Introduction

The apparently thick deposits, generally called the Shimantogawa group, are extensively developed in the southern terrain of the Outer Zone of Southwest Japan. The group consists mainly of shale and sandstone in various grades of thickness and has occasional interbeds or lentils of conglomerate, basaltic lava, tuffite, chert and limestone.

Recently the paleontological study of this group has been carried out on moluscan fossils found at some limited places and offered important biostratigraphical data, as those described by Matsumoto, Kimura and Katto (1952), Katto and Ozaki (1956), Nagai, Nakano, Yoshida and Ohotsuka (1962), Nakai and Hada (1966), Hayami and Kawasawa (1967), Hashimoto (1967), Matsumoto and Hirata (1969) and Morozumi (1970).

Since 1969, I have examined the Inoceramids from this group. In this paper, I deal with the geological age of the

“Misho formation”, one of the Shimantogawa group and the paleontological description on a new species of Inoceramus from that formation, and do not intend to give comprehensive comments on the classification of the Inoceramidae. Only a short remark is given in connections with the allied species.

Before going further, I wish to acknowledge my indebtedness to several persons for their supporting of my work. My gratitude is first due to Professor Tatsuro Matsumoto of Kyushu University for much valuable advices and kind supervision of this work. Thanks are to Dr. Itaru Hayami for his kindness to the laboratory work and the bibliographic survey, to Professor Kozo Nagai of Ehime University and Professor Michitoshi Miyaihisa of Ehime University for their favours to supply me with a number of specimens and the valuable references. Finally my gratitude is dedicated to Mr. Yasushi Yuasa, Mr. Masaharu Seki and Dr. Hakuyu Okada who have stimulated through Prof. Matsumoto the present study with valuable specimens of their
collections.

**Note on Geology**

The "Misho formation" is exposed on the northern coast of Sukumo Bay, which is situated in the southwestern part of the Shimanto belt of South Shikoku. The northern margin is demarcated from another unnamed formation of the Shimantogawa group by fault, and the east area also bounded by fault to the Arioka formation of the Upper Cretaceous developing in the Nakasuji-Rift-Valley. The name of this formation was proposed by NAGAI and others (1962). However, OKADA (1971) disapproves the name of the "Misho formation" by the reason of phonetic confusion that the "undifferentiated Mesozoic" was called "misho Mesozoic" in Japanese.

The geology of this district is shown in Fig. 1. The formation mainly consist of sandstone, shale and their alternation. They are broadly arcuate in strike, showing a trend of NEE-SWW, E-W and NWW-SEE, and divided into several blocks by transverse faults. The geologic structure is generally complicate, with overturned strata and fractured zones. Sandstone in various grades of coarseness is mainly distributed in the southern part of the mapped area. Each sandstone bed is commonly more than 20 cm in thickness, and in some part thin layers of mudstone are frequently inserted. In some other part sandstone

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**Text-fig. 1. Geological Map of the Johen area.**
and mudstone are alternated. The northern part is occupied by mudstone with subordinate intercalation of sandstone of various thickness. Although the thickness of this formation is not precisely known, because of complicated structure, it is divided into two members, of which the Lower member is probably represented by the sandstone of the southern part.

Molluscan fossils occur in the mudstone bed near Nishi, Johen Town and Nakanokawa and Naro, Ippomatsusu Town, Minamiuwa County, Ehime Prefecture. The stratigraphic position of the fossiliferous bed is probably assigned to the middle part of the Upper member of this formation.

The faunal list is as follows: *Inoceramus balticus toyajoanus* NAGAO and MATSUMOTO
*Inoceramus balticus* subsp.
*Inoceramus schmidtii* MICHAEL
*Inoceramus yuasai* n. sp.
*Maoites* sp.
Ammonites gen. et sp. indet.

According to MATSUMOTO in TAKAI and MATSUMOTO (1961), *I. balticus toyajoanus* probably indicates the Lower Hetonaian. NAGAI et al. (1962) reported *Inoceramus balticus toyajoanus* from Naro, Ippomatsu Town, and considered the geological age of this formation as the Upper Urakawan to the Lower Hetonaian (approximately Upper Santonian to Campanian), and they referred the flat large specimen (see NAGAI et al. 1962, Pl. 1, fig. 3) to one of *I. balticus* subsp. Now I am examining on the chronological change of morphology of Upper Cretaceous *Inoceramus*. Thus, I put off, at present, the subspecific determination of that specimen, which will be proposed in a separate paper. Furthermore, MATSUMOTO (personal information) identified *I. schmidtii*, an effec-

**Paleontological Description**

**Family Inoceramidae** GIEBEL, 1852

**Genus Inoceramus** J. SOWERBY, 1814

*Inoceramus yuasai* n. sp.

Pl. 34, figs. 1-10


**Material:** Holotype: GK. H6823, (Pl. 34, fig. 1) internal mould of left valve from Nakanokawa, Ippomatsusu Town, Minamiuwa County, Ehime Prefecture (coll. Y. YUASA). Paratypes: GK. H6824, (Pl. 34, fig. 5), internal mould of right valve, in the same rock as the holotype. GK. H6826 (Pl. 34, fig. 3), internal mould of right valve from the type locality (coll. Y. YUASA). GK. H6831 (Pl. 34, fig. 4), external mould of left valve (coll. M. SEKI), GK. H8005 (Pl. 34, fig. 9), internal
mould of right valve, GK. H8004 (Pl. 3, fig. 7), and GK. H8006 (Pl. 3, fig. 2a, 2b), internal moulds of left valve from Nishi, Johen Town, Minamiuwa County, Ehime Prefecture (coll. M. Noda). Repository: Department of Geology, Kyushu University. There are many other specimens in Noda's private collection.

Specific Characters:—Shell small to medium in size, probably subequivalve or slightly inequivalve, inequilateral, moderately inflated from anterior to posterior and from umbo to ventral extremity, with an abrupt change in convexity along the growth axis. Antero-dorsal part steep or perpendicular to valve plane, postero-dorsal part abruptly flattened to wing-like area without sharp boundary. Hinge-line straight and fairly long, about two thirds of the shell length. The growth axis gently concave to the anterior. Umbo terminal, considerably inflated; left one more prominent than the right, rising above the hinge-line. Beak angle about 80°, apical angle slightly larger than a right angle. Small individuals, less than 10 mm in growth axis, slightly longer than high, and gradually becoming higher with growth, resulting in the outline slightly higher than long in the left valve and as long as high in the right one.

Antero-dorsal margin moderate in length and straight or slightly concave, anterior margin broadly arcuate passing gradually to the narrowly rounded ventral margin and then to the more broadly curved postero-ventral one, which is in turn bent abruptly to the moderately long and nearly straight posterior margin. The angle between the posterior margin and the hinge-line about 130°.

Surface ornamented with low, narrow and sharp concentric ribs which are regular in strength and distance. Interspaces comparatively broad and concave. Two or three round-topped radial folds run from the umbonal part to the anterior and also to the postero-ventral extremity. They vary in strength and stage of appearance. In some specimens the radial folds are very weakened, only showing abrupt bending in concentric ribs.

Measurements:

Table 1. Dimension in mm.

<table>
<thead>
<tr>
<th>Specimen*</th>
<th>H</th>
<th>L</th>
<th>h</th>
<th>l</th>
<th>h/l</th>
<th>HL</th>
</tr>
</thead>
<tbody>
<tr>
<td>GK. H6823* holotype, internal mould of LV.</td>
<td>36</td>
<td>25</td>
<td>30</td>
<td>27</td>
<td>1.1</td>
<td>15</td>
</tr>
<tr>
<td>GK. H6826* paratype, internal mould of RV.</td>
<td>27</td>
<td>27</td>
<td>26</td>
<td>26</td>
<td>1.0</td>
<td>20</td>
</tr>
<tr>
<td>GK. H6831 paratype, external mould of LV.</td>
<td>58</td>
<td>52</td>
<td>55</td>
<td>49</td>
<td>1.1</td>
<td>29</td>
</tr>
<tr>
<td>GK. H8002 paratype, internal mould of LV.</td>
<td>17</td>
<td>11</td>
<td>16</td>
<td>14</td>
<td>1.1</td>
<td>7</td>
</tr>
<tr>
<td>GK. H8005* paratype, internal mould of RV.</td>
<td>29</td>
<td>24</td>
<td>28</td>
<td>25</td>
<td>1.1</td>
<td>—</td>
</tr>
<tr>
<td>GK. H8006* paratype, internal mould of LV.</td>
<td>34</td>
<td>34</td>
<td>33</td>
<td>33</td>
<td>1.0</td>
<td>—</td>
</tr>
</tbody>
</table>

* Less deformed specimen.
LV: left valve, RV: right valve, H: maximum dimension along the growth axis, L: maximum dimension along a line perpendicular to H, h: height; measured perpendicular to the hinge-line, l: length; measured parallel to the hinge-line, h/l: proportion of height to length, HL: length of the hinge-line.
Table 2. Measurement of angle.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>α</th>
<th>β</th>
<th>γ</th>
<th>δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>GK. H6823, holotype</td>
<td>95°</td>
<td>80°</td>
<td>130°</td>
<td>60°</td>
</tr>
<tr>
<td>GK. H6826, paratype</td>
<td>95°</td>
<td>80°</td>
<td>130°</td>
<td>60°</td>
</tr>
<tr>
<td>GK. H8001</td>
<td>95°</td>
<td>80°</td>
<td>130°</td>
<td>55°</td>
</tr>
</tbody>
</table>

α: apical angle between hinge-line and anterior margin.
β: beak angle of umbonal inflation.
γ: postero-dorsal angle between hinge-line and posterior margin.
δ: obliquity, the angle between hinge-line and the line from umbo to ventral extremity.

Table 3. Change of obliquity with growth.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>length of growth axis in mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>GK. H6823</td>
<td>35°</td>
</tr>
<tr>
<td>GK. H6831</td>
<td>—</td>
</tr>
<tr>
<td>GK. H8007</td>
<td>35°</td>
</tr>
</tbody>
</table>

Remarks:—Only four specimens (GK. H6823, GK. H6826, GK. H8005 and GK. H8006) are fairly well preserved showing the original outline, the shell convexity and the surface ornamentation. Many other specimens are more or less modified by secondary deformation, therefore, the marginal outline, the convexity and the proportion of h/l are apparently varied. Generally details of the surface ornamentation are better impressed on the external mould (e.g. GK. H6831). The concentric ribs and radial folds are variable in strength and shape of cross-section, although apparently varied state sometimes occurs owing to the secondary deformation.

In spite of the above situation, from the synthetic judgement of available specimens, the distinctive specific characters are recognized as above.

Comparison:—Inoceramus inconstans Woods from the Upper Chalk of England, shows considerable variation in marginal outline, shell convexity, proportion of h/l and surface ornamentation. The specimen of GK. H8006 is comparable to a certain form of Inoceramus inconstans (Woods, 1912a, p. 285-291, pl. 51, figs. 2a, 4a; 1912b; p. 14, text-figs. 69, 70), in abrupt change of convexity and curvature of concentric ribs, but differs from that form in its less convexity and more clearly developed concentric folds, as well as its radial ornament.

Inoceramus mihoensis Matsumoto, from the upper part of the Lower Ura-kawan (K5α), (approximately Upper Coniacian) of Saghalien, Hokkaido and Kyushu, is also similar to the present species in inequivalveness and abrupt change of convexity along the growth axis but the former is distinguished from the latter in its large size, absence of the posterior wing-like area, curvature of the concentric ribs and absence of the radial ornament.

According to Woods (Woods, 1917), Inoceramus australis Woods (Woods, 1917, p. 27, 28, pl. 12, figs. 17-19; pl. 13, figs. 1-3), from the Campanian of the
Amuri group of New Zealand, is allied to *Inoceramus inconstans*. It is also somewhat allied to the present species in abrupt change of convexity but discriminated from the latter in large proportion of h/1 and absence of the radial folds.

*Inoceramus* (Cordiceramus) brancoiformis SEITZ (SEITZ, 1961, p.15 9-163, pl. 13, fig. 4, pl. 14, figs. 1-3) from the Middle to Upper Santonian of northwest Germany, also closely resembles the present species in abrupt changes of the shell convexity, presence of the posterior wing-like area and also presence of the radial ornamentation, but differ from the latter in larger apical angle, larger obliquity and less proportion of h/1.

NAGAI et al. (1962) regarded that the present species somewhat resembles *Inoceramus balicus* BÖHM and the allies from the Upper Urakawan to the Upper Hetonaian (approximately Santonian to Maestrichtian). Their material, however, as they explained, is a single imperfect specimen, which seems to be specifically indistinguishable from one of the present specimens (GK. H8005).

The present species is apparently similar to *Inoceramus subsulcatus* WILSHIRE (1896) (WOODS, 1911, p. 268, pl. 42, figs. 5, 6), from the Upper Gault of England, in the inequivalveness, development of the radial folds which vary in number, shape of cross-section and stage of appearance, but distinctly differs from the latter in its less prominent umbo, less convexity, presence of wing-like area, more strongly developed concentric ribs and anteriorly curved growth axis.

To sum up, the present species is not identical with any previously described species. Therefore, it is described under a new specific name which is dedicated to Mr. Y. YUASA who provided through Prof. T. MATSUMOTO valuable specimens of his collection for this study.

Consideration:—COX (1969), (in MOORE ed., p. 317) set up subgenus "Cremnoceramus" (=Cephaloceramus HEINTZ, 1932) for the species which are characterized by subequivalve or inequivalve shell, slight or moderate obliquity, abrupt change of convexity along the growth axis and absence of narrow postero-dorsal wing, and designated *Inoceramus inconstans* WOODS as its type species.

Regardless of the presence or the absence of radial folds, the essential characters of inequivalveness and abrupt change of shell convexity are in common between *Cremnoceramus* spp. and *Inoceramus yuasai*. This may suggest some connections between them. Although *Inoceramus inconstans* is not found in Japan, it is said to be very persistent ranging from the Upper Turonian to the Upper Campanian. Furthermore, as WOODS (1912b) himself has already admitted, the very variable *I. inconstans* has been considered as an ancestor which gave rise to many other species. *Inoceramus mihoensis* from the upper part of the Lower Urakawan (K5a) (approximately Upper Coniacian) is regarded by MATSUMOTO as a lateral off-shoot from the main stock of the group of *I. inconstans*. In the essential characteristics mentioned above, *I. mihoensis* is also similar to the present species, but the available specimens, are insufficient for linking stratigraphically these two species.

*Inoceramus australis*, from the Campanian of New Zealand, is probably allied to *I. inconstans*, as WOODS (1917) has mentioned, but I consider that there is more intimate relation in morphology between *I. mihoensis* and the present
species than that of *I. australis* and the present species.

SEITZ (1961) has pointed out that the immature form of *Cremnoceramus* is similar to that of *Heanlainia* (=*Cordiceramus* HEINTZ, 1932) and gradually differentiates from the latter with growth. It seems to suggest the intimate connection between the two subgenera. Regardless of the geographical distance, *Inoceramus* (*Cordiceramus*) *brancoiformis* SEITZ from the Middle to Upper Santonian of northwest Germany, may be possible to link morphologically and stratigraphically the present species with *Inoceramus* (*Cremnoceramus*) *inconstans* WOODS.

To sum up, in view of the above discussions, it is more reasonable to consider that the present species is probably derived from some forms of *I. (Cremnoceramus) inconstans*.

**Occurrence:**—Rather crowded in the black shale of the presumably middle part of the Upper member of the “Misho formation”. Locality MS201; Nakano-kawa, Iponnatsu Town, Miminamiwa County, Ehime Prefecture, location, Long. 132°37'52"E, Lat. 32°57'04"N. Locality MS202; Nishi, Joken Town, Miminamiwa County, Ehime Pref., location, Long. 132°36'37"E, Lat. 32°56'57"N.

NODA and TASHIRO (1973) reported the present species as *Inoceramus* n. sp. (see NODA and TASHIRO, p. 494) from the basal part of the Izumi group at Dogo-Himezuka, Matsuyama City, associated with *I. schmidii* and numerous species of Campanian pelecypods. Loc. IM101, location, Long. 132°51'00"E, Lat. 33°50'42"N.

**References Cited**


628. Inoceramus from Shimantogawa Group


Dogo-Himezuka 道後姫塚
Ipponmatsu 一本松
Johen 城辺
Minamiuwa 南宇和
Nakanokawa 中ノ川

Nakasuji 中筋
Naro 奈路
Nishi 西
Sukumo 宿毛
Explanation of Plate 34

_Inoceramus yuasai_ n. sp.

Fig. 1. GK. H6823, holotype, internal mould of left valve. ×1.3. Loc. MS201, Nakanokawa, Ipponmatsu Town, Minamiuwa County, Ehime Prefecture (coll. Y. YUASA, 1968).

Fig. 2a, 2b. GK. H8006, paratype, internal mould of left valve, 2a, lateral view, 2b, anterior view. ×1.3. Loc. MS202, Nishi, Johen Town, Minamiuwa County, Ehime Prefecture (coll. M. NODA, 1970).

Fig. 3. GK. H6826, paratype, internal mould of right valve. ×1.3. Loc. MS202 (coll. M. SEKI, 1969).

Fig. 4. GK. H6831, paratype, rubber cast of left external mould, natural size. Loc. MS202 (coll. M. SEKI, 1969).

Fig. 5. GK. H6824, paratype, internal mould of right valve. ×1.3. Loc. MS201 (coll. Y. YUASA, 1968).

Fig. 6. JG. H2051, internal mould of left valve, natural size. Loc. MS202 (coll. M. NODA, 1971).

Fig. 7. GK. H8004, paratype, internal mould of left valve. ×1.3. Loc. MS202 (coll. M. NODA, 1970).

Fig. 8. GK. H8002, internal mould of left valve. ×1.3. Loc. MS202 (coll. M. NODA, 1970).

Fig. 9. GK. H8005, internal mould of right valve. ×1.3. Loc. MS202 (coll. M. NODA, 1970).

Fig. 10. GK. H8003, internal mould of both valves. ×1.3. Loc. MS202 (coll. M. NODA, 1971).

NODA: Inoceramus from Shimantogawa Group

Plate 34