Mikasa City.

*Material*.—UMUT.MM7535-3 (= MM7481 = TK.I-151, including four specimens), GK.H10041, 10048, 10056, 10061-10064, 10066-10068, 10108, 10109, 10111-10129, HK7242, 7246, JG.H2128, 2850-2855, TTC0001 and 0002.

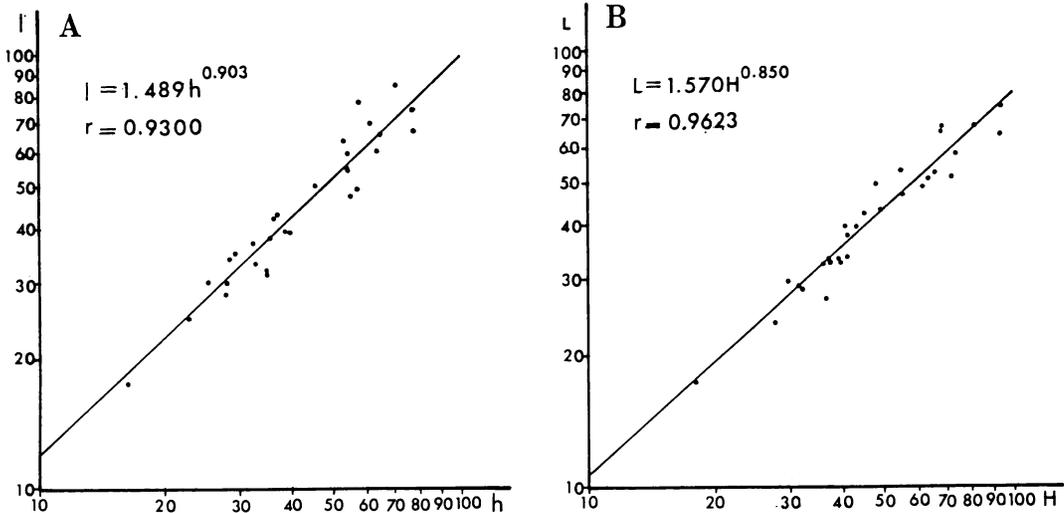
*Diagnosis*.—Shell of medium size, equivalve, inequilateral. Valve moderately inflated, anterior part steep and posterior half gradually flattened, passing into a wing-like area without sharp boundary. Umbo terminal and not prominent. Hinge-line rather long. Marginal outline with large extent of variation, being from oblique oval to subquadrate. Surface ornamented with a combination of major concentric undulations and minor concentric rings. The former being low, broad and regularly spaced and the latter numerous, sharp and much crowded.

*Description*.—Shell of medium size, large

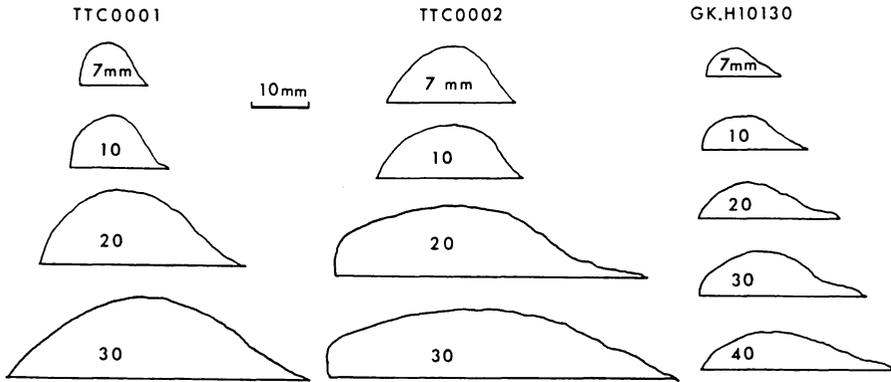
individual about 95 mm in H (JG.H2855, GK.H10087 and 10109). Growth axis straight or slightly concave to anterior and considerably oblique to the hinge-line. Valve gently inflated, anterior part comparatively steep but some individuals perpendicular to the valve plane (TTC0002), posterior half gradually flattened and continuing to the wing-like area without sharp boundary. The section along the growth axis uniformly convex but abrupt change of convexity are observed in a specimen of TTC0002. Outline considerably variable from oval (TTC0001) to subquadrate (TTC0002). The specimens with subquadrate outline generally flat on flank and steep to the marginal part in adult, hinge-line fairly long, about a half of shell length on an average, forming an angle of about  $130^\circ$  with the posterior margin.

Concentric undulations mostly low and rounded with some extent of variation in size, interspace, intensity and density, for example, as in the specimens of GK.H10109, GK.H10087, GK.H10094, GK.H10123, GK.H10118 and TTC0001. Concentric rings distinct, sharp and crowded in all specimens, and continuing from the main part of flank to the wing-like area.

*Measurements and statistics*.—The result of the chi-square test for selected characters of each sample is shown in Table 4. The chi-square values



Text-fig. 4. Averaged relative growth of *Mytiloides incertus*. A:  $l$  and  $h$ , B:  $L$  and  $H$ .



Text-fig. 5. Ontogenetic change of shell convexity, showing the cross sections at the growth stages of 7 mm, 10 mm, 20 mm and 30 mm in H.

Table 2. Biometrical characters of the Samples Ik2013 and Ik2011, and the result of Student's *t*-tests.

	$\alpha$		$\gamma$		l/h		L/H		HL/h		HL/l	
	Ik2013	IK2011	Ik2013	Ik2011	Ik2013	Ik2011	Ik2013	Ik2011	Ik2013	Ik2011	Ik2013	Ik2011
<i>N</i>	21	9	11	6	21	9	21	9	16	7	16	9
<i>m</i>	113°	114°	147.3	146.7	1.04	1.05	0.87	0.86	0.49	0.52	0.49	0.49
<i>s</i>	6.9	5.8	4.84	4.97	0.111	0.134	0.078	0.088	0.075	0.088	0.076	0.037
<i>v</i>	6.106	5.088	3.286	3.388	10.673	12.762	8.966	10.232	15.306	16.923	15.510	7.557
<i>F</i>	1.415		1.054		1.457		1.273		1.377		4.219	
	○		○		○		○		○		●	
<i>t</i>	0.380		0.202		0.213		0.310		0.836		0.000	
	○		○		○		○		○		○	

*N*: sample size, *m*: mean value, *s*: standard deviation, *v*: Peason's coefficient of variation, *F*: value of *F*-test, *t*: value of Student's *t*-test, solid circle: significant, open circle: not significant. significancy showing at 95% confidence level.

of  $\alpha$ ,  $\gamma$ , l/h,  $l/h_{H=40mm}$ , L/H and HL/h are less than 7.81 which is 5 percent significant limit at the degree of freedom 3, and those of T/h and HL/h are less than 3.84, the 5 percent significant limit at the degree of freedom 1, thus the hypothesis of the random sampling from a normally distributed population can be adopted. Therefore various numerical values, i. e. mean value, standard deviation and coefficient of variation, may be meaningful.

The measurement values for every specimen

are omitted for brevity, but those of the selected specimens, that is, the lectotype, JG.H2853–2855 which are most common form and TTC0001, 0002, the extreme forms, are shown in Table 3. Then *F*-test and *t*-test are adopted for characters between the samples Ik2011 and 2013, the results are not significant for all characters examined. Thus the two samples can be combined into a single one. The statistical result is shown in Table 4.

The sample Ik2014 is small, and its specimens

Table 3. Measurements of selected specimens of *M. incertus*. linear dimension in mm.

	h	l	H	L	T	HL	$\alpha$	$\gamma$	$\delta$
UMUT.MM7535-3 lectotype	38.4	35.5+	41.0	32.6	—	20.0	106°	148°	56°
JG.H2853	54.0	58.9	66.0	53.0	—	27.0	116°	150°	47°
JG.H2854	54.0	55.5	61.5	49.3	24.6	27.4	116°	150°	46°
TTC.0001	63.6	61.9	74.1	58.6	31.8	25.0	106°	150°	54°
TTC.0002	65.1	65.5	69.0	67.0	30.0	30.9	119°	145°	52°

	l/h	l/h <sub>H=40mm</sub>	L/H	T/h	HL/h	HL/l
UMUT.MM7535-3 lectotype	0.92+	—	0.80	—	0.52	0.56-
JG.H2853	1.09	1.08	0.80	—	0.50	0.46
JG.H2854	1.03	1.12	0.80	0.46	0.51	0.49
TTC.0001	0.97	0.98	0.79	0.50	0.39	0.40
TTC.0002	1.01	1.13	0.97	0.46	0.47	0.47

Table 4. Biometric characters of *M. incertus*.

	$\alpha$	$\gamma$	l/h	l/h <sub>H=40mm</sub>	L/H	T/h	HL/h	HL/l
<i>N</i>	30	17	30	15	30	10	23	23
<i>m</i>	113.3	147.0	1.043	1.036	0.860	0.494	0.501	0.498
<i>s</i>	6.51	4.60	0.1241	0.1005	0.0808	0.0646	0.0784	0.0669
<i>v</i>	5.745	3.129	11.898	9.701	9.395	13.077	15.649	13.681
<i>X</i> <sup>2</sup>	4.66 <i>n</i> =3	5.82 <i>n</i> =3	1.34 <i>n</i> =3	7.36 <i>n</i> =3	6.81 <i>n</i> =3	3.30 <i>n</i> =1	7.69 <i>n</i> =3	3.26 <i>n</i> =1

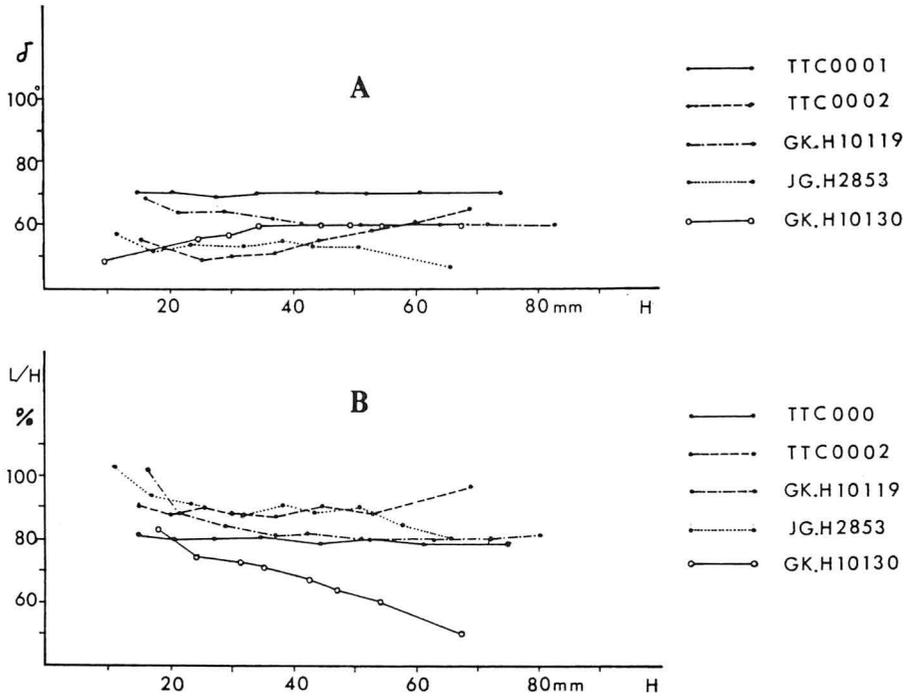
Table 5. Student's *t*-test of the Sample Ik2014 for the Samples Ik2013 and Ik2011.

	Ik2014				
	$\alpha$	l/h	L/H	HL/h	HL/l
Ik2013	0.425	2.729	2.766	3.622	2.681
	○	●	●	●	●
Ik2011	0.654	2.266	3.881	3.295	5.309
	○	▲	●	●	●

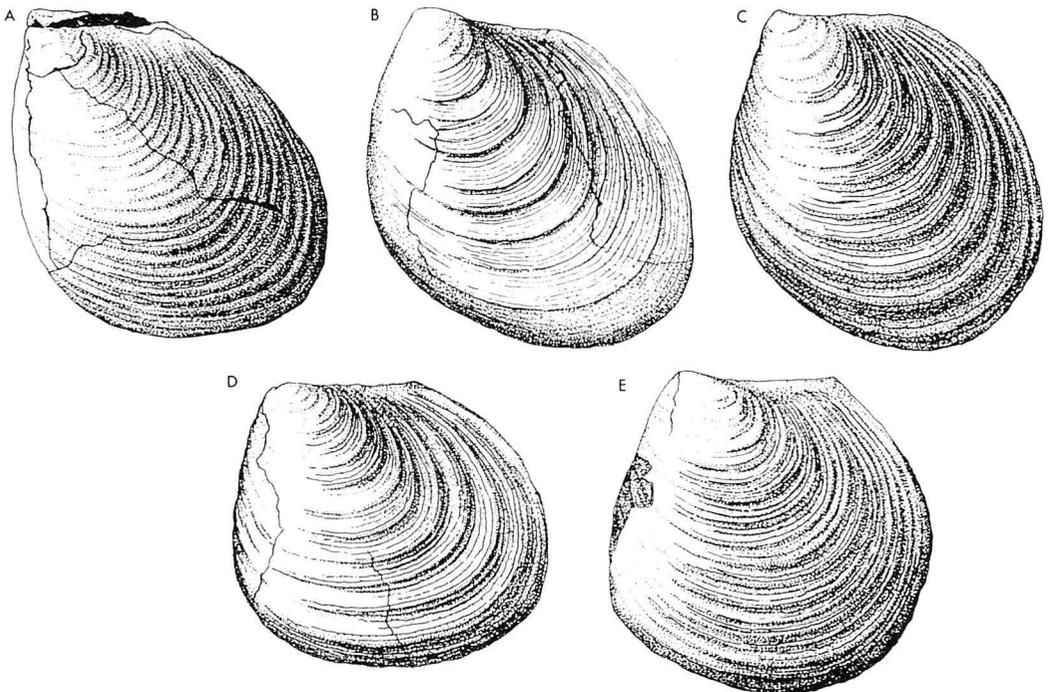
are often of unfavourable preservation. In general aspects, however, a form elongated along the growth axis is more common than the less elongated usual form. The results of *t*-test between the sample Ik2014 and the sample

Ik2011 plus 2013 are significant with respects to certain characters (Table 5).

Then the average relative growth of the samples Ik2011 and 2013 are examined, plotting *h* in abscissa and 1 in ordinate on logarithmic



Text-fig. 6A. Ontogenetic change of obliquity. 6B. Ontogenetic change of L/H.



Text-fig. 7. Variation of shell form in *Mytiloides incertus*.

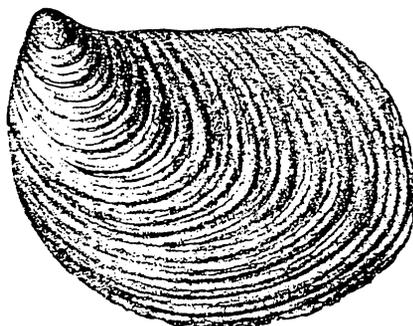
graph paper, and also H and L, and the reduced major axes and the coefficient of correlation are calculated. These are demonstrated in Text-fig. 4A, B.

Text-fig. 5 shows the cross section at the growth stages of 7 mm, 10 mm, 20 mm and 30 mm in H and Text-fig. 6A shows the change of  $\delta$  with growth and Text-fig. 6B that of  $1/h$ .

*Variation.*—Although Jimbo's syntypes are very incomplete, a considerable extent of variation in the outline is suggested by the curvature of the concentric ornaments. In fact, examining a large number of specimens there is considerably wide variation in shell form as is demonstrated in Text-fig. 7. The two extreme individuals may be hardly identified with each other. There are, however, various grades of intermediate forms, and normal distribution is confirmed in various characters by the method of chi-square test. Therefore, these various forms can be regarded as representing one and the same species. On the other hand, some of the specific characters which are not dealt with numerically are rather important as taxonomic criteria. As Matsumoto (1981, personal information) suggested, the surface ornamentation of the specimen TTC0001 has its own characteristics, that is, concentric ribs are low, crowded, round-topped and regular in size, interspace and intensity, whereas the minor rings rather inconspicuous. It differs considerably from the typical form of this species. The specimens GK.H10119 and JG.H2850 show also similar ornaments. But in the specimen GK.H10115 which is closed valves, the ornaments of right valve show an intermediate character whereas the left valve has typical ornament. Furthermore, the right valve of GK.H10109 shows TTC0001-like ornament in the umbonal part but has typical ornament in adult stage. This fact proves a considerable extent of variation even in the surface ornamentation.

*Remarks.*—Despite of the high variability, no specimen of *M. incertus* resembles Jimbo's illustration (reproduced here as Text-fig. 8) which was inadequately restored.

The specimens described under *I. incertus* by



Text-fig. 8. Restoration of *Mytiloides incertus* based on three syntypes by Jimbo (1894).

Nagao and Matsumoto (1940, p. 10) are mostly identified with *M. incertus* defined in this paper. For instance, the specimens HK7246 and HK7242 (Nagao and Matsumoto, 1940, pl. 3, figs. 1, 2) are certainly so. The specimen IGPS22740 (Nagao and Matsumoto, pl. 3, fig. 3) has comparatively sharp concentric ribs but can be regarded as being within the extent of variation of *M. incertus*. HK7162 (pl. 3, fig. 5 in Nagao and Matsumoto), which is an internal mould, has also sharp concentric ribs but can be likewise included in *M. incertus*, despite a different opinion by Kauffman (1977, p. 180), because it closely resembles the young part of JG.H2851 (Pl. 84, Fig. 7). On the internal mould the surface ornament would not be precisely impressed.

An exceptional specimen, IGPS22738 (Nagao and Matsumoto, 1940, pl. 3, fig. 4), which was noted by Nagao and Matsumoto as an abnormal form, is too much elongated along the growth axis and probably identified with *M. sp. aff. M. mytiloidiformis* (Tröger) described below.

The specimen HK5960 (*I. incertus* var. *yubarensis* Nagao and Matsumoto, pl. 6, fig. 1) from Kamihobets is clearly distinct from *M. incertus* as has already mentioned by Matsumoto and Noda (1968).

*Comparison with allied species.*—Nagao and Matsumoto (1940) compared this species to *M. labiatus* (Schlotheim) from the Lower Turonian and *M. hercynicus* (Petrascheck) from the comparatively upper part of the Lower Turonian to



in marginal outline is presumed in that species. The ontogenetic changes of selected characters are demonstrated in Text-figs. 5 and 6 in the same way of Tröger's expression for comparison between the two species. The ontogenetic changes of  $\delta$  and L/H (WA, Na/Ha by Tröger) confirm well between them. The abrupt change of shell convexity on the ventral part as shown in p. 108, fig. 28 (Tröger, 1967) is sometimes found also in *M. incertus*.

An extreme form represented by the specimens TTC0001 and GK.H10119 apparently resembles *M. dresdensis dresdensis* (Tröger) in the outline and surface ornamentations, but as is clear from Text-fig. 6A and B, the ontogenetic changes of  $\delta$  and L/H differ from those of *M. dresdensis dresdensis* (Tröger, 1967, p. 205, fig. 28).

*I. striatoconcentricus striatoconcentricus* Güm-  
bel (1868) from the Upper Turonian of Europe and Africa is similar to *M. incertus* in crowded and sharp concentric rings, but differs in its smaller ratio of L/H (0.70–0.85), smaller beak angle, prominent umbo and clearly demarcated wing.

Another extreme form with subquadrate outline represented by a specimen TTC0002 resembles *M. aviculoides* (Meek and Hayden) from the Upper most Turonian of the Western Interior Province (Kauffman, 1977b, pl. 12, fig. 1, pl. 13, fig. 2), but *M. aviculoides* is much more oblique than *M. incertus*.

Matsumoto (1981, personal information) suggested me to compare *I. sp.* figured by Bürgl (1957, pl. 15, fig. 3) from the Lower Coniacian of Colombia to the present species but the former is discriminated from the present species in the smaller obliquity even in the early stage of growth and the posteriorly placed umbo.

Kauffman (1977a, p. 180) pointed out the similarity between *M. incertus* and *I. (Pl.) chouberti* Sornay from the Lower Coniacian of Tarfaya, Morocco and regarded the latter as a subspecies of the former. But there are some questions for the subspecies which is clearly age-inequivalent. In other alternative, *I. (Pl.) chouberti* may be regarded as a chronological

transient of *M. incertus*.

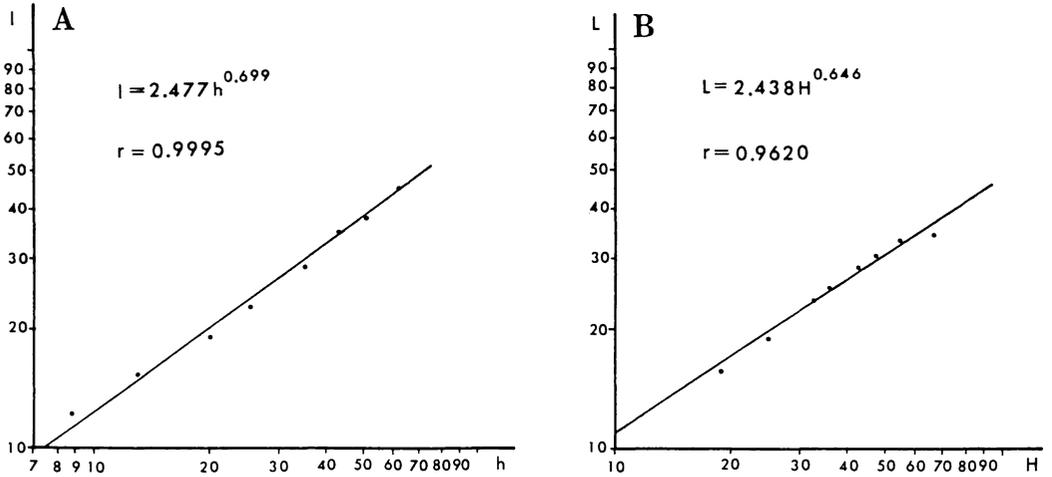
Although Kauffman (1977a) regarded the specimen HK7162 (Nagao and Matsumoto, 1940, pl. 3, fig. 5) as closely similar to or conspecific with *M. labiatoidiformis* (Tröger) (= *I. dresdensis labiatoidiformis* Tröger), they are clearly discriminated from each other. Namely, the antero-dorsal margin of *M. incertus* is nearly straight regardless of a large extent of variation in the outline, whereas that of *M. labiatoidiformis* is considerably convex, and in addition, in the ontogenetic change of L/H, *M. labiatoidiformis* becomes gradually elongated along the growth axis with growth.

Kauffman (1977a) pointed out that the specimen IGPS 57821 (Nagao and Matsumoto, 1940, pl. 10, fig. 2) differs from the typical form of *M. incertus* in the outline and surface ornamentation and that the specimen is very closely allied to the specimens of *M. fiegei fiegei*. But Kauffman's concept depended on the original illustration of Jimbo (1894) is clearly inadequate, as has been mentioned above. Kauffman regarded *M. fiegei fiegei* as a junior synonym of *M. meekianus* (Anderson) from the "Coniacian" (age uncertain) of California. As is examined in Table 7, *M. fiegei fiegei* is a synonym with *M. incertus*. Thus the specimen IGPS 57821 is also ascribed to a form of *M. incertus*.

Some specimens (i. e. GK.H10119, TTC0001) of *M. incertus* are similar to the holotype of *M. modaliaensis* (Sornay) (Sornay, 1981, pl. 1, fig. 1) from the Lower Turonian of Colombia in the orientation of growth axis and shell convexity but *M. modaliaensis* differs from *M. incertus* in its short hinge-line, convex antero-dorsal margin and less conspicuous concentric rings.

*Phylogenetic relationship.*—Matsumoto (1959) pointed out that the present species is closely related to *M. labiatus* from the Lower Turonian and especially akin to *M. latus* ranging from the Lower to Upper Turonian.

Kauffman (1975, 1978a, b) attempted precise zonation of the Turonian of Europe and the Western Interior Province by means of *Mytiloides* species.



Text-fig. 9. Individual relative growth of *Mytiloides* sp. aff. *M. mytiloidiformis*. A: l and h, B: L and H.

Matsumoto and Noda (1975) did not establish zonal subdivision but recognized that "broad form" (with larger L/H) becomes gradually predominant as we ascend the sequence. Although Kauffman (1977a, fig. 1) tentatively suggested the tripartite zonation for the Lower Turonian of Japan, it is practically difficult in the case of Hokkaido.

In Shikoku, Aoki and Tashiro (1982) reported abundant occurrence of *Mytiloides* from a shaly bed of about 20 m thickness at a locality called Doganaro. They tentatively used the specific names *I. (M.) opalensis* (Böse), *I. (M.) mytiloides* (Mantell), *I. (M.) labiatus* (Schlotheim), *I. (M.) subhercynicus* (Seitz), *I. (M.?) hercynicus* (Petrascheck) and *I. (M.?) "latus"* (Mantell). These species are overlapping considerably in stratigraphic range.\*

Furthermore, in the typical exposure of the Lower Turonian in Saumur of France, Badillet and Sornay (1980) recorded various species of *Mytiloides* associating with one another and pointed out the impossibility of finer zonation of the Lower Turonian by means of *Mytiloides* species.

Matsumoto and Noda (1968) pointed out the similarity of *M. teraokai* (Matsumoto et Noda)

from the Middle Turonian of Kyushu, to *M. latus* (Sowerby) or to *M. hercynicus* (Petrascheck) (= *M. latus* by Seitz, 1921, p. 101) from the comparatively upper part of the Lower Turonian. The well-preserved specimens GK.H6836 (Matsumoto and Noda, 1968, pl. 32, fig. 4), JG.H2125 (Matsumoto and Noda, 1975, pl. 18, fig. 7) of *M. teraokai* closely resemble the typical form of *M. incertus*, but *M. teraokai* has an anterior ear. The morphological resemblance and the successive occurrence suggested the intimate relationship between the two species. There are, however, some questions to regard *M. teraokai* as an immediate ancestor of *M. incertus*. It would be unnatural that the once acquired anterior ear disappeared against the law of irreversibility. To sum up, *M. teraokai* is probably an off-shoot, specialized from the main stock of evolution in *Mytiloides*.

Seitz (1934) discriminated six varieties in a species of *M. labiatus* (s. l.), of which var. *subhercynica* occurs in the upper part of the sequence (Tröger, 1967; Kauffman, 1975) and shows a greater extent of variation (Seitz, 1934, fig. 18).

In the case of *M. incertus*, the broad form with a flat valve is also rare in the lower part (Ik2014) and various forms occur in the upper part.

\*Palaeontological discussion on these species should be made on another opportunity.

Considering the lineage of *Mytiloides*, various forms of the genus from the Lower Turonian are successively linked as species or subspecies, although there is some disagreement among authors with respect to the taxonomic ranking.

According to Kauffman (1978a, b), *M. subhercynicus*, *M. hercynicus* and *M. "latus"* (sensu Woods, 1911, fig. 41), which are all broad form, are found in the Middle Turonian of the Western Interior of U. S. A. and England.

From the above discussion, it is reasonable to regard *M. incertus* as an immediate descendant of a Middle Turonian species with a broad outline such as *M. hercynicus* or others.

*Mytiloides* sp. aff. *M. mytiloidiformis* (Tröger)

Pl. 86, Fig. 9

1940. *Inoceramus incertus* Jimbo; Nagao and Matsumoto, *Jour. Fac. Sci., Hokkaido Imp. Univ.*, ser. 4, vol. 6, no. 1, p. 10–13, pl. 3, fig. 4.

*Material*.—GK.H10130 from loc. Ik2014. IGPS 22738 from Pombets.

*Description*.—Shell medium in size, probably equivalve, much elongated along the growth axis, with tongue-like outline. Umbo terminal, somewhat projecting above the hinge-line. Umbonal part considerably inflated. Antero-dorsal and anterior parts steep to the commissure plane, posterior half decreasing the convexity, but inclined fairly steep near the umbo and clearly bounded with wing-like area. Ventral part gradually flattened. Growth axis fairly oblique about 30°–50° in early stage of growth, at the growth stage of about 38 mm in H, the axis nearly straight forming an angle about 60° with the hinge-line. Antero-dorsal and anterior margins broadly arcuate and bent abruptly continuing to acutely curved ventral margin, which in turn passes into broadly rounded posterior margin. Postero-dorsal margin nearly straight, forming an obtuse angle about 150° with the hinge-line. Hinge-line fairly short being about one third of shell length.

Surface ornamented with concentric ribs and

rings in combination. The concentric ribs low, round-topped and regular in strength. The concentric rings sharp-headed and crowded. Wing-like area smooth without any ornamentation. Weak radial ornaments discernible on inner surface.

*Measurements*.—The measurements of the specimen GK.H10130 are shown in Table 8 in comparison with those of the holotype of *M. mytiloidiformis*. Then the individual relative growth for h and l, and H and L are demonstrated in Text-fig. 9A and B respectively. The ontogenetic change of shell convexity,  $\delta$  and L/H are shown in Text-figs. 5 and 6 respectively after Tröger's (Tröger, 1967, p. 201, fig. 24). (Remarks: The value of L/H shown in Table 8 may be somewhat larger in actual specimen, because the anterior part is lacking for a few mm.)

*Discussion*.—The specimen GK.H10130 was firstly regarded as an extremely elongate form of *M. incertus* and was used for statistic analysis altogether with other specimens. However, the value of L/H of GK.H10130 is outside the possible range ( $m \pm 3s$ ) of *M. incertus* population, and the specimen, therefore, may have to be excluded from the sample.

The result of measurements as shown in Table 8 and the ontogenetic change of selected characters demonstrated in Text-fig. 9 are well agreeable with those of the holotype of *M. mytiloidiformis* (Tröger) and also age-equivalent. But the following distinctions are pointed out between the two specimens. (1) The shell of the holotype of *M. mytiloidiformis* is more strongly inflated than that of GK.H10130. (2) The antero-dorsal margin nearly straight in the holotype but broadly convex in the Japanese specimen. (3) The surface ornamentation continues to the wing-like area in the holotype but the area is smooth in the Japanese specimen. (4) The major ribs regular in strength, size and interspace in the holotype but irregular in the Japanese one. To sum up, the present specimen GK.H10130 must be closely allied to but is not identified with *M. mytiloidiformis* (Tröger). However, it is reserved, at present, to give a specific name

Table 8. Measurements of *M. mytiloidiformis* (Tröger) and the specimen GK.H10130. linear dimension in mm.

	$\alpha$	$\gamma$	$\delta$	h	l	H	L
holotype	97°	150°	50°–70°	54.0	47.0	(64)	(36)
GK.H10130	110°	160°	60°	61.4	44.9	68.0	34.0

	HL	l/h	l/h <sub>H=40mm.</sub>	L/H	HL/h	HL/l
holotype	17.0	0.87	(0.87)	(0.54)	0.31	0.36
GK.H10130	12.7	0.73	0.87	0.50+	0.21	0.28

for the specimen because of the insufficient material.

Tröger (1967) established *M. fiegei mytiloidiformis* on four specimens from the Upper Turonian of Sachsen, East Germany, and he recognized also *M. fiegei fiegei* from the same bed. The sympatric occurrence of the two subspecies, however, is very doubtful on biological ground. *M. fiegei mytiloidiformis* is clearly discriminated from *M. fiegei fiegei* by its fairly prominent umbo, more oblique and longer growth axis, and these distinctions are regarded as specific criteria. From the above discussion, therefore, it is more reasonable to separate the two forms as independent species.

*Comparison with allied species.*—The present specimen is clearly discriminated from the comparatively “elongated” form of *M. incertus* in its still more “elongated” outline, prominent

umbo and fairly inflated umbonal region.

In comparison with such “elongated” forms of *Mytiloides* as *M. labiatus*, *M. mytiloides* (Mantell) and *M. opalensis* (Böse), the anterodorsal to anterior margin of the present specimen is much more broadly arcuate. The results of *t*-test for selected characters between the specimen GK.H10130 and *M. mytiloidiformis* are shown in Table 9. As is clarified from Table 9, there are certain characters with significant difference such as larger angle of  $\delta$  in GK.H10130 and small value in HL/h.

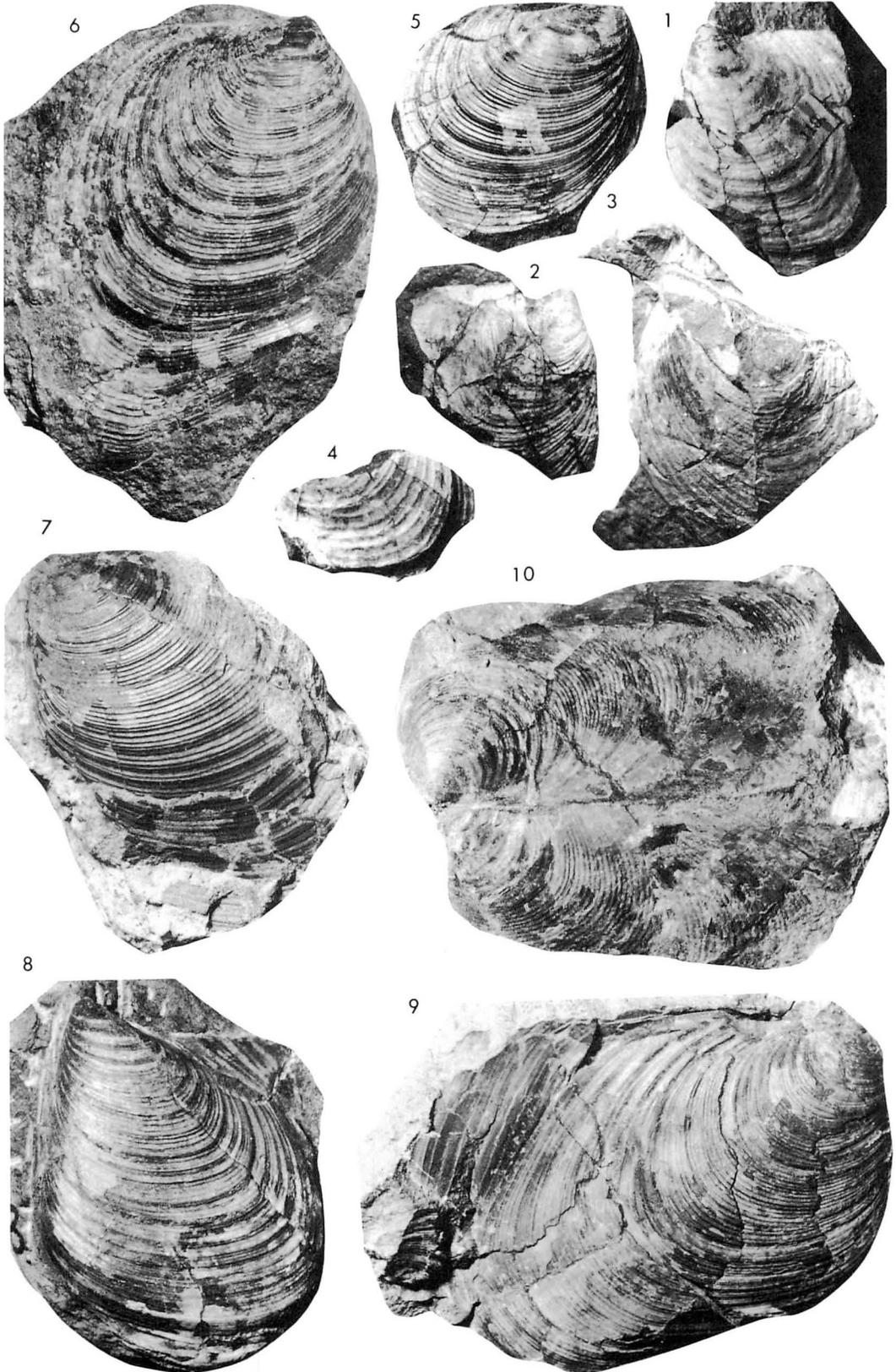
A specimen (Heine, 1929, pl. 5, fig. 27) of *M. sublabiatus* (Müller) is similar to the holotype of *M. mytiloidiformis* in the outline, shell convexity and obliquity of the growth axis, but other specimens (pl. 5, figs. 28, 29) have sharp concentric ribs which continue to the wing-like area. Heine ascribed these characters within an

#### Explanation of Plate 84

(All figures natural size)

Figs. 1-10. *Mytiloides incertus* (Jimbo)

1. UMUT.MM7535-3, lectotype, one of the syntypes of the Jimbo's specimens, from pebble in the River Pombets, Mikasa City, central Hokkaido (coll. Kotora Jimbo)
2. UMUT.MM7535-2, paralectotype, same nodule of the lectotype
3. UMUT.MM7535-4, non paralectotype, same nodule of the lectotype
4. UMUT.MM7535-1, paralectotype, same nodule of the lectotype
5. GK.H10124, right valve. Loc. Ik2013 (coll. T. Matsumoto)
6. JG.H2855, right valve. Loc. Ik2013h (coll. M. Noda, 1982)
7. JG.H2851, left valve. Loc. Ik2011c (coll. M. Noda, 1980)
8. JG.H2850, left valve. Loc. Ik2013 (coll. K. Muramoto, 1975)
9. GK.H10087, right valve. Loc. Ik2013g (coll. T. Matsumoto)
10. GK.H10109, articulate valves. Loc. Ik2011c, dorsal view (coll. T. Matsumoto)



extent of variation. These characters, however, are clearly distinct from those of the specimen GK.H10130.

A specimen of *M. striatoconcentricus striatoconcentricus* (Gümbel) from Peru, figured by Heinz (1928, pl. 4, fig. 3) resembles the present specimen in somewhat elongated outline and crowded concentric ornaments, but the former is clearly discriminated from the latter by well-developed posterior wing.

*M. striatoconcentricus* aff. *carpathicus* (Simionescu) (Heine, 1928; Tröger, 1967; Keller, 1982), from the Upper Turonian of Europe, is similar to the present specimen in ontogenetic changes of  $\delta$  and  $l/h$ , but its value of  $L/H$  is about 0.65–0.80 (Tröger, 1967, p. 197, fig. 27) as compared with 0.50 in the present specimen. As is illustrated in the original paper, *M. striatoconcentricus carpathicus* (Simionescu) (1899, pl. 2, fig. 1a, b) has a smaller beak angle, long and straight antero-dorsal margin, fairly strongly convex ventral part, smaller posterior-hinge angle and smaller obliquity with  $\delta$  about  $90^\circ$ .

*M. labiatoidiformis* (= *I. dresdensis* ? *labiatoidiformis* Tröger) is similar to the present specimen in the mytiloid outline elongated along the growth axis, the ontogenetic change of obliquity and the presence of weak radial ornament on the inner surface of flank. But the former is distinct from the latter in its convex anterior margin, somewhat posteriorly placed umbo, crowded concentric ribs which are sharp-topped and regular in size and strength, and simple ratio of  $L/H$  ranging 0.6–0.9.

*Phylogenetic relationship.*—Various species of *Mytiloides* with elongated outline morphologically resemble the present form. According to Kauffman (1977a, 1978a), the characteristic species of *Mytiloides* are, in ascending order, *M. submytiloides* (lowest part of the Lower Turonian), *M. opalensis* (lower part), *M. mytiloides* (middle part), *M. labiatus* (upper part), and broad form of *Mytiloides* becomes predominant in the lower part of the Middle Turonian. On the other hand, the species of elongated type from the Upper Turonian are *M. striatoconcentricus* aff. *carpathicus*, *M. labiatoidiformis* and *M. mytiloidiformis*, and further upward, from the Lower Coniacian, *M. sublabiatus*.

The species with elongated form from the Upper Turonian may be related to one of the species of the Lower Turonian. As another alternative, they are not derived from a common ancestor but of polyphyletic origin. The similarity may be caused from a similar mode of life as Matsumoto (1959) suggested.

#### Geological range of *Mytiloides incertus*

Nagao and Matsumoto (1940) recorded the stratigraphic position of *M. incertus* as the lowest part of the Upper Ammonite beds in the Pombets area, and Matsumoto (1959) regarded it as representing the upper part of the Upper Gyliakian (approximately Upper Turonian in international scale). Nevertheless, Kauffman (1977a) interpreted that the so-called "*M. incertus*" consists of several heterogeneous species, and they may

Table 9. Student's *t*-test for selected characters of *M. labiatus* and the specimen GK.H10130 from Hokkaido.

		$\alpha$	$\gamma$	$\delta$	$l/h$	$L/H$	$HL/h$	$HL/l$
<i>M. labiatus</i>	N	5	5	5	5	5	5	5
	m	114.0°	155.0°	36.4°	1.262	0.588	0.572	0.458
	s	4.18	5.65	5.59	0.0730	0.1010	0.0656	0.0707
GK.H10130		110°	160°	60°	0.73	0.50	0.21	0.28
<i>t</i>		0.874	0.807	3.854	6.652	0.795	5.038	2.298
significancy		○	○	●	●	○	●	▲

range from the Lower Turonian to possibly the Middle Coniacian. Matsumoto et al. (1981) examined the associated species of ammonites from locs. 2014-2012 in ascending order, with the result that the whole sequence comprising these localities belongs to the Upper Turonian. The ammonites include such excellent indices as *Subprionocyclus neptuni* (Geinitz), *S. normalis* (Anderson) from loc. Ik2014, *Reesidites minimus* (Hayasaka et Fukada) from loc. Ik2012, *Lymaniceras planulatum* Matsumoto, *Prionocyclus aberrans* Matsumoto from locs. Ik2014–2012 and *P. novimexicanus* (Marcow) from loc. Ik2012. Loc. Ik2011, shown in text-fig. 2 of Matsumoto et al. (1981) should be read as 2011a' as corrected by Matsumoto and Noda (1983, fig. 1). The three specimens recorded in Matsumoto et al. (1981, table 2) were obtained in talus probably originate from c bed of Ik2011, as is shown in Text-fig. 2b. Eleven specimens examined in this study are all collected by Matsumoto from the c bed of the same locality. Matsumoto et al. (1981) pointed out the uppermost shaly layer of about 5 m in thickness (loc. Ik2011a), which is below the unconformably overlying Tertiary, is referred to the Lower Coniacian on the basis of the occurrence of *I. uwajimensis* Yehara (younger shell), *Didymotis akamatsui* (Yehara) and *Baculites* cf. *yokoyamai* Tokunaga et Shimizu.

Meanwhile, the definition on the Turonian-Coniacian boundary and also that of the subdivisions of the Turonian are not always agreeable among authors. For example, the German scale had long been used in a different way from

the international one, until it was corrected by Seibertz (1979). We should take these points into consideration in reading the German papers published before 1980. As a matter-of-course, Tröger (1981) corrected his previous paper (1967), but his 1981 scheme is not exactly the same as Seibertz's (1979).

To sum up, the lower part of the Upper Turonian in the sense before 1979 corresponds to the Upper Turonian and the upper part of the Upper Turonian in the same sense to the Lower Coniacian.

According to Tröger (1981), *M. fiegei* ranges throughout the Upper Turonian and barely persists to the Lower Coniacian, and *M. mytiloidiformis* is common in the lower part of the Upper Turonian and a few individuals survived to the Lower Coniacian. According to the precise data of Keller (1982), *M. fiegei* occurs in the Upper Turonian only.

In this paper, I regard *M. fiegei fiegei* (Tröger) as a junior synonym of *M. incertus* (Jimbo) and *M. fiegei mytiloidiformis* as an independent species. The stratigraphic occurrence of these species based on corrected scheme of Tröger (1981) in Germany are quite in harmony with those in Hokkaido.

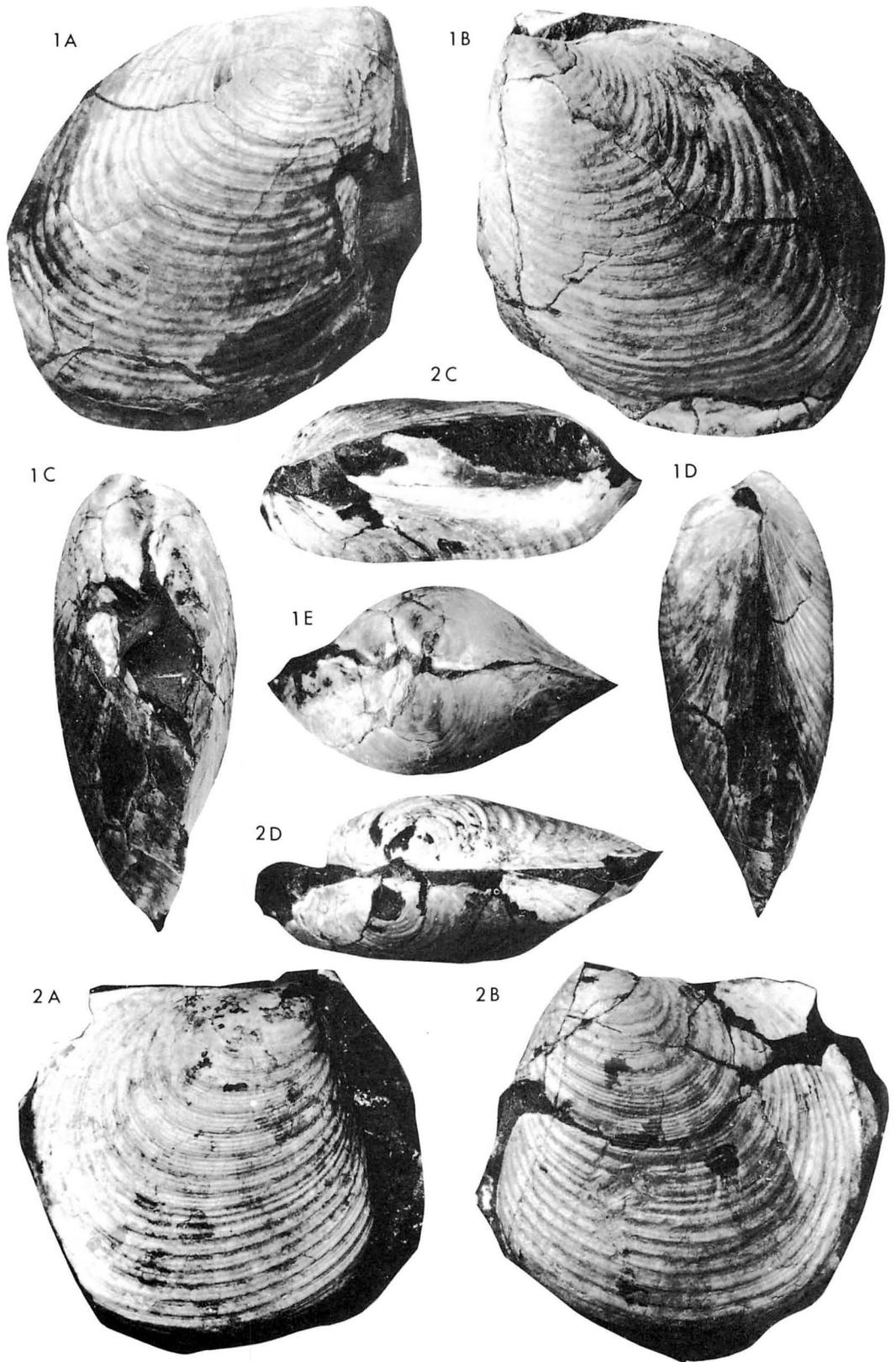
Moreover, *M. fiegei* [= *M. incertus*] or *M. aff. fiegei* occurs from various region of the world such as central Europe (Keller, 1982; Tröger, 1967), the Western Interior of North America (Kauffman et al., 1978), Afghanistan (Sornay, 1974) and Brazil (?). It characterizes the sequence of the Upper Turonian. It can be evaluated as one of the widespread indices of the Upper Turonian.

#### Explanation of Plate 85

(All figures natural size)

Figs. 1, 2. *Mytiloides incertus* (Jimbo)

1. TTC0001. closed valves. An extreme form with oval outline, concentric ribs crowded and concentric rings inconspicuous. Loc. Ik2013 (coll. Takemi Takahashi, 1978) A: lateral view of the right valve, B: lateral view of the left valve, C: anterior view, D: posterior view, E: dorsal view
2. TTC0002. closed valves. An extreme form with subquadrate outline. Loc. Ik2013 (coll. T. Takahashi, 1978) A: lateral view of the right valve, B: lateral view of the left valve, C: posterior view showing the abrupt change of shell convexity, D: dorsal view



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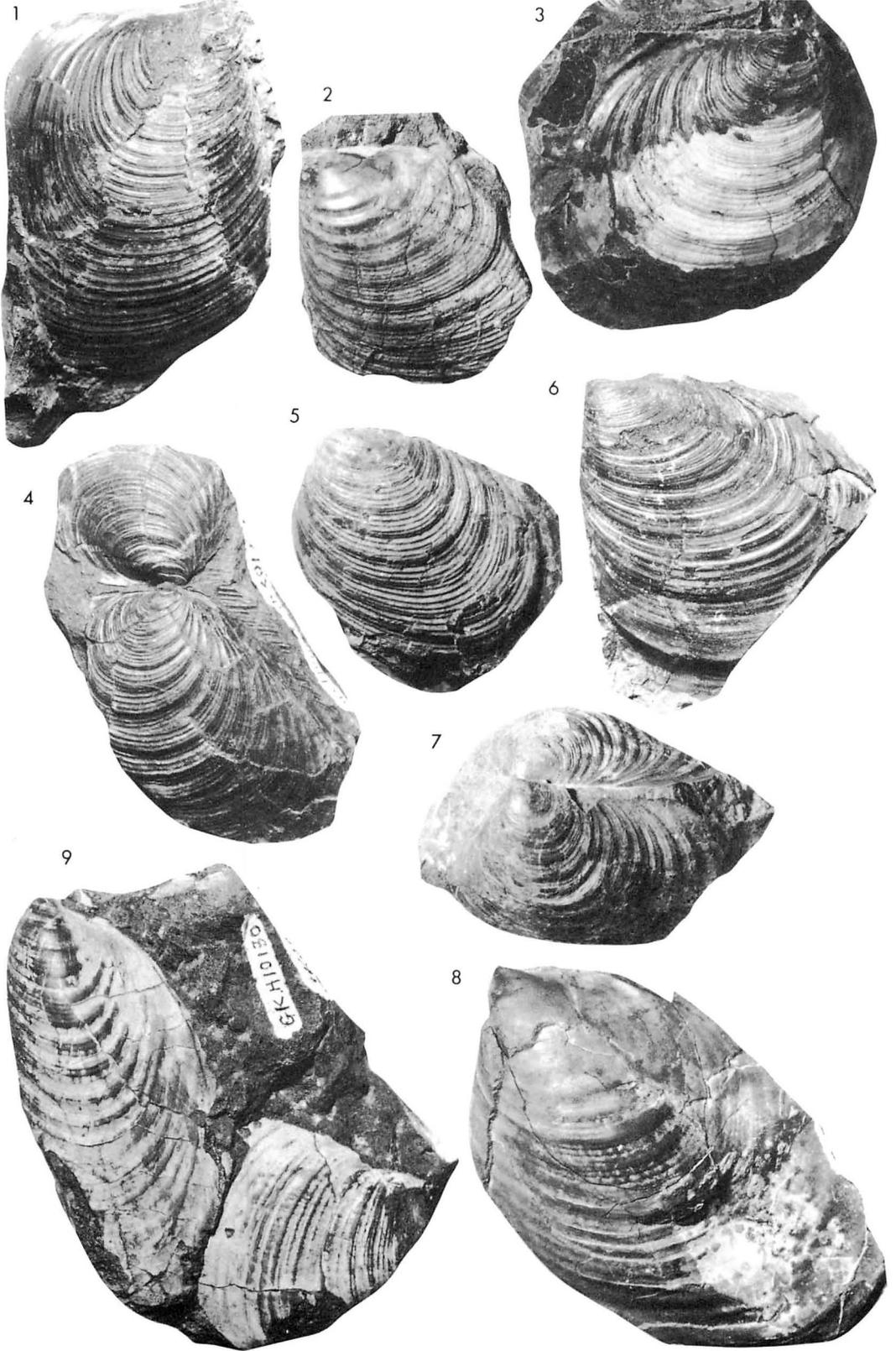
### Explanation of Plate 86

(All figures natural size)

Figs. 1-8, *Mytiloides incertus* (Jimbo)

1. JG.H2852, closed valves. Loc. Ik2013 (coll. M. Noda, 1980)
2. GK.H10094, closed valves. Loc. Ik2013d (coll. T. Matsumoto)
3. JG.H2853, right valve. Loc. Ik2013 (coll. M. Noda, 1980)
4. GK.H10112, articulate valves. Loc. Ik2013 (coll. T. Matsumoto)
5. GK.H10123, closed valves. Loc. Ik2013 (coll. T. Matsumoto)
6. GK.H10118, closed valves. Loc. Ik2013g (coll. T. Matsumoto)
7. GK.H10111, articulate valves. Loc. Ik2011c (coll. T. Matsumoto)
8. GK.H10121, internal mould of closed valves. Loc. Ik2013 (coll. T. Matsumoto)

Fig 9. *Mytiloides* sp. aff. *M. mytiloidiformis* (Tröger) GK.H10130, left valve. Loc. Ik2014 (coll. T. Matsumoto)



Doganaro 堂ヶ奈路, Horomui 幌向, Ikushumbets 幾春別, Iwamizawa 岩見沢, Jonan 城南, Kagami-machi 香我美町, Kami-gun 香美郡, Kamihobets 上穂別, Mikasa 三笠, Minamioita 南大分, Pombets 奔別, Uwagumi 上組

北海道奔別地域チューロニアン上部産の *Mytiloides incertus* について: 本論では *Inoceramus incertus* Jimbo, 1984 について従来の研究方法に加えて生物測定学的見地から, また, 化石層序学的見地から再検討した。まず, 奔別地域の各露頭からのサンプルに対して, カイ2乗検定によって各形質について正規分布の認定を行い, あらためて種の定義づけをした。次にいくつかの形質について, その変異を数量的に明らかにした。さいごに該種の化石層序学的意義について論及した。その概要は次のようである。

1. 従来, *Inoceramus incertus* Jimbo とされていたものは *Mytiloides incertus* (Jimbo) と呼ぶべきである。これまで *I. incertus* といわれていた奔別産の標本の大部分は *M. incertus* でよく, 形, 表面装飾ともかなり大きい変異を示す。また上位の層準のサンプルほど変異が大きくなる。

2. 種の定義づけについては本文 (p. 459) を見よ。

3. 産地 Ik2014 から産出した *Mytiloides* の標本の中には明らかに *M. incertus* の変異のうちとは認められないものがある。これは *Mytiloides* sp. aff. *M. mytiloidiformis* (Tröger) ともいうべきものである。

4. “*M. fiegei* (Tröger)” とか “*M. aff. fiegei*” とか呼ばれているものが世界のいろいろな地域のチューロニアン上部から報告されている。本研究の計測にもとづく形質の数量的な解析や, その他の検討から *M. fiegei* (Tröger), 1967 は恐らく *M. incertus* の新参シノニムと見なされる。したがって, *M. incertus* はチューロニアン上部を特徴づける広い地域にわたる有効な帯指示化石といえる。

野田雅之

788. A MIDDLE DEVONIAN TRILOBITE FAUNA FROM THE KITAKAMI MOUNTAINS. NORTHEAST JAPAN -- I. THE LICHIDAE\*

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**Abstract.** A trilobite fauna has been discovered from the Middle Devonian Nakazato Formation in the southern part of the Kitakami Mountains in northeastern Honshu, Japan. The fauna is composed of lichid, scutellid, dechenellid, calymenid, phacopid, dalmanitid and odontopleurid trilobites from the Higuchi-zawa and Ohmori-zawa, Hikoroichi-cho, Ofunato City, Iwate Prefecture. The purpose of the present paper is to give a description of the trilobites from the Higuchi-zawa locality of the fauna. A new lichid genus *Nipponarges* gen. nov. and its type-species *Nipponarges mediosulcatus*, gen. et sp. nov. and a new lichid species *Acanthopyge* (*Acanthopyge*) *duplicispinata*, sp. nov. are proposed in this part.

*Thysanopeltella paucispinosa* (Okubo, 1951) and *Dechenella* (*Dechenella*) *minima* (Okubo, 1951), which had been previously considered to be reliable fossil evidences of the Eifelian in the Ohmori-zawa and of the Givetian in the Higuchi-zawa respectively, co-exist at the Higuchi-zawa locality. In the present state of knowledge it is only *Thysanopeltella* Kobayashi 1957 that can be used as an age indicator of this trilobite fauna. Therefore, the geological age of the fauna may be Eifelian.

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### Introduction

Until recently, only a few Devonian species of trilobites had been reported from the Kitakami Mountains in northeastern part of Honshu, Japan.

In the Devonian System in the Kitakami Mountains, most of trilobites have been reported from the Middle Devonian formation named the Nakazato Formation by Yabe and Sugiyama in their preliminary note (1937).

In 1941, Sugiyama and Okano described the first discovery of *Phacops* (s. s.) sp. indet. on

the basis of a fragmental cephalon and a left eye from the southwestern slope of Takainariyama, Hikoroichi-cho, Ofunato City, and then Sugiyama (1944) gave it a new specific name *Phacops* (s. s.) *okanoi*. Their locality has been called the "Phacops Zone", but its stratigraphic horizon is uncertain. The author considers that the locality may be situated near the Kuronbora at the middle part of the Ohmori-zawa, Hikoroichi-cho, Ofunato City, where *Bronteus* (*Thysanopeltis*) *paucispinosa* was newly documented on the basis of a pygidium by Okubo (1951). According to Okubo (1950), the *paucispinosa*-bearing horizon belongs to his 49 bed in the upper part of the Middle Devonian III Group of his Takainari System, which corresponds to

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\* Received October 8, 1983.

\* J.T.A.F. (Studies on Japanese Trilobites and Associated Fossils) contrib. no. 28.

the Nakazato Formation of Yabe and Sugiyama (1937). At the same time, Okubo (1951) also proposed a new species *Dechenella minima* on the basis of a cranidium from the middle part of the Higuchi-zawa, Hikoroichi-cho, Ofunato City and pointed out an occurrence of *Phacops* (s. s.) differing from *Phacops okanoi*. In 1956, Okubo described a new species *Phacops nonakai* on the basis of a cephalo-thorax and two cranidia from the Higuchi-zawa locality.

The above-mentioned four species of trilobites have been reported from the Devonian System in the Kitakami Mountains. The stratigraphic horizon at which these Devonian trilobites occurred can be assigned to the Middle Devonian Nakazato Formation.

In 1957, Kobayashi redescribed Okubo's (1956) specimens. Namely Kobayashi assigned *Bronteus* (*Thysanopeltis*) *paucispinosa* to his new subgenus *Thysanopeltella* within the genus *Scutellum* (i.e. a senior synonym of *Bronteus*) and *Dechenella minima* to the subgenus *Dechenella* (*Dechenella*) Kayser, 1880. Kobayashi regarded the former as Couvinian in age or thereabout and the latter as Givetian in age because in Europe *Thysanopeltella* occurs only in the Eifelian Stage and the subgenus *Dechenella* (*Dechenella*) in the Givetian Stage.

In 1974, Kobayashi and Hamada assigned *Scutellum* (*Thysanopeltella*) *paucispinosa* (Okubo) to the subgenus *Thysanopeltella* (*Septimopeltis*) Přibyl & Vaněk 1971.

In 1977, Kobayashi and Hamada have regarded the geological age of *Thysanopeltella* (*Septimopeltis*) *paucispinosa* (Okubo) as Eifelian because the subgenus occurs only in the Eifelian in Bohemia, and at the same time they transferred *Phacops nonakai* Okubo to the genus *Reedops* R. & E. Richter, 1925.

Recently, judging from the faunal assemblage of corals and brachiopods, Minato *et al.* (1979) also pointed out that the *Calceola*-bearing horizon at the Ohmori-zawa locality, from which they reported an occurrence of fragmental trilobites such as lichid, scutellid, dalmanitid and phacopid, can be regarded as Late Couvinian and the fossiliferous horizon at the Higuchi-zawa

locality as Givetian. According to their opinion, "The forms from Loc. A (i.e. the Ohmori-zawa locality) may be Couvinian, since they include *Calceola*, "Favosites" of *polymorphus* group and *Heliolites* ex. gr. *porosus*, all with "Eifelian" affinities. However, it also carries *Macgeea*, which is normally Givetian-Frasnian in age. Also commonly Givetian, *Chascothyris* is found amongst the brachiopods from Loc. A. ... (several passages omitted)... Fossils from Loc. B in Higuchi-zawa contain the Givetian *Dechenella* (M. Okubo, 1951) and *Undispirifer* (*Nakazatothyris*) which closely resembles an "Eifelian" to Givetian form from the USSR (M. Minato and M. Kato, 1978). The fossil horizon at Loc. B may thus be Givetian." Minato *et al.* (1979) introduced Haga's stratigraphic subdivision of the Nakazato Formation into four members, the third named N3 which contains the fossiliferous horizons at the Ohmori-zawa and Higuchi-zawa.

In the early summer of 1980, the author discovered a trilobite-bearing fossiliferous horizon at a small tributary of the Higuchi-zawa, Hikoroichi-cho, Ofunato City, Iwate Prefecture. The horizon is composed of fine-grained sandstone with tuffaceous intercalations and can be assigned to the Middle Devonian Nakazato Formation and Haga's N3 member. The locality may be the same as that from which Okubo reported the occurrence of *Dechenella minima* in 1951 and *Phacops nonakai* in 1956. The author's painstaking fossil hunting at that locality resulted in a discovery of various kinds of trilobites. They belong to the Lichidae, Scutellidae, Dechenellidae, Calymenidae, Phacopidae, Dalmanitidae, Odontopleuridae and so on. In addition to this trilobite fauna, various kinds of brachiopods including atrypoids, gastropods, tabulate and rugose corals including *Calceola* sp., orthocone cephalopods and plants are also abundantly represented. *Dechenella* (*Dechenella*) *minima* (Okubo) and *Thysanopeltella paucispinosa* (Okubo), which consists not only of the pygidium but also of the cranidium and librigena, co-exist at the above-mentioned locality. Therefore, both horizons at the Higuchi-zawa locality and Ohmori-zawa locality can be considered to

be synchronous.

The subgenus *Dechenella* (*Dechenella*) can be no longer used as an indicator of Givetian age because Ormiston (1967) has described several species of the subgenus from the Eifelian Blue Fiord Formation in the Canadian Arctic. Furthermore, according to Ochs and Wolfart (1961), the subgenus *Dechenella* (*Dechenella*) has been discovered even from the Upper Eifelian of the Eifel district of Germany. The other members of the present Devonian trilobite fauna except *Thysanopeltella* are either endemic or long-ranging, so it is difficult to use them as indicators of geological age. On the other hand, since the genus *Thysanopeltella* has been never known from strata younger than the Upper Eifelian in the European succession, it is safe to say that the geological age of the present Devonian trilobite fauna may be no younger than late Eifelian.

Very recently, Copper, Tazawa, Mori and Kato (1982) have come to a similar conclusion on the basis of their study of the atrypoid brachiopods from Haga's N3 member of the Nakazato Formation. They have pointed out that the *Atrypa*-bearing bed of the Higuchi-zawa (i.e. the *minima* horizon *sensu* Kobayashi and Hamada (1977, p. 11)) is correlatable to that of the Ohmori-zawa (i.e. the *paucispinosa* horizon) since *Atrypa pauciplicata* Okubo, 1956 from the Higuchi-zawa could be regarded as a junior synonym of *Atrypa desquamata* mut. *japonica* Sugiyama, 1942 from the Ohmori-zawa. Those authors assigned them to the subgenus *Atrypa* (*Planatrypa*) and suggested that it is quite possible for the Japanese species to be a junior synonym of *Atrypa* (*Planatrypa*) *squamifera* from the Upper Eifelian of the Eifel district of Germany and that at least the N3 member of the Nakazato Formation is middle to late Eifelian in age because of the *Atrypa* (*Planatrypa*) never ranging into Givetian.

The Kitakami Devonian trilobite fauna shows a considerable degree of endemism at the generic level. As for the Japanese Devonian trilobite faunas, there are no correlative elements at the generic level with the exception of the genus *Acanthopyge* (s. l.), which is almost cosmo-

politan, between the Kitakami Devonian trilobite fauna and the Hida Devonian trilobite fauna described by Kobayashi and Hamada (1977) from the Fukuji Formation and its equivalents in the Hida Massif in central Honshu. The age of the Fukuji Formation was considered to be Gedinnian to Eifelian or probably lower Eifelian by Kobayashi and Hamada (1977) or to be Siegenian to Emsian by Copper *et al.* (1982).

At the familial level, the Kitakami Devonian trilobite fauna is most remarkably different from the Hida Devonian trilobite fauna in being dominated by Phacopidae and Dechenellidae, whose representatives are much more numerous than all other faunal members of the trilobites. The Hida Devonian trilobite fauna has no elements of the Phacopidae and Dechenellidae. Furthermore, the former trilobite fauna commonly also contains Dalmanitidae, but lacks Cheiruridae. By contrast, the latter trilobite fauna lacks Dalmanitidae, but contains Cheiruridae frequently. Calymenidae are common to the two faunas, but the two calymenids belong to different subfamilies proposed by Siveter (1977). The calymenid from the Kitakami Mountains shows evidently the papillate-butress structure on the cranium typical of the subfamily Calymeninae (s. s.), while that from the Hida Massif shows the absence of that structure typical of the subfamily Flexicalymeninae.

Kobayashi and Hamada (1977) described flexicalymenids from the Hida Devonian trilobite fauna as *Gravicalymene yamakoshii* and pointed out that their new species is very closely allied to *Gravicalymene maloungaensis* (Mansuy), which is widely distributed in South China, north Viet-Nam and possibly East Burma (p. 131). The above-mentioned two species are closely allied to *Gravicalymene zhenzishanensis* Nan, 1980 from the Givetian (D<sub>2</sub>) Heitai Formation at Heitai near Mishan near the northwestern shore of Lake Hsingkai (= Khanka), Northeast China. These Devonian species of *Gravicalymene* evidently show that these faunas can be correlated to one another. Chatterton and Campbell (1980) proposed to apply their new generic name *Apocalymene* to the post-Ordovician species of

*Gravicalymene* from Australia, Morocco and Turkey. Chatterton *et al.* (1979) suggested the East to Southeast Asian species of the Devonian *Gravicalymene* to be assignable to *Apocalymene*.

The Kitakami Middle Devonian trilobite fauna can not be considered to be descended from the Hida Lower Devonian trilobite fauna, which, on the other hand, may possibly be one of the ancestors of the Heitai Givetian fauna.

### Systematic Palaeontology

Family Lichidae Hawle & Corda, 1847

Subfamily Ceratarginae Tripp, 1957

Genus *Nipponarges* Kaneko, gen. nov.

*Derivation of name:* *Nippon* = Japan + an invalid trilobite name *Arges* Goldfuss, 1839, which was replaced by *Ceratarges* Gürich, 1901 as a junior homonym of *Arges* DeHaan, 1835 in the Crustacea from Japan.

*Type-species:* *Nipponarges mediusulcatus* Kaneko, gen. et sp. nov. from the Middle Devonian (probably Eifelian) Nakazato Formation in the southern part of the Kitakami Mountains, northeastern Japan.

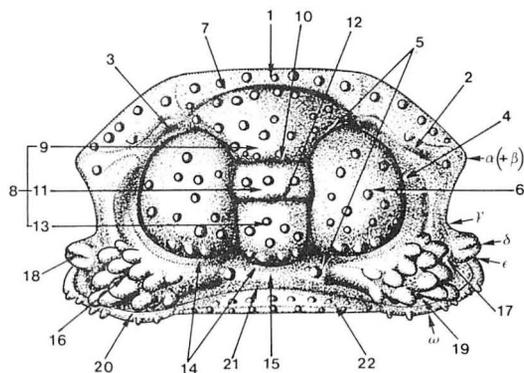
*Species assigned:* Presently only the type-species is known.

*Generic diagnosis:* A large ceratarginid with 2p and 3p transglabellar furrows clearly defined on median glabellar lobe. Cranium vaulted, with a median glabellar lobe which consists of frontal and 2p and 3p glabellar lobes, a pair of bullar lobes and a pair of posterolateral cranial lobes, which are all circumscribed. Frontal glabellar lobe weakly inflated, much wider (trans.) than long, expanding in front of bullar lobe. Bullar lobe subreniform in outline, weakly inflated, much wider (trans.) than central area of median glabellar lobe. Posterolateral cranial lobe short (exsag.), highly inflated with a very steep slope, slightly overhanging surrounding furrows anteriorly and posteriorly, bearing closely spaced, thick, obtusely spinose tubercles. Preoccipital depressed area clearly defined, very profound, transversely elongate, with a pair of

tubercles. Palpebral lobe relatively small, mesially furrowed. Anterior border almost flat, short (sag.) medially, but well-developed anterolaterally. Anterior pit in front of anterolateral corner of bullar lobe. Occipital ring relatively narrow (sag. and exsag.) moderately arched transversely, widest (sag.) medially, narrowing (exsag.) laterally, with very steep anterior slope, bearing two rows of tubercles; one on anterior slope, the other on the crest. Librigena unknown. Hypostome unknown.

Thorax unknown.

Pygidium strongly spinose on margin, with no marginal border. Axis strongly inflated, bluntly rounded off in posterior, gently tapering anteriorly along elongate (exsag.) adaxial margin of second pleural segment to in front of second ring furrow, with extremely thickened, short, obtuse spines posterolaterally. First axial ring strongly convex, with vertical posterior slope. Second axial ring moderately inflated laterally.



Text-fig. 1. Diagram of morphological terminology of ceratarginid cranium. (1) anterior border, (2) anterior border furrow, (3) anterior pit, (4) axial furrow, (5) longitudinal furrow, (6) bullar lobe, (7) preglabellar furrow, (8) median glabellar lobe ((9)+(11)+(13)), (9) frontal glabellar lobe, (10) 3p transglabellar furrow, (11) 3p glabellar lobe, (12) 2p transglabellar furrow, (13) 2p glabellar lobe, (14) 1p glabellar furrow, (15) preoccipital depressed area, (16) posterolateral cranial lobe, (17) palpebral furrow, (18) palpebral lobe, (19) posterior border furrow, (20) posterior border, (21) occipital furrow, (22) occipital ring

Pleural region elongate (exsag.), at least with three pairs of pleural segments and cylindrical marginal spines. First two pleural segments subdivided by pleural furrows into two bands, the posterior ones of which are massive and continue into spines laterally. Pygidial surface coarsely tuberculose.

*Discussion:* On the basis of the observation of the ontogenic development of "bicomposite lobes" *sensu* Reed (1902, p. 66) of three taxonomically diverse lichid species, *Lichas laciniatus* (Wahlenberg, 1818), *Acanthopyge (Mephiarges) bifida* Edgell, 1955 and *Amphilichas minganensis* (Billings, 1865) shown by Temple (1969), Chatterton (1971) and Shaw (1968) respectively, Temple (1972, pp. 373-374) pointed out that they are not bicomposite in origin, i.e. they are not formed by the fusion of 2p and 3p lateral glabellar lobes and by backward prolongation of the inner ends of the 3p glabellar furrows, and so proposed the term *bullae* for the rudimentary swelling in axial furrow on its adaxial side opposite the 2p glabellar lobe in the early lichid growth stage and the term *bullar lobe*, instead of "bicomposite lobe", for the forwardly grown-up lobe along the side of the glabella. According to his interpretation of lichid morphology, the 2p and 3p glabellar furrows are present only on the median glabellar lobe. Temple (1969, pp. 213-214, Text-fig. 2a, pl. 2, fig. 11) showed that in the earliest known (presumably meraspid) growth stage of *Lichas laciniatus* the median glabellar lobe bears the 2p transglabellar and 3p lateral glabellar furrows. And then Chatterton (1971, pp. 34-35, fig. 9B) showed that in the early metaprotaspid stage of *Acanthopyge (Mephiarges) bifida* the glabella without the bulla, which corresponds with the median glabellar lobe in the later growth stage, bears the 2p and 3p transglabellar furrows. Recently Tripp and Evitt (1981, pp. 667, fig. 1a) also showed that in the early metaprotaspid stage of *Hemiarges turneri rasetti* Tripp & Evitt, 1981 two (2p and 3p) lateral glabellar furrows are occasionally indicated. These furrows are usually lost during the ontogeny in the family Lichidae. Therefore, *Nipponarges* gen. nov. can

be easily distinguished from all other members of the family Lichidae by the presence of the clearly defined 2p and 3p transglabellar furrows on the median glabellar lobe. In the basic structural pattern of lobation of the glabella and the presence of the clearly defined preoccipital depressed area with a pair of tubercles at the base of the median glabellar lobe, *Nipponarges* is comparable with some genera in the subfamily Ceratarginae Tripp, 1957.

The basic morphology of the genus *Nipponarges* gen. nov. is most similar to that of the Middle Silurian to Middle Devonian genus *Acanthopyge* Hawle & Corda, 1847, which is geographically wide-spread. However, there are several distinctive features of generic importance in addition to 2p and 3p transglabellar furrows on the median glabellar lobe, which are as follows: 1) a much less inflated frontal glabellar lobe; 2) extremely wider (trans.) bullar lobe than the central area of the median glabellar lobe; 3) much more highly inflated, exsagittally shortened posterolateral cranial lobe with closely spaced, prominent, obtusely spinose tubercles; 4) relatively well-developed anterior border; 5) more anteriorly situated anterior pit; 6) relatively small palpebral lobe which is strongly furrowed mesially; 7) more strongly inflated, massive posterior bands of the first two pleural segments whose distal extensions form conspicuous, cylindrical spines; 8) much more elongate (exsag.) adaxial margin of second pleural segment; 9) conspicuous, short, obtuse spines on the pygidial axis.

In so far as the massiveness of the pleural segments including the cylindrical marginal spines of the pygidium and the large size for a ceratarginid are concerned, *Nipponarges* gen. nov. is similar to the Lower to Middle Devonian genus *Terranovia* Maximova, 1977 from Novaya Zemlya and Salair of U.S.S.R. and the Canadian Arctic rather than *Acanthopyge*. However, in *Nipponarges* the first two pleural segments are inclined more posteriorly and the second pleural segment, of which adaxial margin is extremely elongate (exsag.), widens more rapidly laterally and is subdivided into two bands by the pleural

furrow except its anteroadaxial portion. Furthermore, in *Terranovia*, according to Ormiston (1982), the cranidium bears two conspicuous pairs of upwardly and backwardly directed spines, instead of the transglabellar furrows, on the median glabellar lobe and the pygidium bears two pairs of upwardly directed pleural spines, and there is a transverse union of posterolateral cranial lobes, instead of the preoccipital depressed area, a character typical of *Acanthopyge*, *Nipponarges* and some of other ceratarginids, at the base of the median glabellar lobe as in the case of *Ceratarges* Gürich, 1901 from the Lower to Middle Devonian of Germany and France; the median and bullar lobes are a little more inflated, but the posterolateral cranial lobe is much less inflated than those of *Nipponarges*.

*Radiolichas* Reed, 1923 from the Middle Devonian of Germany is more similar to *Nipponarges* gen. nov. than *Terranovia* in the weak inflation of the frontal glabellar lobe, in the extreme development of the bullar lobe, in the clearly defined, transversely elongate preoccipital depressed area with a pair of tubercles and in the inclination of the first two pleural segments of the pygidium. However, *Radiolichas* has no transglabellar furrows on the median glabellar lobe, but has much less inflated and more laterally situated posterolateral cranial lobe and the oar-shaped pygidial marginal spine which is mesially furrowed.

At first glance, the pygidium of the *Nipponarges* gen. nov. looks similar to that of the monotypic genus *Terataspis* Hall, 1863 in the subfamily Lichinae on the basis of *Lichas grandis* Hall, 1861 from the Emsian Schoharie Formation and its equivalent in New York State, U.S.A. in the strong spinosity on margin and in the large size (Hall and Clarke (1888), pp. 73–77, pls. 17–19). However, *Nipponarges* has exsagittally more elongate pleural region as in the case of *Acanthopyge* and *Radiolichas* in the subfamily Ceratarginae than *Terataspis*, and has the conspicuous, short, obtuse spines on the axis, whose analogues can be seen in *Acanthopyge*, for example, such as *Acanthopyge consanguinea* (Hall, 1894) illustrated by Whittington (1956,

p. 1203, pl. 131, figs. 14–17, 19), *Acanthopyge* (*Mephiarges*) *bifida* Edgell, 1955 illustrated by Chatterton (1971, p. 34, pl. 6, figs. 19–20, 22) and *Acanthopyge* (*Acanthopyge*) *duplicispinata* sp. nov. (p. 481, Pl. 89, Figs. 3a–c) and in *Terranovia* illustrated by Ormiston (1982, p. 1264, pl. 2, figs. 1–4, 10). Ormiston (1982) assigned the pygidium which Corgan (1963) reported as *Terataspis* sp. indet. from the Lower Devonian (Onesquethawan) in the Canadian Arctic to the genus *Terranovia* and regarded it as conspecific with its type-species *Terranovia naliukini* Maximova, 1977, and points out that *Terataspis* can be regarded as a genus restricted to the Emsian rocks of eastern North America (personal communication from Dr. A. R. Ormiston, 6 October, 1981).

The author comes to conclusion that the *Nipponarges* morphology was derived from an *Acanthopyge* morphology, probably from the Asian species morphology characterized by a slender median glabellar lobe and a well-developed bullar lobe as discussed below.

*Distribution:* Confined to the Nakazato Formation in northeastern Honshu, Japan.

*Nipponarges mediosulcatus* Kaneko,  
gen. et sp. nov.

Pl. 87, Figs. 1–3, Pl. 88, Figs. 1–4, Text-fig. 2.

*Derivation of name:* From the Latin words *medius*, median + *sulcus*, furrow.

*Holotype:* Incomplete cranidium, KAC-DT0101 [PA17144] (Pl. 87, Figs. 1a–c, Pl. 88, Figs. 1a–e), coll. A. Kaneko, 1980.

*Specific diagnosis:* As for the genus.

*Description:* Two pieces of the holotype cranidium are orientated in due consideration of both a plane of cleavage of matrix and ceratarginid morphology: Cranidium moderately vaulted; anterior outline straight in front of anterior pits, and then directed posterolaterally from each of anterior pits at an angle of about 60 degrees from sagittal line. Median glabellar lobe with 2p and 3p transglabellar furrows; frontal glabellar lobe slightly inflated, roughly pentagonal in outline, much wider (trans.) than

long, expanding in front of bullar lobe, isolated by 3p transglabellar furrow from semi-cylindrical central area of median glabellar lobe; 3p glabellar lobe rectangular in outline, about three times as long (sag. and exsag.) as wide; 2p glabellar lobe slightly divergent posteriorly and sloping down nearly vertically at its base. Bullar lobe subreniform in outline, slightly inflated, extremely large, much wider (trans.) than central area of median glabellar lobe, sloping down nearly vertically at its posterior end. Posterolateral cranial lobe roughly elongate (trans.) oval in outline, shortening (exsag.) adaxially, much shorter (exsag.) than bullar lobe, expanding strongly dorsolaterally so that its raised portion slightly overhangs surrounding furrows anteriorly and posteriorly. Palpebral lobe short (exsag.), elongate (trans.) oval in outline, directed outward and slightly forward and downward, deeply furrowed mesially, highly elevated with an almost vertical slope except adaxial side which slopes down gently for a short distance to most raised portion of narrow (trans.) palpebral furrow which runs on nearly vertical inflation of fixigenal carapace to form a butress between palpebral lobe and anterolateral corner of posterolateral cranial lobe. 1p glabellar furrow relatively wide (sag. and exsag.); outside longitudinal furrow 1p glabellar furrow diverging anteriorly at an angle of about 60 degrees from sagittal line, deepest and clearly U-shaped at its most raised portion in front of anteroadaxial corner of posterolateral cranial lobe, from which 1p glabellar furrow slopes down steeply anterolaterally to merge axial furrow and slopes down slightly less steeply posteromedially to intersect longitudinal furrow at funnel-shaped, profound concavity behind posteroadaxial corner of bullar lobe; inside longitudinal furrow 1p glabellar furrow shallowing rapidly medially, running in a broad arc along distal end of median glabellar lobe. Longitudinal furrow narrow (trans.), sharply incised in front of 1p glabellar furrow, but represented by change of slope without incised furrow behind 1p glabellar furrow; from concavity to level of 2p transglabellar furrow on median glabellar lobe longitudinal

furrow moderately deep, converging slightly, rising nearly vertically, and then becoming deeper, sloping down gently; beside 3p glabellar lobe longitudinal furrow deep, deflected slightly outward; from level of 3p transglabellar furrow to anterior pit longitudinal furrow becoming progressively shallower, curving more or less sharply outward and downward along anterior margin of bullar lobe; behind 1p glabellar furrow longitudinal furrow rising steeply on posterior slope of concavity for a short distance to adaxial extremity of posterolateral cranial lobe, thereafter merging with occipital furrow. Transglabellar furrows on median glabellar lobe moderately incised, more or less wide (sag. and exsag.), curving downward and forward distally; 2p transglabellar furrow running into abaxial extremity of slight deflection of longitudinal furrow. Preoccipital depressed area clearly defined by 1p glabellar furrow behind median glabellar lobe, elongate transversely, profound, surrounded by steep walls, shortest (sag.) medially, with a pair of distinct, large tubercles on posteroadaxial slopes of concavities; slight swelling continuing adaxially from large tubercle, but narrowing (exsag.) rapidly and dying out medially. Anterior border separated only by preglabellar furrow from frontal glabellar lobe, almost flat, but very slightly inflated transversely inside anterior pit, shortest (sag.) medially, becoming rapidly longer (exsag.) and attaining maximum length in front of, or slightly inside, anterior pit and then shortening as far as  $\alpha (+\beta)$ . Preglabellar furrow weakly incised, curving gently along anterior margin of frontal glabellar lobe. Anterior pit situated in front of anterolateral corner of bullar lobe, profound, relatively large, joining anterior border furrow and preglabellar furrow and axial furrow and longitudinal furrow; on ventral surface anterior pit represented by prominent boss. Anterior border furrow on fixigena wide (exsag.), shallow, rising slightly posterolaterally at an angle of about 80 degrees from sagittal line. Anterior portion of fixigena very broad (trans.), convex behind anterior border; known part of middle portion rising with a very steep slope and progressively

inflated posteriorly between anterior extension of palpebral furrow and axial furrow, running into antero-abaxial corner of posterolateral cranial lobe.

Occipital ring wide (trans.), slender, moderately arched transversely, longest (sag.) medially, narrowing (exsag.) laterally, with very steep anterior slope and almost straight posterior margin. Occipital furrow merging with 1p glabellar furrow medially; behind a pair of tubercles and its adaxial extensions occipital furrow wide (exsag.), shallow; behind posterolateral cranial lobe occipital furrow deep, U-shaped, progressively narrowing laterally. Librigena unknown. Hypostome unknown.

Thorax unknown.

Pygidium strongly spinose on margin, with no marginal border. Axis strongly inflated, bearing extremely prominent, dorsolaterally directed, short, obtuse spines posterolaterally, whose subhorizontal section reveals elliptical outline; articulating half-ring short (sag. and exsag.), separated from first axial ring by change of slope without incised articulating furrow; first axial ring strongly convex, sloping down vertically posteriorly; second axial ring moderately inflated laterally. Axial furrow most deeply excavated in front of first ring furrow, moderately convergent from anterior margin to in front of second ring furrow, thereafter curving out gently. Pleural region except border spines narrow (trans.), considerably elongate (exsag.); first two pleural segments directed posterolaterally, widening (exsag.) rapidly laterally; first pleural segment subdivided by narrow (exsag.), shallow pleural furrow into short (exsag.), slightly convex anterior band and much more highly inflated, longer (exsag.), massive posterior band whose anterior and posterior slope is almost vertical adaxially and whose distal extension forms massive, cylindrical, long (trans.), gently upturned marginal spine; second pleural segment except marginal spine with posterolaterally elongate sub-rhomboid outline resulting from extremely elongate (exsag.) adaxial margin along axial furrow, subdivided by narrow (exsag.), shallow pleural furrow, which becomes shallower

and curves outward distally, into anterior and posterior bands except its anteroadaxial portion which is shorter (exsag.) than posterior band of first pleural segment; anterior band of second pleural segment about as long (exsag.) as posterior band except margin, a little less inflated adaxially but sloping gently away laterally; third pleural segment longitudinally elongate sub-rhomboid in outline, less inflated than the precedings, with massive spine on postermost margin. First interpleural furrow deep, narrow (exsag.), V-shaped, almost parallel with second interpleural furrow, which is less deep and narrow; third interpleural furrow less deep and narrow (exsag.) than the second one, nearly longitudinal.

*Surface ornamentation:* posterolateral cranial lobe and at least postermost portions of median and bullar lobes covered with dense, thick, obtusely spinose tubercles; judging from the plugged tubercle bases on the external mould of the holotype, rest of median and bullar lobes bear the same type as above-mentioned or less prominent, thick tubercles; medium-sized tubercles scattered on anterior border and fixigena and posterior border; occipital ring bearing two rows of medium-sized tubercles, one of which is somewhat spinose and present on the crest, the other of which is present on anterior slope. Small to large, more or less pointed tubercles scattered on pleural region including marginal spine of pygidium; much larger ones on third pleural segment; smaller ones on marginal spine.

Genus *Acanthopyge* Hawle & Corda, 1847

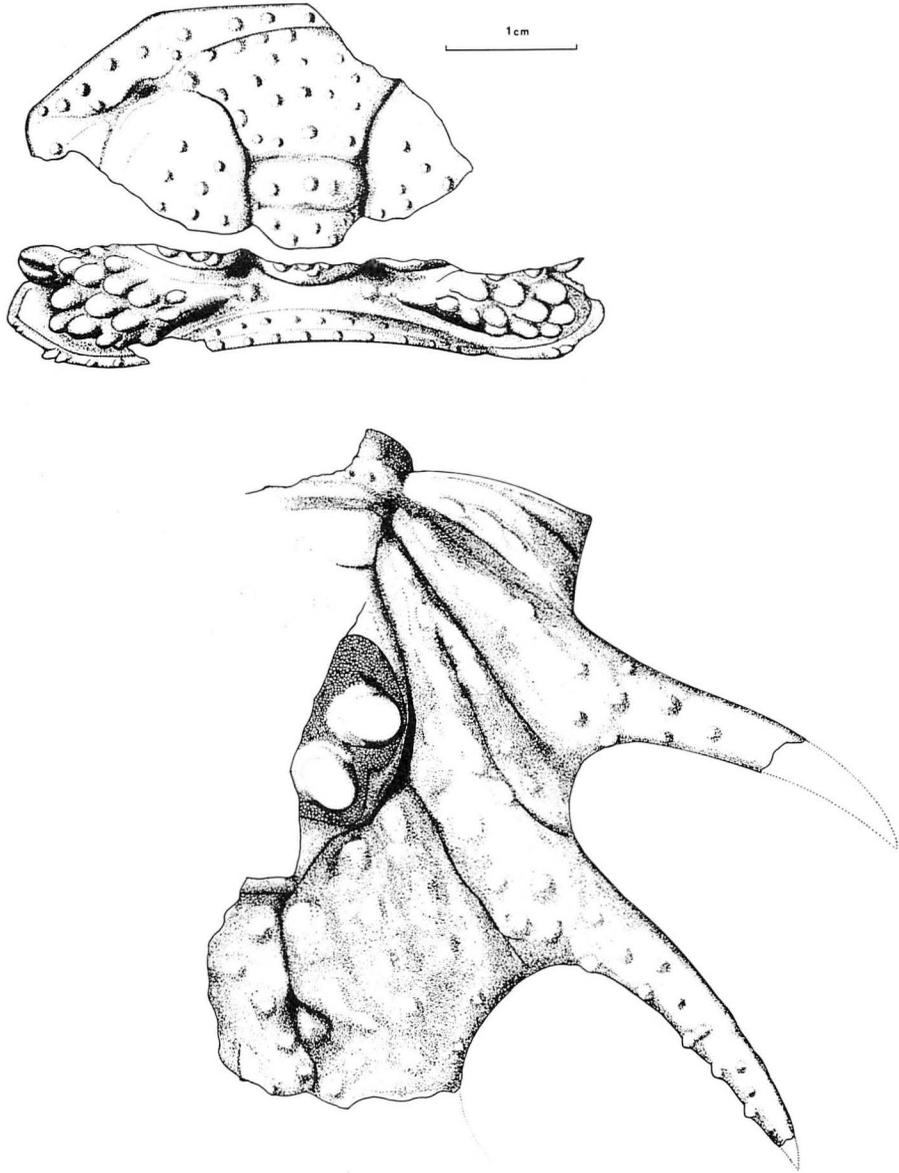
Subgenus *Acanthopyge* Hawle & Corda, 1847

The subgenera of *Acanthopyge* have been discussed recently by Chatterton *et al.* (1979).

*Acanthopyge (Acanthopyge) duplicispinata*  
Kaneko, sp. nov.

Pl. 88, Figs. 5–7, Pl. 89, Figs. 1–3, Text-fig. 3.

*Derivation of name:* From the Latin words *duplex*, paired + *spina*, spine.



Text-fig. 2. Restoration of *Nipponarges mediosulcatus* Kaneko, gen. et sp. nov. Two pieces of the cranidium are slightly differently orientated from Plate 87, Figs. 1a–b.

*Holotype*: Incomplete cranidium, KAC-DT10106 [PA17149] (Pl. 89, Figs. 1a–e), coll. A. Kaneko, 1980.

*Specific diagnosis*: An *Acanthopyge* species with a slender median glabellar lobe flanked by well-developed bullar lobe and with paired

and unpaired, spinose tubercles and spines on cranidium, some of which represent spines 1, 2, 3?, 4, 5, A1 *sensu* Chatterton (1971). Palpebral lobe highly elevated, with rudimentary P1 *sensu* Chatterton. Ventral surface of hypostome apparently smooth. Pygidium strongly spinose on

margin, with no marginal border, and with elongate (exsag.) pleural region, and with well-developed axis.

*Description:* Cranidium vaulted, subtrapezoidal in outline, with a median glabellar lobe, a pair of bullar lobes and a pair of posterolateral cranial lobes, which are all circumscribed. Glabella strongly convex; median glabellar lobe about one-third as wide as (trans.) occipital ring at its base, elongate (sag.), highly arched transversely, rising above and expanding in front of bullar lobe, geniculate anteriorly; bullar lobe roundly subtriangular in outline, moderately convex. Posterolateral cranial lobe roundly subrhomboid in outline, about as long (exsag.) as bullar lobe, strongly inflated, with very steep posterior slope; its anterolateral portion slightly ridging on internal mould, descending very gently from prominent spine pair to palpebral furrow, from bottom of which short (exsag.) palpebral lobe rises vertically above the crest of posterolateral cranial lobe excluding prominent spine pairs (A1). Eye ridge unknown. Longitudinal furrow in front of 1p glabellar furrow slightly converging anteriorly toward the highest point of glabella at about one-third the length (sag.) of median glabellar lobe from its base, and then slightly deflected outward, and then becoming slightly shallower and curving sharply outward and downward to merge preglabellar furrow and axial furrow; longitudinal furrow behind 1p glabellar furrow gently diverging posteriorly to merge with occipital furrow. 1p glabellar furrow directed posteriorly diagonally from axial furrow to in front of anterolateral corner of posterolateral cranial lobe, intersecting longitudinal furrow at profound concavity behind postero-axial corner of bullar lobe, merging with occipital furrow on sagittal line; its adaxial portion outside longitudinal furrow deeply incised, so that posterolateral cranial lobe is completely separated from bullar lobe. Preglabellar and axial furrows lightly incised. Preoccipital depressed area behind median glabellar lobe profound, clearly defined by lightly incised adaxial portion of 1p glabellar furrow, by posterior portion of longitudinal furrow and by occipital furrow,

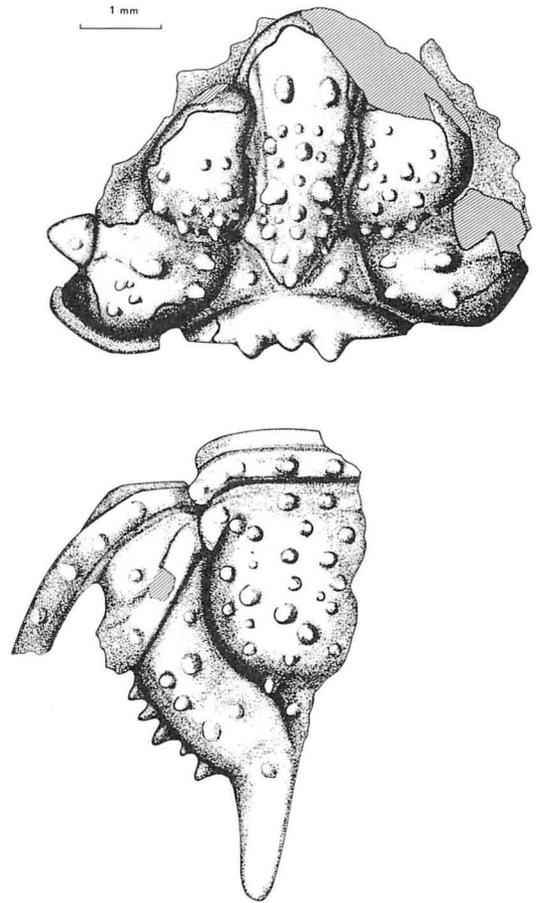
divided into a symmetrical pair of slightly swelling, subtriangular areas by junction of 1p glabellar and occipital furrows on sagittal line. Occipital ring wide (trans.), moderately arched transversely, longest (sag.) medially, shortening (exsag.) abaxially; its posterior margin nearly straight. Librigena unknown. Hypostome subtrapezoidal in outline, about three-quarter as long as wide (trans.); median body gently convex, slightly less than a half of hypostomal length (sag.), a half as long as wide (trans.); median furrow short (exsag.), deep, subtransverse, only incised abaxially in posterior one-third of median body; abaxial portion of posterior lobe of median body slightly inflated to form macula; lateral border furrow deep, wide (trans.), directed posteriorly diagonally to merge deep, short (sag. and exsag.), transverse posterior furrow; anterior wing short (exsag.), directed upward and outward opposite median furrow of median body; posterior border long (sag. and exsag.), wide (trans.), most convex anteromedially; doublure extending beneath lateral and posterior borders; axial one-third of doublure excavated to form an anteriorly deepening pit, whose posterior slope has a pair of elongate (exsag.), narrow (trans.), low ridges.

Thorax unknown.

Pygidium excluding marginal spines semielliptical in outline. First two pleural segments clearly defined except very slightly inflated medial part of second axial ring, transverse medially, flexed posterolaterally near abaxial end of axial ring; flexed part of second axial ring inclined more posteriorly than that of first axial ring. Axis wide (trans.), semi-cylindrical, moderately arched transversely, most convex posteromedially, rounded off abruptly but continued by low, convergent post-axial ridge posteriorly; articulating half-ring short (sag. and exsag.), moderately convex, separated from rest of axis by short (sag. and exsag.), transverse, moderately incised articulating furrow; first axial ring strongly convex, sloping down vertically posteriorly, with narrow (trans.), slightly backwardly flexed adaxial part, only behind which second axial ring moderately inflated; ring

furrows very faint behind medial part of first two axial rings, but becoming distinct behind remainder part of them. Axial furrow distinct, slightly converging posteriorly from anterior margin to in front of second ring furrow, thereafter slightly diverging to posterolateral corner of axis, and then converging in a gentle curve, then flexed backward and converging slightly beside post-axial ridge. Pleural region elongate (exsag.), horizontal; first two pleural segments represented by long (exsag.), strongly convex, posterior pleural band which continues into prominent marginal spine distally; anterior pleural band of first pleural segment short (exsag.), almost flat; anterior pleural band of second pleural segment slightly longer (exsag.) than posterior pleural band, represented by slight swelling between very faint pleural furrow and more distinct interpleural furrow; third pleural segment elongate (exsag.), with prominent, upturned marginal spine at posterior end which very slightly diverges posteriorly and with five, small, irregularly sized spines on posterolateral margin.

*Surface ornamentation:* Most prominent spine pair (A1) upwardly directed on posterolateral cranial lobe behind abaxial extremity of bullar lobe; median glabellar lobe bearing two prominent spine pairs (4, 5); one (4) on the highest point of glabella more prominent than the other at level of anterior extremity of bullar lobe, and small to medium-sized median spinose tubercles in a row on sagittal line; small- to medium-sized spinose tubercles, some of which may have a tendency to be subsymmetrically arranged, scattered on bullar and posterolateral cranial and rest of median glabellar lobes; small spinose tubercle pair present on slight swelling of pre-occipital depressed area; palpebral lobe bearing slight tuberculate swelling (reduced Pl); a medium-sized median spine flanked by a pair of more prominent spines on occipital ring; ventral surface of hypostome apparently smooth, but one specimen (Pl. 88, Figs. 5a-d) showing a few pits on median body; widely to moderately spaced, medium-sized, spinose tubercles, which may be subsymmetrically arranged, scattered



Text-fig. 3. Restoration of *Acanthopyge* (*Acanthopyge*) *duplicispinata* Kaneko, sp. nov.

on pygidial axis, post-axial ridge and pleural region; most prominent ones on most convex posteromedial part of axis.

*Discussion:* *Acanthopyge* species with spinose carapaces are occasionally included in the subgenus *Acanthopyge* (*Mephiarges*) R. & E. Richter, 1930. R. & E. Richter (1917) described a spiny lichid cephalon as *Lichas* (*Euarges*) *mephisto* from the Middle Devonian Crinoiden-Zone at Auburg near Gerolstein in the Eifel region in Germany. In 1930, they proposed for this form a new subgenus *Mephiarges* within the genus *Acanthopyge* Hawle & Corda, 1847, which is a senior synonym of the genus *Euarges* Gürich, 1901, and gave the following diagnosis; "eine *Acanthopyge* mit stacheltragenden Augen und

gelappten Freiwangen (p. 39)". Later Edgell (1955) emended the subgeneric diagnosis when he described *Acanthopyge* (*Mephiarges*) *bifida* from the limestone of the Murrumbidgee Group at Wee Jasper, New South Wales, Australia, which was considered to be lower Middle Devonian (Couvinian). He diagnosed *A. (Mephiarges)* as follows; "An *Acanthopyge* with eyes on spiny stalks, barbed genal spines and spines on the anterior glabellar lobe". Whittington (1956) did not accept Edgell's assignment of the species *bifida* to the subgenus *Mephiarges* and pointed out many similarities to *Arges consanguineus* Clarke, 1894, from the Lower Devonian New Scotland limestone (the Helderberg group) in Albany County in New York State, U.S.A., which he redescribed as an *Acanthopyge* species. On the contrary, in 1971, Chatterton redescribed *Acanthopyge* (*Mephiarges*) *bifida* Edgell from the upper Emsian to probably lower Eifelian Taemas Formation of the Murrumbidgee Group at the Taemas-Cavan area near Yass, New South Wales. He accepted Edgell's emendation of the subgeneric diagnosis and emphasized more similarities between *A. (Mephiarges) bifida* Edgell and *A. consanguinea* (Clarke) than Whittington (1956) did and so suggested that the North American species might belong to the subgenus *Mephiarges* (pp. 40–41). Perry and Chatterton (1976) described a ceratarginid with a spiny cranidium as *Acanthopyge* (*Mephiarges*) sp. from the Emsian Delorme Formation, Mackenzie Mountains, northwestern Canada and considered it to be very closely related to *A. consanguinea*. Kobayashi and Hamada (1977), however, pointed out that there is no link between *A. (M.) bifida* and *A. consanguinea* (p. 52). In 1979, Chatterton, Johnson and Campbell discussed as follows; *Acanthopyge* (*Mephiarges*) *bifida* "has many features in common with *A. consanguinea* (Clarke) and the *Acanthopyge* sp. of Perry and Chatterton (1976), which do not show the distinguishing characteristics of *A. (Mephiarges)*, though they do have an ornament of pits rather than tubercles on the hypostome indicating that the other similarities may not really indicate a relationship as close as has been previously

suggested (Chatterton 1971; Perry and Chatterton 1976). It is nevertheless becoming increasingly difficult to diagnose *A. (Mephiarges)*, whose type species *A. (M.) mephisto* seems to be an extreme form at the end of a range of variation in a number of characters (pp. 819–820)".

Compared with *A. (M.) bifida* Edgell and *A. consanguinea* (Clarke), the present new species has several similarities. They are prominent spine pairs (4, 5) on the median glabellar lobe, prominent spine pair (A1) on the posterolateral cranial lobe, more or less well-developed occipital spines (though median one much less prominent than that of *A. (M.) bifida*), a highly elevated palpebral lobe to buttress the stalk-like eye socle, a relatively large axis of the pygidium, narrow anterior bands on the first two pleural segments and large median tubercles on the posterior portion of the axis of the pygidium. However, in the present new species the palpebral spine (Pl), which is a diagnostic character of *A. (Mephiarges)* and can be observed to some extent in *A. consanguinea*, *A. (M.) bifida* and *A. (Mephiarges)* sp. by Perry and Chatterton (1976), is quite rudimentary, the posterior bands of the first two pleural segments of the pygidium bear no prominent, dorsally directed spine pairs, the median body of the hypostome is neither tuberculate nor pitted, but almost smooth, though one specimen (Pl. 88, Figs. 5a–d) shows a few "pits", which may be attributable to preservation. Furthermore the Japanese species differs from the above-mentioned overseas species in the degrees of development of the median glabellar and bullar lobes. Namely, *A. (A.) duplicispinata* sp. nov. shows a slender median glabellar lobe flanked by well-developed bullar lobes, whereas *A. consanguinea* and *A. (M.) bifida* show a well-developed median glabellar lobe attended by relatively reduced bullar lobes. It is a remarkable fact that the glabellar morphology of a similar type to the present new species can be observed in most Asian (Turkestan including Kazakhstan, the Kuznetsk Basin) species of *Acanthopyge* (s. l.). As opposed to this, in most extra-Asian species with the exceptions such as *Lichas* (*Arges*) *contusus* Hall, 1863

and *Lichas devonianus* Whidborne, 1889 which were compared to the genus *Radiolichas* Reed, 1923 by Reed (1923) and Příbyl and Erben (1952), the glabellar morphology shows a similar type to the above-mentioned, two overseas species.

It should be noted that similar prominent spinose tubercle or spine pairs on the cranium can be observed also in some of lichid genera and subgenera, for example, such as the Middle Ordovician species *Hemiarges turneri* Chatterton & Ludvigsen, 1976 (pl. 19, figs. 3–16, 21, 25, 26), the Wenlockian species *Hemiarges mikulici* Perry & Chatterton, 1977 (pl. 5, figs. 23–25, pl. 6, figs. 1–2) and the Lower Devonian species *Acanthopyge (Lobopyge) sinuata* (Ratte, 1886) illustrated by Chatterton *et al.* (1979, pl. 109, figs. 1–7, 12, 14).

Therefore the author considers that the present new species is not assignable to the subgenus *Acanthopyge (Mephiarges)* and is not related to *A. consanguinea* and *A. (M.) bifida*, but is most closely allied to the Asian species discussed below rather than to most extra-Asian species.

The specimens illustrated as *Lichas haueri* Barrande, 1846 by Weber (1932) from the Lower Devonian in Turkestan is probably not conspecific with *Lichas haueri* Barrande, a senior synonym of type-species *Acanthopyge leuchtenbergii* Hawle & Corda, 1847 (pl. 1, figs. 5–7) from the Eifelian, so-called *Acanthopyge* Limestone which is the shallow-water equivalent of the Choteč Limestone of the Barrandian in Bohemia (personal communication from Dr. Ivo

Chlupáč, 7, March, 1983) because of the difference in the degree of development of the median glabellar and bullar lobes as mentioned above. The Turkestan specimens are closely comparable to the present new species rather than with the Bohemian species. Figure 37 of Weber's plate 1 from the locality no. 285 is too poor to observe the surface ornamentation, but is similar to the present new species in glabellar morphology in dorsal view. However, the Turkestan specimens has a parallel-sided median glabellar lobe and somewhat wider (trans.) bullar lobes. Figure 26 of Weber's plate 1 from the locality no. 268 show somewhat less elongate (sag. and exsag.) median glabellar lobe and wider (trans.) longitudinal furrow than those of the present new species, but shows the signs of tubercle pairs on the median glabellar lobe, which is slightly convergent posteriorly as in the present new species.

As an exception to the extra-Asian species, *Acanthopyge contusa* (Hall, 1863) illustrated by Hall and Clarke (1888, pl. 19B, figs. 3–6) is more comparable with the present new species and the Turkestan specimens than to *Lichas (Euarges) sibiricus* Tschernysheva, 1951 from the Middle Devonian ( $D_2^1$ ,  $D_2^2$ ) in the Kuznetsk Basin which had been compared to it by Tschernysheva (1951). In the North American species the central area of the median glabellar lobe is parallel-sided (fig. 3) as in the case of figure 37 of Weber's plate 1 or slightly divergent at its base (figs. 4, 5); the bullar lobe is more rounded than that of the Turkestan specimens; the cranium is ornamented with only scattered tubercles.

In *Acanthopyge sibirica* (Tschernysheva,

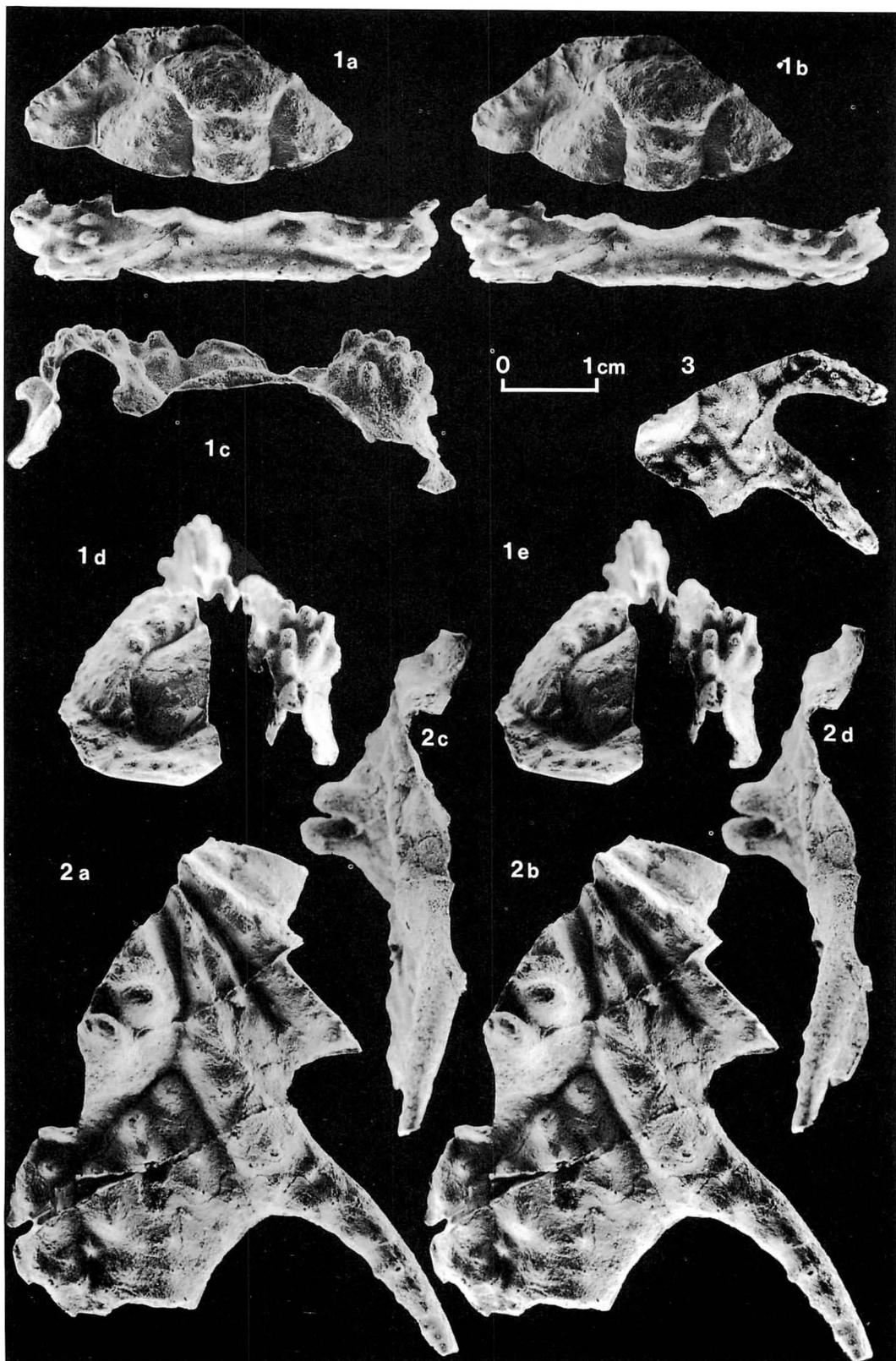
#### Explanation of Plate 87

Figs. 1-3. *Nipponarges mediosulcatus* Kaneko, gen. et sp. nov.

Figs. 1a-e. Holotype, KAC-DT-0101 [PA17144]. Rubber cast from external mould, which is a counterpart of internal mould shown in Figs. 1b, c of Pl. 88 of incomplete cranium; a, b, dorsal stereo pair,  $\times 1.5$ . c, posterior view,  $\times 1.5$ . d, e, oblique lateral stereo pair,  $\times 1.5$ .

Figs. 2a-d. Paratype, KAC-DT-0102 [PA17145]. Rubber cast from external mould, which is a counterpart of internal mould shown in Figs. 2a, b of Pl. 88 of incomplete pygidium; a, b, dorsal stereo pair,  $\times 1.5$ . c, d, right lateral stereo pair,  $\times 1.5$ .

Fig. 3. Rubber cast from external mould of another fragmental pygidium, KAC-DT-0103 [PA-17146], dorsal view,  $\times 1.5$ .



1951), the cranidium is gently inflated and the bullar lobe is extremely well-developed and the median glabellar lobe seems extremely slender as in the case of *Radiolichas araneus* (Holzapfel, 1895); the associated pygidium shows a well-developed axial lobe with a rounded outline as in the case of the present new species, but the pleural region is poorly known.

*Lichas (Euarges) planus* Weber, 1932 from the Middle Devonian at the locality no. 37 in the district of Khodjent in Turkestan, which has a considerably large and weakly inflated carapace for the genus *Acanthopyge* (s. l.), shows a glabellar morphology of similar type to the present new species.

In *Lobopyge limbata* Maximova, 1968 from the Lower Devonian ( $D_1^1$ ,  $D_2^2$ ) of Central Kazakhstan, the glabella has a more or less slender median glabellar lobe flanked by well-developed bullar lobes as in the case of the present new species, but the anterior border is relatively well-developed as in *Craspedarges* Gürich, 1901 and the associated pygidium is typical of *Acanthopyge (Lobopyge)* Přibyl & Erben, 1952.

*Acanthopyge (Lobopyge ?)* sp. indet. illustrated by Kobayashi and Hamada (1977, pl. 4, fig. 2) from the Lower Devonian of the Hida Massif in central Honshu, Japan, though a fragment of a cranidium, seems to show a relatively slender median glabellar lobe to be flanked by well-developed bullar lobes.

In *Acanthopyge latelobe* Nan, 1976 from the upper Middle Devonian ( $D_2^2$ ) at Dong Ujimqin Qi in Inner Mongolia and an extremely convex cranidium illustrated as *Lichas (Euarges) parvulus* Novak var. *convexa* by Tschernysheva (1951) from the upper Lower Devonian ( $D_1^1$ ) in the Kuznetsk Basin, the median glabellar lobe is more or less wider (trans.) than those of the above-mentioned Asian species, but the bullar lobe is well-developed.

As an exception to the Asian species, *Acanthopyge* aff. *contusa* (Hall) illustrated by Maximova (1960) from the lower Middle Devonian ( $D_1^1$ ) in Rudny Altai seems to be dissimilar to *A. contusa* (Hall) from North America in having considerably reduced bullar lobe as do most

extra-Asian species.

A glabellar morphology of the extra-Asian type can be seen also in the South American species *Acanthopyge ballivianii* (Kozłowski) redescribed by Baldis (1967) from the Middle Devonian Chavela Formation of the Province San Juan, Argentina, but the pygidium of it has four pairs of pleural segments terminating in sharp spines.

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### Explanation of Plate 88

Figs. 1-4. *Nipponarges mediusulcatus* Kaneko, gen. et sp. nov.

Figs. 1a-e. Holotype, KAC-DT-0101 [PA17144]. Incomplete cranidium. a, rubber cast from external mould, enlargement of part of glabella shown in Figs. 1a, b of Pl. 87 to show junctions between longitudinal and transglabellar furrows, about  $\times 5.5$ . b, c, internal mould, dorsal stereo pair,  $\times 1$ . d, e, rubber cast from internal mould shown in b, c, ventral stereo pair,  $\times 1$ .

Figs. 2a, b. Internal mould of paratype pygidium, KAC-DT0102 [PA17145]. a, b, dorsal stereo pair,  $\times 1$ .

Fig. 3. Internal mould of paratype, incomplete pygidium, KAC-DT-0104 [PA1747], dorsal view,  $\times 1$ .

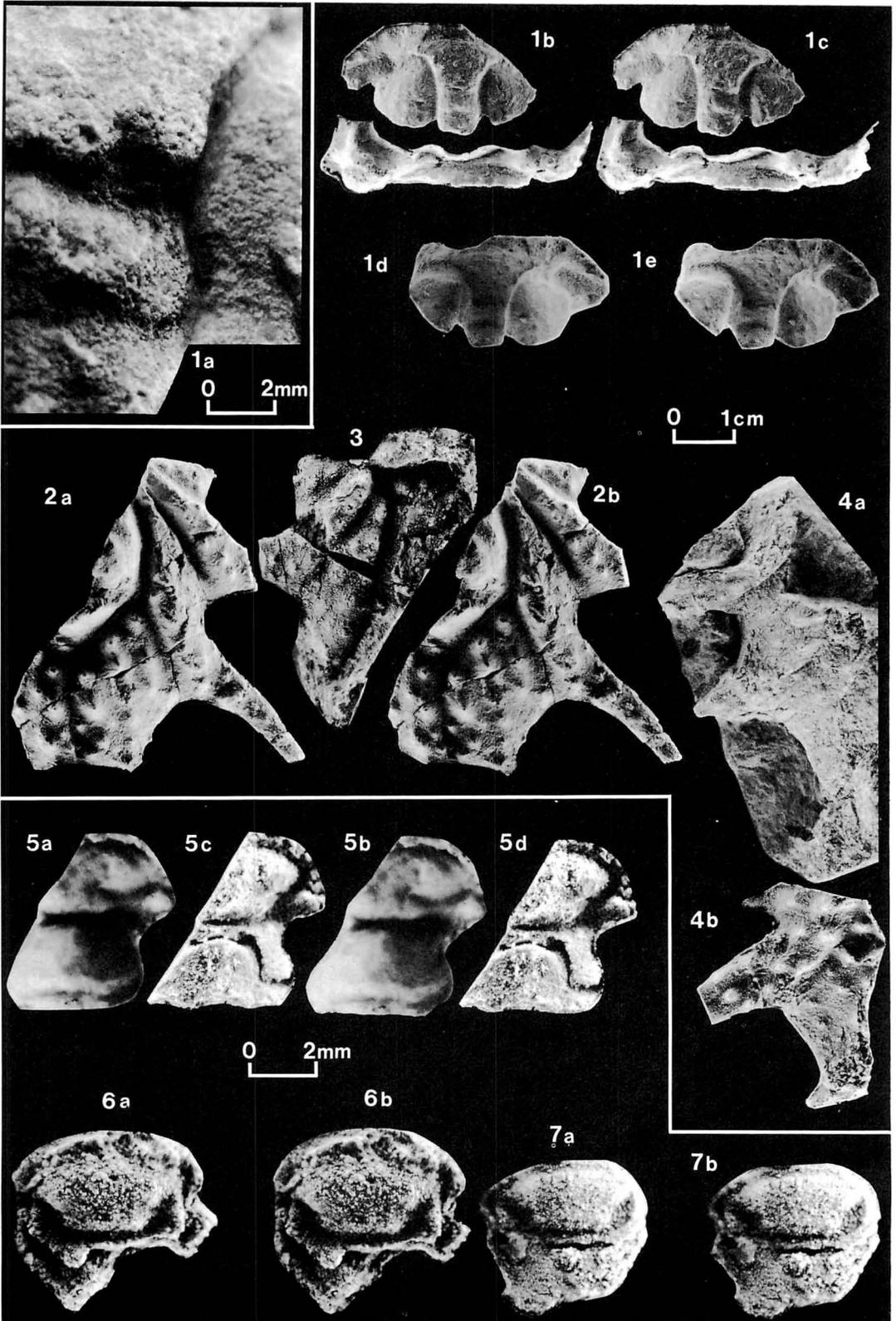
Figs. 4a, b. Fragmental pygidium, KAC-DT-0105 [PA17148]. a, dorsal view of internal mould,  $\times 1$ . b, dorsal view of cast from external mould showing third marginal spine,  $\times 1$ .

Figs. 5-7. *Acanthopyge (Acanthopyge) duplicispinata* Kaneko, sp. nov.

Figs. 5a-d. Paratype, KAC-DT-0108 [PA17151]. Incomplete hypostome. a, b, ventral stereo pair of rubber cast from external mould showing a few "pits" on the median body, which may be attributable to preservation,  $\times 5.5$ . c, d, ventral stereo pair of internal mould,  $\times 5.5$ .

Figs. 6a, b. Incomplete hypostome, KAC-DT-0109 [PA17152]. a, b, ventral stereo pair of internal mould,  $\times 5.5$ .

Figs. 7a, b. Incomplete hypostome, KKfc-0604 [PA17154]. a, b, ventral stereo pair of internal mould,  $\times 1.5$ .

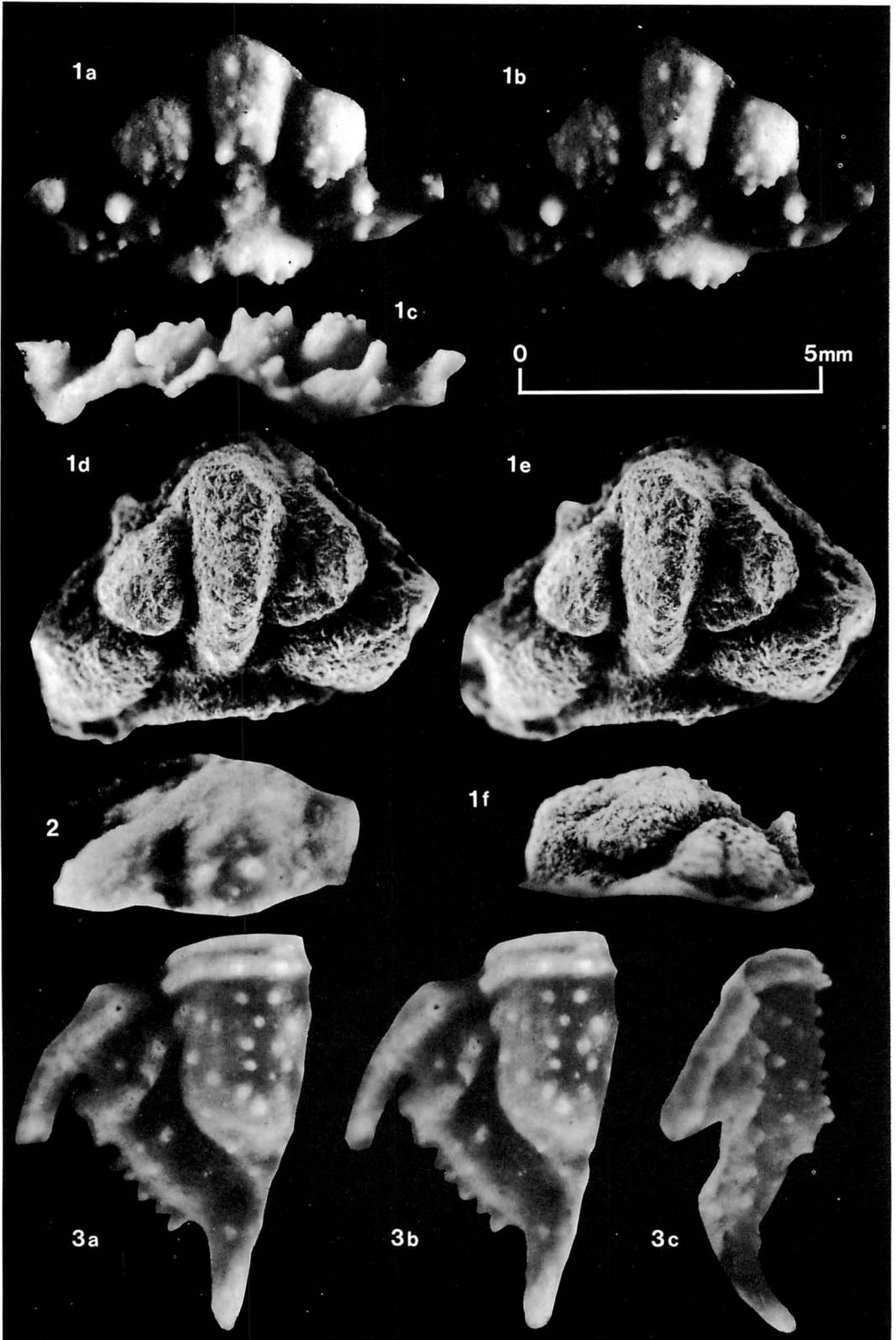


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#### Explanation of Plate 89

- Figs. 1-3. *Acanthopyge (Acanthopyge) duplicispinata* Kaneko, sp. nov.
- Figs. 1a-f. Holotype, KAC-DT-0106 [PA17149]. Incomplete cranidium. a-c, rubber cast; a, b, dorsal stereo pair,  $\times 9.5$ . c, posterior view,  $\times 9.5$ . d-f, internal mould; d, e, dorsal stereo pair,  $\times 9.5$ . f, left lateral view,  $\times 9.5$ .
- Fig. 2. Rubber cast from external mould of fragmentary cranidium showing anterior border, KAC-DT-0107 [PA17150], dorsal view,  $\times 9.5$ .
- Figs. 3a-c. Paratype, KAC-DT-0110 [PA17153]. Rubber cast from external mould of incomplete pygidium. a, b, dorsal stereo pair,  $\times 9.5$ . c, left lateral view,  $\times 9.5$ .



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北上山地中部デボン系中里層産の三葉虫動物群について—その 1, Lichidae 科: 中部デボン系中里層 N<sub>3</sub> 部層から, Lichidae, Scutelluidae, Dechenellidae, Calymenidae, Phacopidae, Dalmanitidae 及び Odontopleuridae の各科に属する豊富な三葉虫動物群を発見した。この動物群は岩手県大船渡市日頃市町の大森沢及び樋口沢産の三葉虫から成る。両産地はこれまで互いにその産出層準を異にするものと考えられてきた。即ち, *Thysanopeltella paucispinosa* (Okubo, 1951) 及び *Dechenella (Dechenella) minima* (Okubo, 1951) は, それぞれ大森沢に在ってアイフェル世を, 樋口沢に在ってジペー世を指示するものと考えられてきた。しかし, 両者は樋口沢の産地に於て共存することが明らかになったのである。現在では時代の指示者として用いることのできるものは *Thysanopeltella* のみである。それ故本三葉虫動物群の生息年代はアイフェル世を下らないものと考えられる。これは Copper et al. (1982) の腕足類 *Atrypa* の検討結果とも符合する。

本三葉虫動物群の構成に関しては, 属レベルでは東北日本に固有の型と考えられるものが少なくなく, 飛驒山地の下部デボン系三葉虫動物群とはただ汎世界型の *Acanthopyge* (s. l.) 1 属のみを共通にするに過ぎない。科及び亜科の構成からみても本三葉虫動物群は飛驒山地三葉虫動物群の後裔であるとは考えられない。

本篇に於ては Lichidae 科に属する 2 新種を記載し, 内ひとつに対し新属を提唱し *Nipponarges* と命名した。新属は頭鞍中葉上を明瞭な頭鞍溝 (2p 及び 3p) が横切る点で本科としては特異である。模式種の新種 *Nipponarges mediosulcatus* 以外にこのような性質を示すものは未だ知られていない。他の 1 新種は *Acanthopyge (Acanthopyge) duplicispinata* である。筆者は, 樋口沢産の三葉虫を順次記載して行く予定である。金子 篤

## 789. CASSIDULINIDAE (FORAMINIFERIDA) FROM THE EASTERN PART OF LÜTZOW-HOLM BAY, ANTARCTICA\*

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**Abstract.** Four species of Cassidulinidae, *Globocassidulina biora* (Crespin), *Cassidulinoides porrectus* (Heron-Allen and Earland), *C. parvus* (Earland) and *Ehrenbergina glabra* Heron-Allen and Earland, from the raised beaches and modern bottom sediments in the eastern part of Lützow-Holm Bay, Antarctica are described and revised on the basis of ontogenetic and new anatomic information.

The ontogenetic development of the aperture in *G. biora* is divided into the following three steps: I-shaped, L-shaped, and =-shaped, so that *G. biora* is morphologically similar to *Globocassidulina subglobosa* (Brady) and *G. crassa rossensis* Kennett in immature stages respectively. Uncoiled forms, such as *C. porrectus* and *C. parvus*, are also similar to *G. subglobosa* in globular immature stages.

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### Introduction

During systematic studies of the foraminiferal family Cassidulinidae, many specimens were obtained from the bottom sediments and Pleistocene raised beaches in the eastern part of Lützow-Holm Bay, Antarctica. As a result of detailed examination, four species assigned to three genera were determined: *Globocassidulina biora* (Crespin), *Cassidulinoides porrectus* (Heron-Allen and Earland), *Cassidulinoides parvus* (Earland) and *Ehrenbergina glabra* Heron-Allen and Earland. They are the most characteristic species in the Antarctic foraminiferal province.

In recent years, a number of paleontologists have focused attention on the wall structure and internal character of foraminifera. Among foraminiferal taxa, the family Cassidulinidae has attracted the most attention because members possessing different wall structures in spite

of their having a similar external morphology. Ever since Loeblich and Tappan (1964a) erected the family Islandiellidae for the forms having radial wall texture and a toothplate, and distinguished it from the family Cassidulinidae, there has been much confusion in foraminiferal systematics. However, their suprageneric classification has been questioned by several subsequent workers as described by Nomura (1983b).

Further pertinent information is needed to resolve this controversial problem, such as the internal character of the test and its morphologic variability, in addition to the wall structure. Thus the purpose of the present work is to provide systematic information on the Antarctic cassidulinid foraminifera by integrating several taxonomic characters, including the ontogenetic and anatomic observations, in order to document the similarities and differences in internal and external morphology within the Cassidulinidae.

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### Materials and Methods

Materials used in this study were taken from the raised beaches (9 and 11.5 m above sea level) in Skarvsnes and Langhovde and Recent bottom sediments at the depths 31.5 and 98 m around East Ongul Island, which were collected by Mr. M. Hayashi of Geographical Institute, Shimane University, during the 16th Japanese Antarctic Research Expedition, 1975–1976. Their localities are as follows:

Sample 75012901: Raised beach sand, 11.5 m above sea level, Skarvsnes (69°29.2'S, 39°38.4'E).

Sample 75110201: Raised beach sand, 9 m above sea level, East Ongul Island (69°0.7'S, 39°34.5'E).

Sample 75112101: Recent bottom sediments, 31.7 m in depth, northeast of East Ongul Island (68°59.7'S, 39°37.3'E).

Sample 75112102: Recent bottom sediments, 98 m in depth, north of East Ongul Island (69°00'S, 39°33.1'E).

The materials from the raised beaches consist of massive, poorly sorted sand containing molluscan fossils, *Laternula elliptica* (King and Boderip), *Adamussium colbecki* Smith, and other fossils such as serpuloid tubes. The material studied here is from the foraminiferal assemblages from the Pleistocene raised beach sediments described by Nomura (1983d).

For anatomical observations using a SEM, the specimens were prepared using the Canada balsam-xylene method described by Nomura (1983a).

### Systematic Description

Before going further, several morphologic terms for apertural structures based on comparative anatomy, which were defined by Nomura (1983b) in the study of Japanese Cassidulinidae need to be explained.

Primary tongue (PT): internal free portion of toothplate.

Cristate tooth (CT): external free portion of toothplate.

Copula (CP): conjugate portion of primary tongue and cristate tooth.

Cavity (CA): depressed portion between septal chamber wall and primary tongue.

Sulcus (S): depressed portion between septal chamber wall and cristate tooth or lip.

Lip (L): overturned structure of septal chamber wall, which is linked with the cristate tooth.

Secondary tongue (ST): free portion formed on the anterior corner of the aperture.

Apertural ridge (AR): ridge-like structure at the base of the aperture, which is formed on the preceding chamber.

Apertural flap (AF): imperforate plate formed on the lower side of the aperture.

Capitals in brackets indicate the abbreviation used in illustrations.

Family Cassidulinidae d'Orbigny, 1839

Genus *Globocassidulina* Voloshinova, 1960

*Globocassidulina biora* (Crespin)

Pl. 90, Figs. 1a, b—3, 12; Pl. 91, Figs. 1—7;  
Text-fig. 1

*Cassidulina biora* Crespin, 1960, p. 28, 29, pl. 3, figs. 1—10.

*Cassidulina crassa* d'Orbigny. Crespin, 1960, p. 29, pl. 3, figs. 12, 13.

*Cassidulina* sp. Crespin, 1960, p. 29, 30, pl. 3, fig. 11.

*Globocassidulina biora* (Crespin). Fillon, 1974, p. 139, pl. 1, figs. 9—12, 14, 15; Osterman and Kellogg, 1979, p. 264, pl. 2, fig. 1; Finger and Lipps, 1981, p. 129, pl. 4, figs. 6a—c, 7a, b.

*Globocassidulina biora* ? (Crespin). Fillon, 1974, p. 139, pl. 1, figs. 8, 13.

*Globocassidulina* ? sp. Fillon, 1974, p. 140, pl. 4, fig. 4.

*Anticleina antarctica* Saidova, 1975, p. 331, pl. 89, fig. 14, pl. 114, fig. 5.

*Globocassidulina* cf. *biora* (Crespin). Milam and Anderson, 1981, pl. 10, figs. 2, 3a, b.

*Globocassidulina crassa rossensis* Kennett. Milam and Anderson, 1981, pl. 10, figs. 1a, b.

*Globocassidulina* sp. Finger and Lipps, 1981, p. 129, pl. 4, figs. 1a—c, 2a—c, 3a—c, 4a—c.

*External morphology*.—The external morphology of *Globocassidulina biora* has been described in detail by Crespin (1960) in her original description. The test is generally sub-globular, but somewhat prolonged and compressed-oval in side and edge views respectively in mature stage. Chambers in final whorl are usually five pairs, and slightly inflated or not; so that the periphery of the test is lobulate or sometimes smooth. The umbilical region is slightly depressed. Sutures are almost straight and narrowly limbate. The aperture, as described below, consists of two openings parallel with each other at the middle portion of the final apertural face. However, its shaped varies from a vertical slit to tripartite in the immature stage. The test wall is polished and translucent and pierced with fine pores.

Through ontogenetic development, the external morphology of the test is divided into three growth stages: nepionic to neanic, ephebic and gerontic stages. In nepionic to neanic stages, two forms, the megalospheric and microspheric are easily distinguished as follows: the former is characterized by a globular test with proloculus diameter of 72  $\mu\text{m}$  in average, whereas the latter shows a compressed test having a proloculus diameter of less than 10  $\mu\text{m}$ . In the ephebic stage, the test shows the shape described above. The gerontic stage is characterized by having a more prolonged test with a tendency toward an uncoiled appearance.

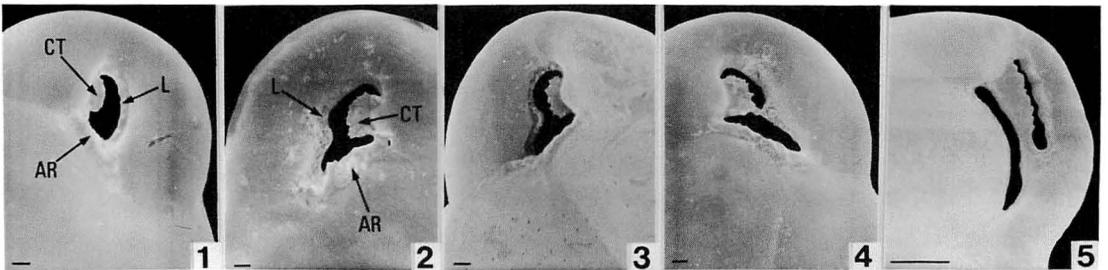
*Apertural structure*.—The peculiar structure of the aperture in both external and internal

views is the most diagnostic feature of this species. As noted in Crespin's original description, the aperture is divided into two narrow openings both parallel to the periphery of the preceding chamber margin; the longer one is usually situated on the proximal side.

SEM observation reveals that the apertural compartment is formed by the junction of a strongly developed cristate tooth and partly protruded lip (Text-fig. 1, nos. 4, 5). Text-fig. 1 shows the developmental mode of the cristate tooth and lip. As seen in these figures, the development of the cristate tooth through ontogeny is larger than that of the lip. Similar developmental pattern is noted by Finger and Lipps (1981) as described later. Owing to the conspicuous elongation of the cristate tooth toward the lip, the sulcus is not significant. Each tip of the cristate tooth and lip is nodulate, and an apertural ridge is also formed in early growth stage.

When viewed from the interior in dissected specimens, it is noted that the anterior and posterior corners of the aperture are devoid of free structures corresponding to primary and secondary tongues (Pl. 91, Fig. 4).

Another notable character of the aperture is the variable feature in the outline of apertural openings through the nepionic to gerontic. Nepionic to neanic apertures are almost vertically arranged loop-like slits to the basal suture of the apertural face. Subsequently the early ephebic stage aperture shows a tripartite feature consisting of basal and areal apertural branches, in



Text-fig. 1. Apertural development of *Globocassidulina biora* (Crespin). CT=cristate tooth, L=lip, AR=apertural ridge. 1; neanic stage, 10  $\mu\text{m}$  scale. 2; early ephebic stage, 10  $\mu\text{m}$  scale. 3; early ephebic stage, 10  $\mu\text{m}$  scale. 4; ephebic stage, 10  $\mu\text{m}$  scale. 5; late ephebic stage, 100  $\mu\text{m}$  scale.

which the cristate tooth is formed on the posterior side of the areal one. Such mature stages as ephebic and gerontic demonstrate the parallel openings (Text-fig. 1).

*Wall texture*:—Fragments of test wall crushed in Lakeside cement reveal a jagged-granular texture under crossed nicols. However, the septal wall of the proloculus, being very thin, is also sometimes similar to the mosaic structure (Pl. 90, Fig. 12).

*Perforation*:—Pores are slit-shaped, parallel with each other on the earlier portion (Pl. 91, Fig. 1), irregular in later (Pl. 3, Fig. 2), and rounded on the final chamber; length of slit-shaped pores is 3.3  $\mu\text{m}$  in average; pore density is 16 pores per 20  $\mu\text{m} \times 20 \mu\text{m}$ .

*Remarks*:—Since Crespin (1960) described this species from the Vestfold Hills area of Antarctica, it has been reported as being very common in the Antarctic region. However, the apertural morphology of this species is not uniform and the ontogenetic variation of the aperture used to distinguish this species from other related species has not been well known until now. Owing to the morphological change of the aperture through ontogeny, much confusion, particularly in the form of immature stages, is seen in recent literature.

In the original description of this species, Crespin was not aware of its ontogenetic variation, so that seemingly immature forms which should have been assigned to this species were not included in the continuous range of the variation (e. g., *Cassidulina* sp. in her pl. 3, fig. 11 clearly shows a rudimentary cristate tooth). All dissected specimens here examined clearly demonstrate that continuous variation of the aperture is divided into three basic steps through ontogeny: slit (I-shaped)  $\rightarrow$  tripartite (L-shaped)  $\rightarrow$  parallel openings (=shaped). Finger and Lipps (1981) similarly noted these ontogenetic changes of the aperture in the *Globocassidulina crassa* plexus (particularly *G. crassa rossensis* and *G. biora*), in stating that the *G. subglobosa*-like aperture grades into the aperture characterized by one or two apertural branches.

In fact, this ontogenetic variation has per-

plexed the species identification and the relationship of *G. biora*, *G. crassa rossensis* Kennett, and *G. subglobosa* (Brady) as discussed by Fillon (1974), Kellogg et al. (1979), and Finger and Lipps (1981). Fillon (1974) considered that *G. biora* and *G. crassa rossensis* are in close phylogenetic relationship because of their close similarity in adult forms. On the other hand, pointing out the resemblance of immature forms of *G. biora* and *G. crassa rossensis*, Finger and Lipps (1981) stated "dissection reveals that earlier chambers of the larger (adult) *G. crassa rossensis* and *G. biora* display their characteristic (fully developed) apertures without any indication of apertural growth stages". So far as *G. biora*, however, their observations are not in agreement with the present ones. As already stated, *G. biora* shows the variation of apertural shape during ontogeny.

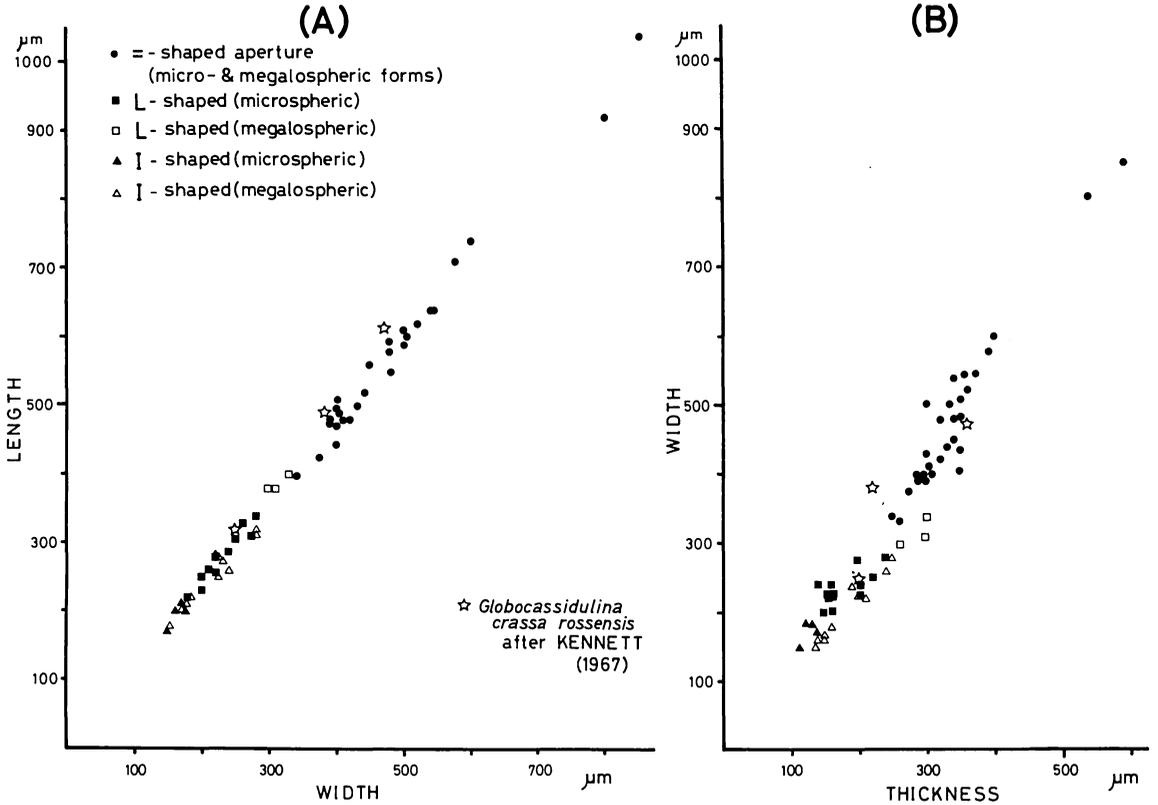
Close examination of the final apertures of the holotype and paratypes illustrated by Kennett (1967, p. 134, pl. 11, figs. 4–6) and subsequent workers including Finger and Lipps (1981) shows that *G. crassa rossensis* possesses a tripartite aperture with a very long basal and less developed cristate tooth. These apertural features indicate that the two are clearly differentiated in the mature stage. However, *G. biora* and *G. crassa rossensis* have a similar ontogenetic development in the shape of the test (Text-fig. 2) and *G. biora* possesses a tripartite (L-shaped) aperture like that of *G. crassa rossensis* in immature stage. Taking these features into consideration, the two taxa are not conspecific, but they are expected to be grouped in the closest phylogenetic relationship as stated by Fillon (1974).

#### Genus *Cassidulinoides* Cushman, 1927

##### *Cassidulinoides porrectus* (Heron-Allen and Earland)

Pl. 90, Figs. 4a, b–7, 13; Pl. 92, Figs. 6–9

*Cassidulina crassa* d'Orbigny var. *porrecta* Heron-Allen and Earland, 1932, p. 358, 359, pl. 9, figs. 34–37.



Text-fig. 2. Interrelations of test length and width (A) and test width and thickness (B) for *Globocassidulina biora* (Crespin) showing the apertural type. Sample from 75012901.

### Explanation of Plate 90

Figs. 1-3. *Globocassidulina biora* (Crespin)

1a, b; ephebic stage (DESS 82038),  $\times 60$ . 2; early ephebic stage (DESS 82039),  $\times 105$ . 3; neanic stage (DESS 82040),  $\times 105$ .

Figs. 4-7. *Cassidulinoides porrectus* (Heron-Allen and Earland)

4a, b; ephebic stage (DESS 82041),  $\times 45$ . 5; neanic stage (DESS 82042),  $\times 60$ . 6; neanic stage (DESS 82043),  $\times 60$ . 7; neanic stage (DESS 82044),  $\times 60$ .

Figs. 8, 9. *Ehrenbergina glabra* (Heron-Allen and Earland)

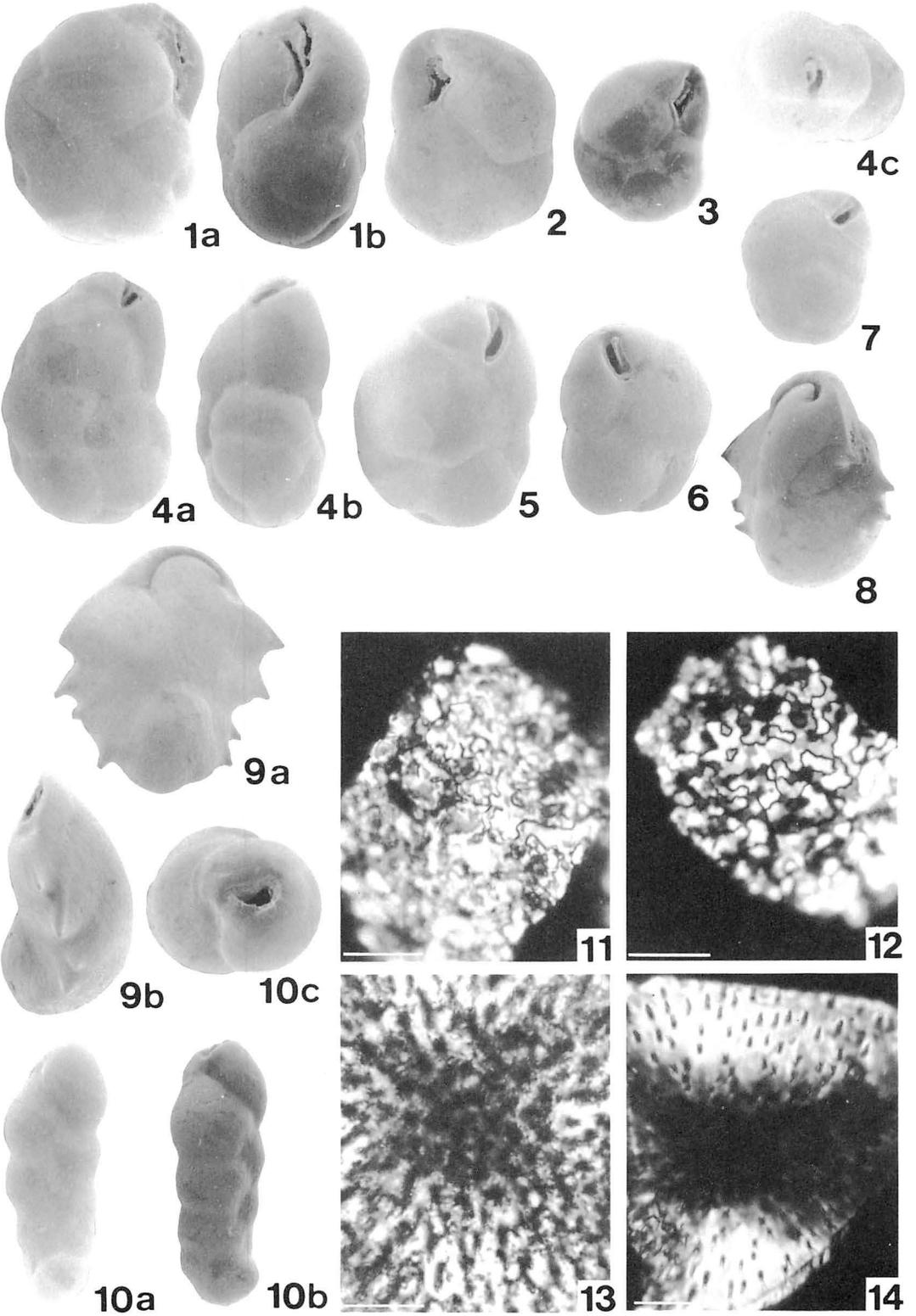
8; megalospheric form (DESS 82045),  $\times 65$ . 9a, b; microspheric form (DESS 82046),  $\times 80$ .

Figs. 10a-c. *Cassidulinoides parvus* (Earland), (DESS 82047),  $\times 80$ .

Figs. 11-14. Wall textures, 40  $\mu\text{m}$  scale.

11; jagged-granular texture (*Ehrenbergina glabra*). 12; mosaic-granular texture (neanic stage of *Globocassidulina biora*). 13; indistinctly radial texture (*Cassidulinoides porrectus*). 14; distinctly radial texture (*Cassidulinoides parvus*).

DESS: Department of Earth Sciences, Shimane University



*Cassidulinoides porrectus* (Heron-Allen and Earland). Parr, 1950, p. 344, pl. 12, fig. 26; Fillon, 1974, p. 139, pl. 4, figs. 1–3.

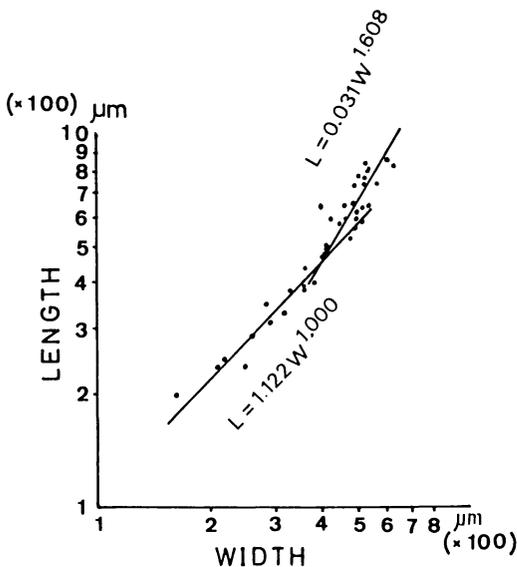
*Cassidulina crassa porrecta* Heron-Allen and Earland. McKnight, 1962, p. 126, 127, pl. 21, fig. 139.

*Cassidulinoides porrecta* (Parr). Osterman and Kellogg, 1979, p. 264, pl. 2, figs. 8, 9.

*Cassidulinoides porrecta* (Heron-Allen and Earland). Milam and Anderson, 1981, pl. 6, fig. 6.

*External morphology*:—*Cassidulinoides porrectus* has been considered to have a pyriform test, though in the immature (nepionic to neanic) stage it has a globular test like that of *Globocassidulina subglobosa* (Brady). Therefore, the relative growth shows isometry in the immature stage and positive allometry in the mature stage (Text-fig. 3). These features are described in the following three growth steps.

Nepionic to neanic tests showing isometric growth are globular to oval, and have three pairs of chamber just before attaining the ephebic stage (Pl. 90, Figs. 5, 6). Ephebic tests, showing positive allometry, form an uncoiled chamber



Text-fig. 3. Interrelation of test length and width for *Cassidulinoides porrectus* (Heron-Allen and Earland), indicating the isometry in immature stage and positive allometry in mature stage. Sample from 75012901.

arrangement. In the gerontic growth stage, tests are somewhat cylindrically prolonged (Nomura, 1983d, pl. 2, figs. 2a, b).

In contrast to the original description, chambers are distinct and somewhat inflated through these growth stages. Sutures are distinct, slightly depressed and limbate. The last-formed chamber is narrowed. The aperture is a loop-like slit arranged almost at right angles to the basal suture of the apertural face, and situated at the middle portion of the face. The wall in well-preserved state is transparent, polished, pierced by numerous fine pores, and earlier chambers in the preceding whorl are visible externally. However, poorly preserved walls are opaque as in the original description.

*Apertural structure*:—Detailed examination of the aperture reveals that the loop-like slit opening is surrounded by a well-developed cristate tooth on the posterior side and a lip on the anterior side (Pl. 92, Fig. 6). In the immature stage, the cristate tooth is attached to the lip on its anterior end, but not in mature stages (Pl. 92, Figs. 6, 8, 9).

Dissected specimens show that the primary tongue is very narrow even in the mature stage, but it appears to be present from the nepionic aperture onwards; a rudimentary primary tongue with cavity is clearly observable in the first whorl (Pl. 92, Fig. 8). On the contrary, the secondary tongue is not formed throughout ontogeny.

Morphological change in the aperture through ontogeny is very slight and not serious for specific distinction of this species from other similar forms; the loop-like slit gradually increases in length as chambers are added.

*Wall texture*:—In polarized light, fragments of test wall reveal indistinctly radial texture (Pl. 90, Fig. 13).

*Perforation*:—Pores are rounded in all growth stages (Pl. 92, Fig. 7); pore diameter is 1.3  $\mu\text{m}$  in average and pore density is 7 pores in 20  $\mu\text{m} \times 20 \mu\text{m}$ .

*Remarks*:—In at least immature forms such as the nepionic and neanic stages, there are some apparent similarities between *C. porrectus* and *Globocassidulina subglobosa*. The two species

have subglobular tests and the apertures are perpendicular to the basal suture. However, the wall texture differs; the wall of *G. subglobosa* is of jagged-granular texture (Nomura, 1983c).

The ephebic to gerontic specimens of this species are apparently close to *Cassidulinoidea parkerianus* (Brady), illustrated in the Challenger Report, in the size and shape of the test, having a protruded final chamber. However, *C. porrectus* differs from *C. parkerianus* in having a more compressed test and narrower apertural face.

*Cassidulinoidea parvus* (Earland)

Pl. 90, Figs. 10a–c, 14; Pl. 92, Figs. 1–5

*Ehrenbergina parva* Earland, 1934, p. 139, 140, pl. 6, figs. 28–32.

*Cassidulinoidea parkerianus* (Brady). Parr, 1950, p. 344, pl. 12, fig. 25; McKnight, 1962, p. 127, pl. 22, fig. 141; Fillon, 1974, p. 139, pl. 4, fig. 5; Finger and Lipps, 1981, p. 129, pl. 2, fig. 8.

*External morphology*:—Test is small for the genus; test width is up to 120  $\mu\text{m}$  in microspheric form and 170  $\mu\text{m}$  in megalospheric, and length is up to 600  $\mu\text{m}$  in microspheric form and 400  $\mu\text{m}$  in megalospheric. As described by Earland (1934), this species possesses a biseral arrangement throughout, and it is usually found at the crosier-shaped state consisting of a very small coiled or loosely coiled early portion and linear or arcuate later one. Many microspheric forms

here examined indicate the following two growth stages: Nepionic to neanic tests are very small (140  $\mu\text{m}$  in length, 120  $\mu\text{m}$  in width, and 100  $\mu\text{m}$  in thickness) and globular in shape; ephebic to gerontic stages show uncoiled-linear development (Pl. 92, Fig. 3).

Chambers are inflated, particularly distinct in later growth stages; sutures are therefore depressed and the test periphery is lobulate. The aperture is a loop-like slit set obliquely in the middle portion of the final apertural face, but in mature stages it is usually situated subterminally on the apertural face. Well-preserved walls are transparent, showing the earlier chambers.

*Apertural structure*:—Viewed from the exterior, the apertural structure is simple (Pl. 92, Fig. 1). The cristate tooth is prominent, but its anterior and posterior ends are linked to the lip (Pl. 92, Fig. 2). Internally no free structures are observed (Pl. 92, Figs. 3–5); a copula without the primary tongue originates from the middle portion of the anterior apertural face, close to the preceding aperture. The proximal end of the aperture is not fused with the preceding or previous chamber, so that an oval apertural opening is formed in the subterminal face. Thus, there is apparently no marked change in apertural structure and shape of the apertural opening through ontogenetic growth.

*Wall texture*:—All fragments of test wall show distinctly radial texture in polarized light (Pl. 90, Fig. 14).

*Perforation*:—Pores on coiled and uncoiled

### Explanation of Plate 91

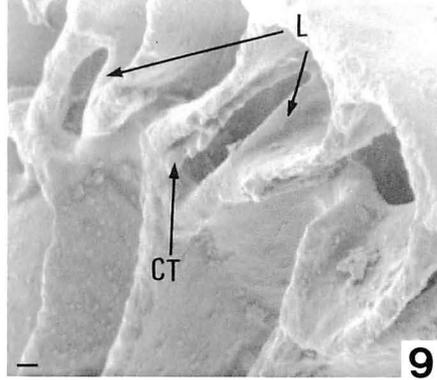
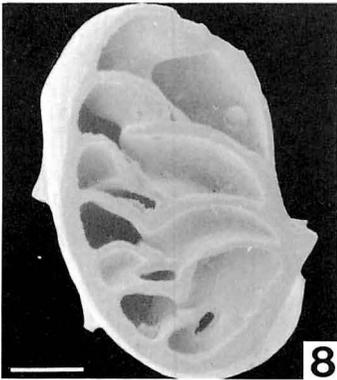
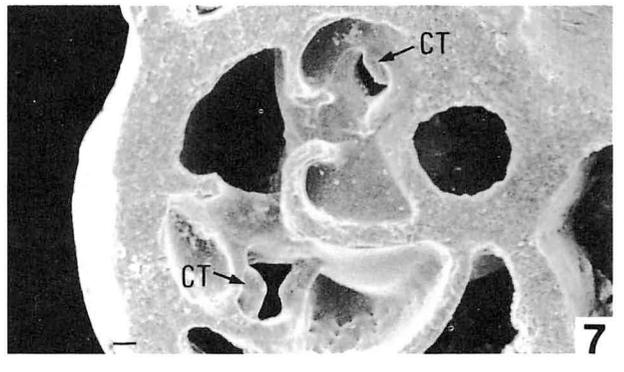
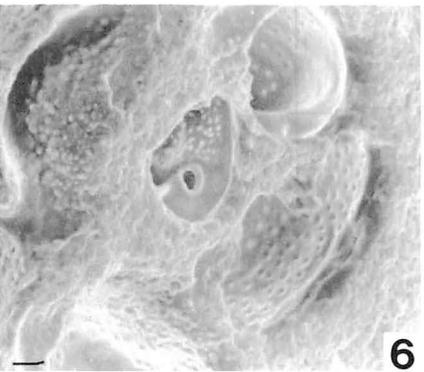
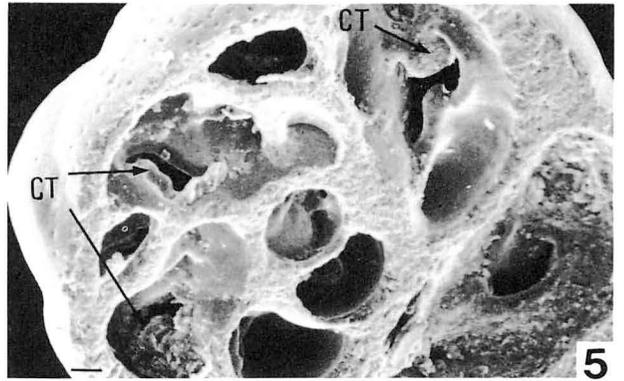
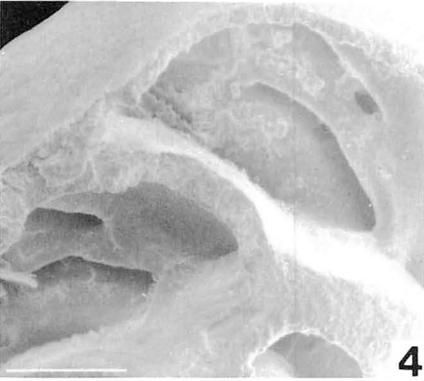
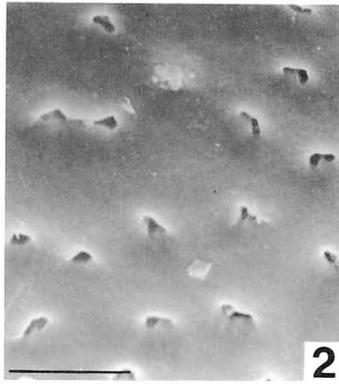
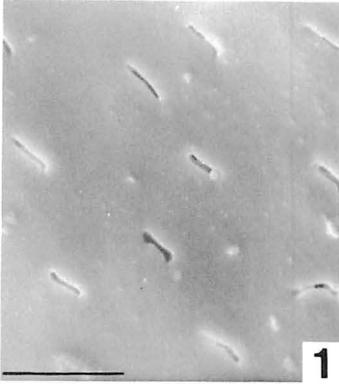
CT=cristate tooth, L=lip

Figs. 1-7. *Globocassidulina biora* (Crespin)

1; outer test surface showing slit-shaped pores, 10  $\mu\text{m}$  scale. 2; outer test surface showing irregular pores, 10  $\mu\text{m}$  scale. 3; dissected specimen, 100  $\mu\text{m}$  scale. 4; enlargement of Fig. 3, 100  $\mu\text{m}$  scale. 5; internal structure showing the change of apertural shape, 20  $\mu\text{m}$  scale. 6; internal structure showing proloculus aperture, 10  $\mu\text{m}$  scale. 7; internal structure of neanic stage, 20  $\mu\text{m}$  scale.

Figs. 8, 9. *Ehrenbergina glabra* Heron-Allen and Earland

8; dissected specimen, 100  $\mu\text{m}$  scale. 9; internal structure showing apertural development, 10  $\mu\text{m}$  scale.



chamber walls are rounded without decoration. Pore diameter is 0.5  $\mu\text{m}$  in average and pore density is 8 pores in 20  $\mu\text{m} \times 20 \mu\text{m}$ .

*Remarks*.—This species was originally described under the genus *Ehrenbergina* by Earland (1934). Compared with other typical *Ehrenbergina* species, however, such morphological aspects as chamber shape and apertures indicate that this species is more reasonably put in *Cassidulinoides*; the genus *Cassidulinoides* is characterized by having a non-compressed test on both dorsal and ventral sides, globular chambers and subterminal loop-shaped aperture, whereas the genus *Ehrenbergina* is characterized by compressed, laterally prolonged chambers and elongate slit aperture with apertural flap.

The presence of a toothplate has been used as one of the basic criteria for the genus *Cassidulinoides* (Loeblich and Tappan, 1964a). However, *C. parvus* does not possess the toothplate as described above. From this point of view, Nomura (1983b) stressed that the structure of the toothplate is variable between respective species as well as within one species. Therefore the presence or absence of a toothplate is not sufficient to justify generic distinction. The same is true for *Cassidulinoides parvus*, which is devoid of a primary tongue in spite of the presence of a cristate tooth.

It is noted that *C. parvus* has not been reported so often from the Antarctic region. In the original description, Earland pointed that this species is confined to the Bransfield Strait, South Shetlands and Palmar Archipelago, and that it is easily overlooked owing to the small size. However, this species is commonly found in Lützow-Holm Bay area.

#### Genus *Ehrenbergina* Reuss, 1850

*Ehrenbergina glabra* Heron-Allen and Earland

Pl. 90, Figs. 8, 9a, b, 11, Pl. 91, Figs. 8, 9

*Ehrenbergina hystrix* Brady var. *glabra* Heron-Allen and Earland, 1922, p. 140, pl. 5, figs. 1–6, 11.

*Ehrenbergina glabra* Heron-Allen and Earland. Uchio, 1960, pl. 1, figs. 1–3; McKnight, 1962, p. 127, pl. 22, figs. 142a, b; Fillon, 1974, p. 139, pl. 5, figs. 9, 10; Anderson, 1975, p. 86, pl. 11, figs. 2a, b; Saidova, 1975, pl. 89, fig. 13; Osterman and Kellogg, 1979, p. 264, pl. 2, fig. 4; Milam and Anderson, 1981, pl. 9, fig. 7.

*External morphology*.—The test is triangular, with laterally prominent spines. Spines are well developed in later ontogenetic stages, as they gradually increase in length in harmony with chamber development. In both megalos- and microspheric forms, the earliest portion is coiled, but its roundness is different due to the size of proloculus; microspheric forms appear to be sharpened, whereas megalospheric ones are more rounded. Chambers are low and broad, not inflated, and overlap about half of the breadth on the dorsal side. Sutures are limbate and well shown on the dorsal side, but on the ventral side the limbation is not distinct. The aperture is a long-narrow arcuate slit almost parallel to the dorsal line in apertural view. The wall is translucent, pierced by fine pores, but not perforate on the apertural flap.

Test length is up to 765  $\mu\text{m}$ ; width up to 740  $\mu\text{m}$ ; thickness up to 380  $\mu\text{m}$ .

*Apertural structure*.—Owing to the development of an apertural flap, the aperture of this species is a simple slit. However, many dissected specimens reveal that a primary tongue and cristate tooth are formed on the dorsal side of the aperture. These structures, which are formed by the turnover of the septal chamber wall on the dorsal side, are internally connected with each other.

Ontogenetically viewed, a rudimentary structure is already formed in the earliest stages, presenting a very shallow cavity beneath the primary tongue. But compared with the development of the cristate tooth, the primary tongue is not so conspicuous (Pl. 91, Figs. 8, 9).

*Wall texture*.—Examination of the test through polarized light shows that walls are of jagged-granular texture (Pl. 90, Fig. 11).

*Perforation*:—Pores are slit-shaped on earlier chambers, rounded to irregular on later portion, but absent on the apertural flap as well as the apertural margin. Length of slit-shaped pores is 1.2  $\mu\text{m}$  in average; pore density is 8 pores in 20  $\mu\text{m} \times 20 \mu\text{m}$ .

*Remarks*:—Heron-Allen and Earland (1922) first described this taxon from many stations around the seas of New Zealand's subantarctic islands and the Antarctic, as one of the most thriving forms in Antarctic cold water. At that time, they considered this species to be a variety of *E. hystrix*, pointing out such differences as absence of apertural grooves and a more inflated apertural face. As discussed by Loeblich and Tappan (1964a, b), however, this species is distinctly differentiated from *E. hystrix* (= *Reissia hystrix*, Loeblich and Tappan, 1964b) in having the test wall of jagged-granular texture. Recognition of *E. glabra* as a distinct species is safely accepted.

So far as examined in the literature, this species seems to bear a greater resemblance to *E. pupa* (d'Orbigny). Some specimens show very short peripheral spines, but typical *pupa*-like forms are not found from Lützow-Holm Bay area.

#### Acknowledgements

I express my sincere gratitude to Mr. M. Hayashi of Shimane University, for providing the materials. I also thank Associate Professor Yasumochi Matoba of Akita University, for his

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#### Explanation of Plate 92

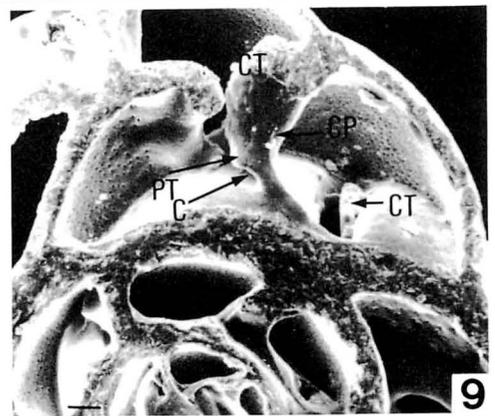
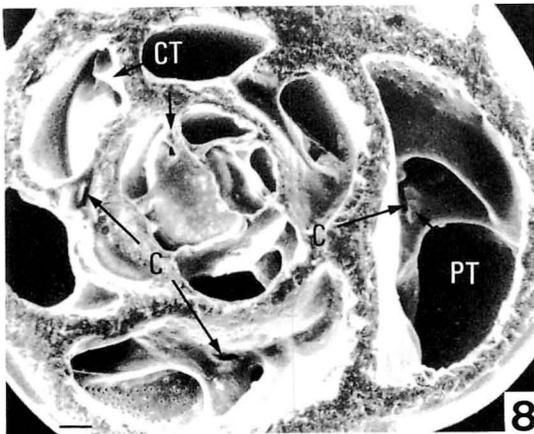
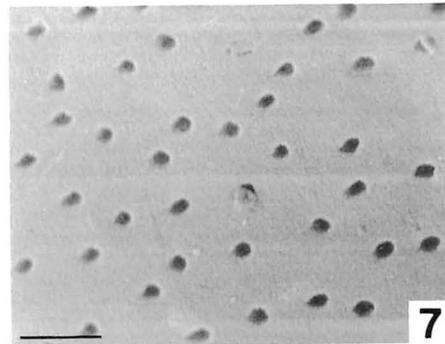
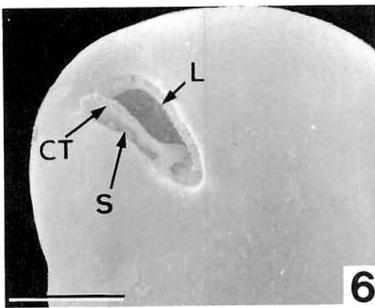
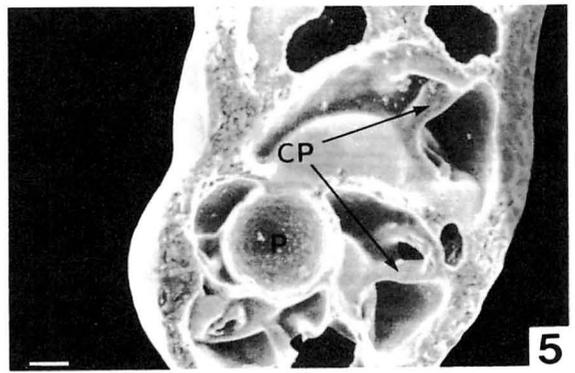
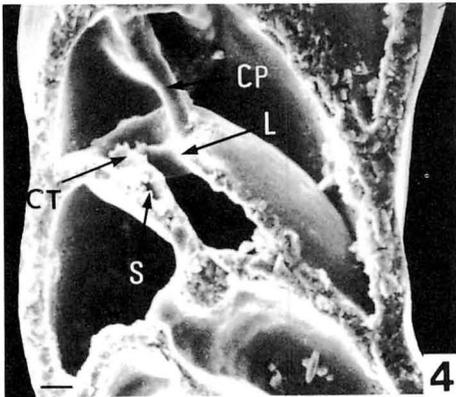
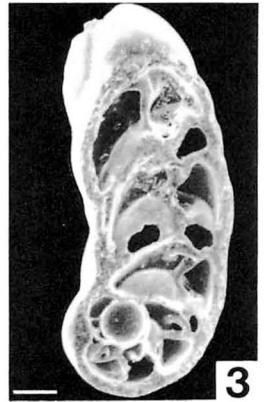
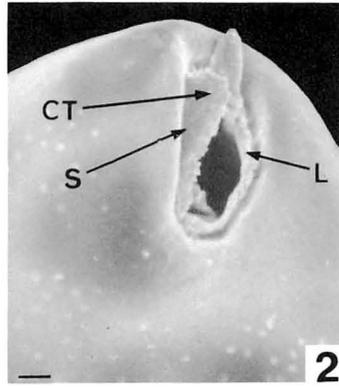
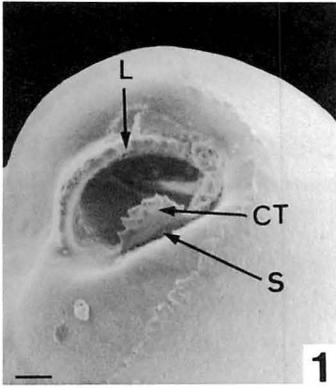
C=cavity, CP=copula, CT=cristate tooth, L=lip, P=proloculus, PT=primary tongue, S=sulcus

Figs. 1-5. *Cassidulinoides parvus* (Earland)

1; external structure of aperture in mature stage, 10  $\mu\text{m}$  scale. 2; external structure of aperture in immature stage, 10  $\mu\text{m}$  scale. 3; dissected specimen, 50  $\mu\text{m}$  scale. 4; internal structure of uncoiled portion, 20  $\mu\text{m}$  scale. 5; enlargement of Fig. 3, showing apertural development, 20  $\mu\text{m}$  scale.

Figs. 6-9. *Cassidulinoides porrectus* (Heron-Allen and Earland)

6; external structure of aperture, 100  $\mu\text{m}$  scale. 7; outer test surface showing rounded pores, 10  $\mu\text{m}$  scale. 8; internal structure of coiled portion, 20  $\mu\text{m}$  scale. 9; internal structure of uncoiled portion, 30  $\mu\text{m}$  scale.



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南極, リュツォ・ホルム湾東岸からの Cassidulinidae 科の有孔虫: 南極のリュツォ・ホルム湾東岸の隆起汀線と現世海底堆積物 (海拔 11.5, 9, -31.5, -98 m) から Cassidulinidae 科の4種の有孔虫, *Glöbocassidulina biora* (Crespin), *Cassidulinoides porrectus* (Heron-Allen and Earland), *Cassidulinoides parvus* (Earland), *Ehrenbergina glabra* Heron-Allen and Earland について個体発生および解剖学的知見のもとに記載した。

*G. biora*, *C. porrectus*, *C. parvus* の3種は, 個体発生を通じて形態変化がそれぞれ確認される。たとえば, *G. biora* の口孔は個体発生を通じて I 型 → II 型 → III 型の3段階の形態変化を示すため, I 型と II 型の幼殻期の外部形態は *G. subglobosa* (Brady) と *G. crassa rossensis* Kennett にそれぞれ類似する。また, 成長が開施回を示す *C. porrectus* と *C. parvus* は幼殻期に *G. subglobosa* に似る。しかし, これらの種と類似種とは殻構造と口孔の内部構造の違いによって区別することが可能である。

## 日本古生物学会特別号の原稿募集

PALAEONTOLOGICAL SOCIETY OF JAPAN, SPECIAL PAPERS, NUMBER 29 を 1986 年度に刊行したく、その原稿を公募します。適当な原稿をお持ちの方は、次の事項に合わせて申込書を作成し、原稿の写しを添えて、〒812 福岡市東区箱崎 九州大学理学部地質学教室 気付、日本古生物学会特別号編集委員会（代表者首藤次男）宛に申し込んで下さい。

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