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Palaeontology and stratigraphy of the inoceramid species from the mid-Turonian through upper Middle Coniacian in Japan

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ABSTRACT:

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Upper Cretaceous strata are well exposed in many areas of Japan, although good exposures through the Turonian/Coniacian boundary are not common. This paper focuses on six areas in Hokkaido, Shikoku and Kyushu and documents the stratigraphical distributions of inoceramid species. These data are used to summarise the stratigraphical ranges of Turonian/Coniacian taxa in Japan. In part 1 of the paper, 17 species are described, with some biometric data and phylogenetic interpretation. These species are: *Inoceramus* (*Inoceramus*) *hobetsensis* NAGAO & MATSUMOTO, *I.* (*I.*) *teshioensis* NAGAO & MATSUMOTO, *I.* (*I.*) *iburiensis* NAGAO & MATSUMOTO, *I.* (*I.*) *tenuistriatus* NAGAO & MATSUMOTO, *I.* (*I.*) *pedalionoides* NAGAO & MATSUMOTO, *I.* (*I.*) *lusatiae* ANDERT, *I.* (*I.*) *uwajimensis* YEHARA, *I.* (*Cremnoceramus*) *rotundatus* FIEGE, *I.* (*Cr.*) *ernsti* HEINZ, *I.* (*Cr.*) *deformis* MEEK, *I.* (*Cr.*) *lueckendorfensis* TRÖGER, *I.* (*Platyceramus*) *tappuensis* nom. nov., *I.* (*Pl.*) *szaszi* NODA & UCHIDA, *I.* (*Volviceramus*) *koeneni* MÜLLER, *Mytiloides incertus* (JIMBO), *M. mytiloidiformis* (TRÖGER), and *M. sublabiatus* (MÜLLER). In part 2, the stratigraphical distribution and correlation of these species are discussed.

INTRODUCTION

Inoceramid species from the Cretaceous of Hokkaido were first described by JIMBO (1894). YEHARA (1924) recorded some species from SW Japan. NAGAO & MATSUMOTO (1939, 1940) comprehensively described the Cretaceous *Inoceramus* of Japan. At that time, however, the knowledge of the stratigraphy and interregional correlation was relatively poor. Subsequently, with progress in stratigraphic investigations, many species of Cretaceous inoceramids, including new ones, have been described. Some of these seem to be critical to an understanding of the Turonian-Coniacian boundary problem (MATSUMOTO & NODA 1985; NODA 1992, 1996; NODA & UCHIDA 1995). In addition, owing to the generous field assistance of several friends the material available for palaeontological study has increased greatly (NODA 1975, 1984, 1988).

Recently, integrated biostratigraphic studies have been undertaken by a number of researchers specializing in Cretaceous ammonites, inoceramids and micro-fossils (MATSUMOTO 1954, 1959, 1969, 1977; NODA & MATSUMOTO 1976; MATSUMOTO & *al.* 1991). Furthermore, the magnetostratigraphy has been made in some selected areas (TOSHIMITSU & *al.* 1995a, b). Thus, the

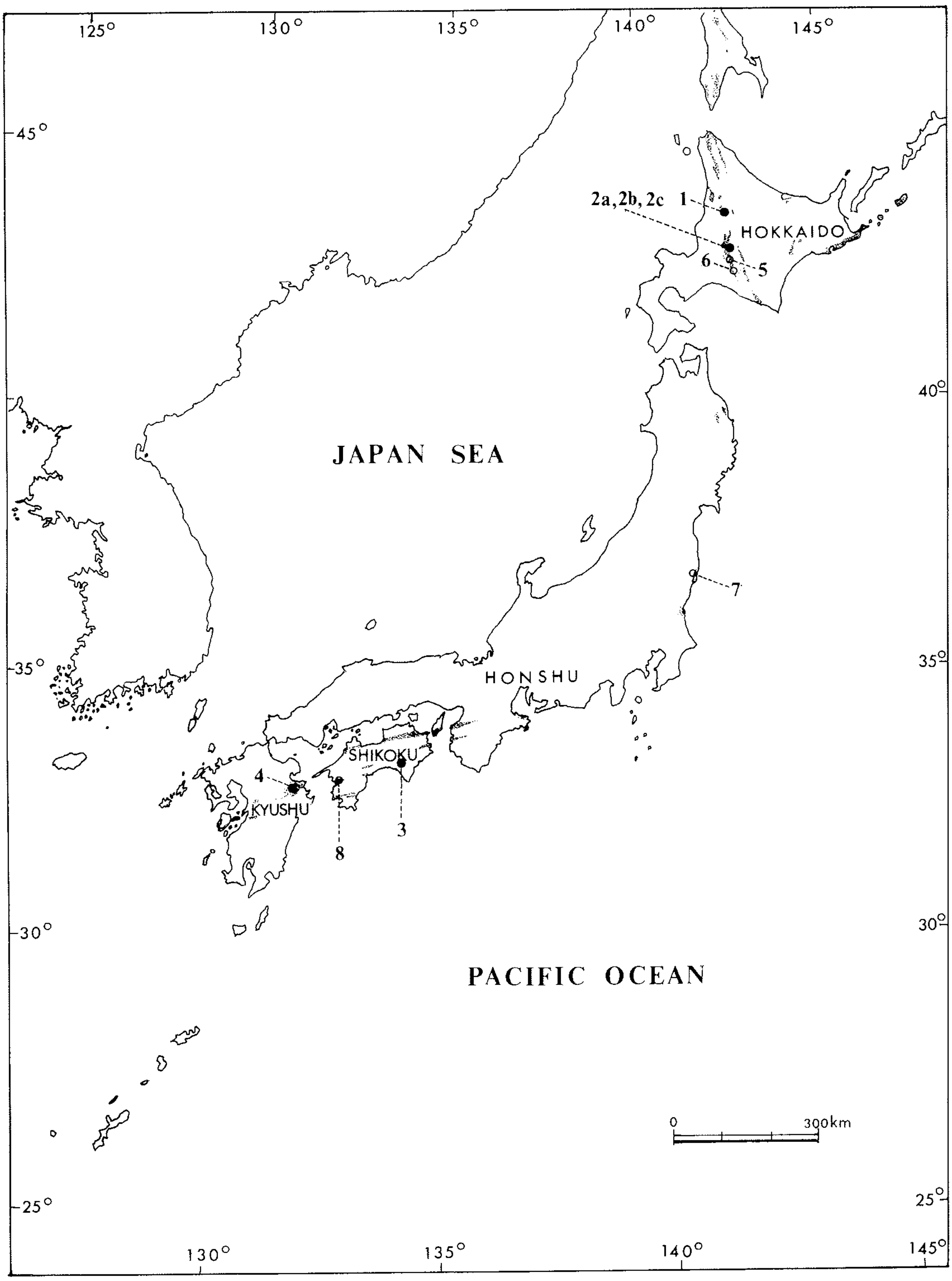


Fig. 1. Map of Japan and adjacent areas; shaded areas mark outcrops of Upper Cretaceous marine strata; solid circles mark areas of mid-Turonian to Coniacian strata described in detail in this paper: 1 – Obira or Obirashibe Valley, 2a-c – Ikushunbetsu Valley or Mikasa district, 2a – main course of the R. Ikushunbetsu, 2b – Ponbetsu, 2c – Ponbetsu-Gono-sawa, 3 – Kajisako, 4 – Onogawa Basin; open circles mark other areas mentioned briefly: 5 – Oyubari, 6 – Hobetsu, 7 – Futaba, 8 – Uwajima

inoceramid zonation has been much improved in Japan (*see* Table) since the work of NAGAO & MATSUMOTO (1939, 1940). Some species are apparently endemic to the North Pacific Province, but currently a considerable number of cosmopolitan species have been identified, which, together with the associated ammonites, are very useful for precise international correlation.

Japan is palaeogeographically distant from Europe and the Western Interior Province of North America, where good Upper Cretaceous biostratigraphic zonations have been established. Moreover, the Cretaceous deposits in Japan consist mainly of thick clastic sediments of variable facies, in contrast to the much thinner, calcareous sediments of uniform or less variable facies in the shelf region of Euramerica. The inoceramid species which occur abundantly in Turonian and Coniacian strata of Japan are mostly endemic and their stratigraphic ranges are comparatively long. Despite this they are used as biozonal indices, in range zones, abundance zones or assemblage zones with associated ammonites. Some species that occur normally in the shelf regions of Europe, North America and elsewhere have been found recently in Japan, but their occurrences in Japan are rather sporadic or restricted to particular localities or stratigraphic horizons.

For the reasons mentioned above, this paper describes the palaeontology and stratigraphy of the species of Inoceramidae from the mid-Turonian through the upper part of the Middle Coniacian in Japan.

Part 1: Palaeontology

by MASAYUKI NODA

INTRODUCTION

Seventeen species of inoceramids from the mid-Turonian through the upper Middle Coniacian are described below. Some biometric data and phylogenetic interpretations are included with the description.

MATERIAL

The specimens examined were obtained from various areas of Japan. Turonian/Coniacian boundary succession studied in detail are shown in Text-fig. 1 (solid circles). Other areas where the Upper Turonian or Lower to upper Middle Coniacian sediments are exposed are also shown in Text-fig. 1 (empty circles). In general, the specimens from Hokkaido and northeast Honshu are well-preserved and little deformed, especially so in calcareous nodules. These specimens are amenable to biometric analysis. In contrast, material from southwest Japan, *i. e.*, Shikoku and Kyushu is commonly poorly preserved, crushed, and cannot be used for biometric analysis.

Some species occur densly crowded in shell beds and nodules, such as, *I.* (*I.*) *tenuistriatus*, *I.* (*I.*) *uwajimensis*, *I.* (*Cr.*) *rotundatus*, *I.* (*Pl.*) *tappuensis*, and *M. incertus*. These taxa are suitable for population studies.

The specimens examined are lodged in the following institutions.

Repositories:

GMH: Geological Collections of Hokkaido university, Sapporo.
IGPS: University Museum, Tohoku University, Sendai.
UMUT: University Museum, The University of Tokyo, Hongo, Tokyo.
WE: Geological Collections of Waseda University, Waseda, Tokyo.
OES: Geological Collections of Odochi Primary School, Odochi, Kochi Prefecture.
KMNH: Kitakyushu Museum of Natural History, Kitakyushu.
GK: Geological Collections of Kyushu University, Fukuoka.
JG: Collections of Jonan Geological Association, Oita, tentatively held in NODA's personal laboratory.
TTC : Collections of Takemi TAKAHASHI, Mikasa.

METHODS

Most of the species described here have been described previously by NODA (1975, 1984, 1988, 1992; 1994 and 1996) and NODA and others (1990, 1995). The present work gives suplementary notes and observations based on the new data; for full description the reader should refer to the earlier papers. Measurements are presented for selected specimens; again, where relevant, full biometric analyses are detailed in the earlier works. As noted above, some species are sufficiently abundant to permit population analysis of variation and this approach is reflected in the descriptions. Other species are known from relatively few specimens and hence their descriptions are typological in approach. Morphological measurements are shown in Text-fig. 2.

SYSTEMATIC DESCRIPTION

Family Inoceramidae, ZITTEL, 1881
Genus *Inoceramus* SOWERBY, 1814
Subgenus *Inoceramus* SOWERBY, 1814

TYPE SPECIES: *Inoceramus cuvieri* SOWERBY, 1814, designation by COX (1969).

DIAGNOSIS: *See* COX (1969, p. N315), KAUFFMAN *in* HERM & *al.* (1979, pp. 52-53) and WALASZCZYK (1992, p. 29).

REMARKS: *Inoceramus* (*Inoceramus*) is probably derived from *Actinoceramus* MEEK, by way of species such as *I.* (s.l.) *tenuis* MANTELL, *I.* (s.l.) *inaequivalvis* SCHLÜTER and *I.* (s.l.) *costatus* NAGAO & MATSUMOTO. These taxa show an intermediate character in various grades of inequivalveness, with more inflated left valve and more projected left umbo than that of the right valve. *I.* (*Inoceramus*) is directly or indirectly ancestral to *I.* (*Platyceramus*) SEITZ, 1961, *I.* (*Cremnoceramus*) COX 1969, *I.* (*Cordiceramus*) SEITZ, 1961 and *I.* (*Volviceramus*) STOLICZKA, 1871.

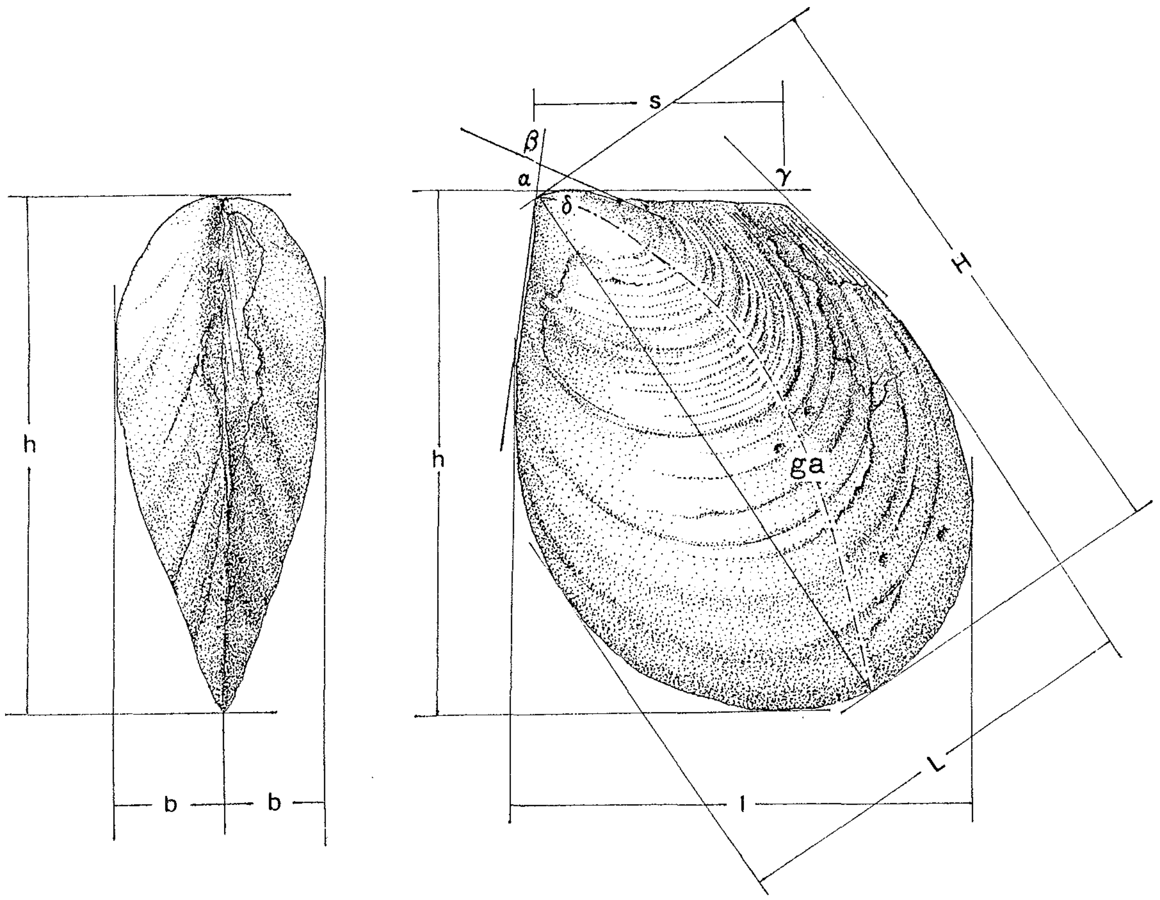


Fig. 2. Basic linear measurements and angles used in inoceramid description
h – shell heigth, l – shell length, b – shell width, s – length of hinge line, H – maximum distance between umbo and ventral extremity, L – maximum distance perpendicular to H, α – anterior hinge angle, β – beak angle (angle of umbonal inflation), γ – posterior hinge angle, δ – obliquity (angle between hinge and H), ga – growth axis

Inoceramus (*Inoceramus*) *hobetsensis* NAGAO & MATSUMOTO, 1939
Pl. 16, Figs 1-3

1939. *Inoceramus hobetsensis* NAGAO & MATSUMOTO, p. 281, Pl. 28, Fig. 3; Pl. 29, Figs 1-6; Pl. 30, Figs 2-3.
1939. *Inoceramus hobetsensis* var. *nonsulcatus* NAGAO & MATSUMOTO, p. 282, Pl. 27, Fig. 3; Pl. 28, Fig. 4; Pl. 30, Fig. 1.
1959. *Inoceramus hobetsensis* NAGAO & MATSUMOTO; MATSUMOTO, p. 84, Pl. 11, Fig. b.
1975. *Inoceramus hobetsensis* NAGAO & MATSUMOTO; NODA, pp. 249-251, Pl. 32, Figs 6-9; Pl. 33, Figs 1-7; Pl. 34, Figs 1-5; Pl. 35, Fig. 1.
1977. *Inoceramus* (*Inoceramus*) *hobetsens hobetsensis* NAGAO & MATSUMOTO; KAUFFMAN, p. 177.
1977. *Inoceramus* (*Inoceramus*) *flaccidus* WHITE; KAUFFMAN, pp. 177-178 (*non* WHITE, 1874).

LECTOTYPE: The specimen figured by NAGAO & MATSUMOTO (1939, Pl. 29, Fig. 3; this paper Pl. 16, Fig. 2), Hokkaido University Collection, unregistered; designation by NODA (1975).

MATERIAL: 14 specimens from the Obira area, Hokkaido, 13 specimens from the Ikushunbetsu area, Hokkaido, 6 specimens from the Oyubari area, Hokkaido, 10 specimens from the Hobetsu area, Hokkaido, 15 specimens from the Kajisako area, Shikoku and 35 specimens from the Onogawa Basin, Kyushu.

DIAGNOSIS: Shell medium-sized to large, sometimes attaining more than 40 cm in H, inequivalve, moderately inflated along growth axis, anterior face steep or perpendicular to plane of commissure, posterior one moderately inclined. General outline variable, normally obliquely elongate parallel to H but some specimens are relatively broad. Posterior wing developed with some variation. Surface ornamented with two grades of commarginal sculpture; major ribs commonly coarse, gradually broaden with growth; minor rings superimposed on major ribs and interspaces. Shallow radial sulcus developed to posterior of growth axis from somewhat beyond umbo to postero-ventral margin.

REMARKS: Three forms of *I. hobetsensis* can be recognized: a typical form, as described above, a non-sulcate form and a nodose form. The non-sulcate form was assigned to the subspecies *I. hobetsensis nonsulcatus* by NAGAO & MATSUMOTO (1939) and MATSUMOTO (1959). This form either has an incipient radial sulcus, or lacks this character altogether. The nodose form, on the other hand, has nodose swellings on the commarginal folds on either side of the radial sulcus.

These three forms occupy a morphological continuum and all morphological grades have been observed between the forms. For this reason I believe that, under the biological species concept, they do not warrant recognition as distinct subspecies (NODA 1975).

The proportions of the three forms vary throughout the stratigraphic range of *I. hobetsensis*. The typical form is found throughout the range whereas the non-sulcate form is restricted to, and dominates, lower horizons and the nodulosus form is restricted to, and dominates, upper horizons.

KAUFFMAN (1977) suggested that the nodose form of *I. hobetsensis* is synonymous with *I.* (*I.*) *flaccidus* WHITE, 1874, from the upper Middle Turonian of the Western Interior Province of North America. Similarities between *I. flaccidus* and the nodose form of *I. hobetsensis* had been noted previously by NAGAO & MATSUMOTO (1939) and MATSUMOTO (1959).

OCCURRENCE: *I.* (*I.*) *hobetsensis* is commonly associated with *Subprionocyclus neptuni* (GEINITZ), although the latter normally occurs in the Upper Turonian.

1. Saku, Haboro and Kotanbetsu areas, northwestern Hokkaido (MATSUMOTO & OKADA 1973).
2. Obira area, northwestern Hokkaido.
3. Ikushunbetsu area, central Hokkaido.
4. Manji, Yubari and Oyubari areas, central Hokkaido.
5. Hobetsu area, southern Hokkaido.
6. Kajisako area, southern Shikoku.
7. Uwajima area, western Shikoku (TANABE 1972, TERAOKA & *al.* 1986).
8. Onogawa Basin, eastern Kyushu.

RANGE: middle part of the Turonian.

Inoceramus (*Inoceramus*) *teshioensis* NAGAO & MATSUMOTO, 1939
Pl. 1, Figs la-b, 2, 4, 6-7

1939. *Inoceramus teshioensis* NAGAO & MATSUMOTO, p. 274, Pl. 24, Figs 6, 7, 9; Pl. 26, Figs 5-7.

specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
OES51019	20.7	18.0	-	13.0	22.5	-	90°	-	114°	65°	0.87	-	-	0.72
JG.H2238	50.3	43.1	-	18.8	55.0	43.3	97°	72°	132°	66°	0.86	-	0.79	0.44
JG.H2240	41.3	37.9	-	17.6	42.6	35.8	107°	80°	131°	64°	0.92	-	0.84	0.46
JG.H2185	45.7	38.3	-	16.3	47.2	36.4	107°	-	125°	68°	0.84	-	0.77	0.43
JG.H3078a	40.0	34.5	15.0	17.4	42.5	33.6	102°	-	129°	68°	0.86	0.38	0.79	0.50
JG.H3078b	40.8	33.5	16.4	-	44.6	34.2	101°	-	-	65°	0.82	0.40	0.77	-
JG.H3519	35.0	29.8	11.0	-	36.0	29.2	-	82°	-	-	0.85	0.31	0.81	-
JG.H3520	28.1	21.5	10.2	12.6	29.1	23.0	122°	76°	126°	75°	0.77	0.36	0.79	0.59
JG.H3522	36.2	31.5	-	17.4	39.8	31.2	97°	-	122°	63°	0.87	-	0.78	0.55
lectotype	28	24	8	14	29	25	-	-	-	-	0.86	0.29	0.86	0.58

Table 1. Measurements of *Inoceramus* (*Inoceramus*) *teshioensis* NAGAO & MATSUMOTO; linear dimensions in mm
Abbreviations: l/h – simple ratio of shell length vs. shell height, b/h – simple ratio of shell width vs. shell height, L/H – simple ratio of L vs. H, s/l – simple ratio of length of hinge line vs. shell length; for other symbols readers may refer to Text-fig. 2

1959. *Inoceramus teshioensis* NAGAO & MATSUMOTO; MATSUMOTO, p. 84.
1975. *Inoceramus teshioensis* NAGAO & MATSUMOTO; Noda, pp. 251-253, Pl. 35, Figs 2-7.
1976. *Inoceramus teshioensis* NAGAO & MATSUMOTO; Noda & MATSUMOTO, no. 45-265, Figs 7-9.
1977. *Inoceramus* (*Inoceramus*) *teshioensis* NAGAO & MATSUMOTO; KAUFFMAN, p. 178.
1982. *Inoceramus* (*Inoceramus*) *teshioensis* NAGAO & MATSUMOTO; MATSUMOTO & *al.*, p. 56, Pl. 8, Fig. 5, Pl. 9, Figs 6-8.
1993. *Inoceramus teshioensis* NAGAO & MATSUMOTO; ZONOVA & *al.*, pp. 103-104, Pl. 40, Figs 13-15.

MATERIAL: 12 specimens from the Ponbetsu area, Hokkaido, 7 from the Ikushunbetsu area, Hokkaido, 23 from the Kajisako area, Shikoku and 20 from the Onogawa Basin, Kyushu.

MEASUREMENTS: Measurements are shown in Table 1.

DIAGNOSIS: Shell rather small, with maximum size of about 90 mm in H, slightly inequivalve, moderately convex, slightly higher than long, surface ornamented with major ribs and minor rings in combination which are regular in size and intensity.

REMARKS: For details of the specific characters refer to NAGAO & MATSUMOTO (1939) and NODA (1975). The specimens examined from various areas of Hokkaido are, in general, well-preserved, showing the original shell shape, and those from other areas are more or less secondarily deformed or crushed. Secondarily deformed specimens may superficially resemble other species through elongation of the outline, broadening and flattening of the shell convexity and/or apparent strengthening of the ornament.

AFFINITY: Some specimens of *I.* (*I.*) *teshioensis* resemble *I.* (*I.*) *tenuistriatus* in the small size, shell convexity and marginal outline, but are distinct in surface ornamentation. According to MATSUMOTO (1959), certain specimens of *I.* (*I.*) *teshioensis*, are also similar to *I.* (*I.*) *costellatus* WOODS, 1911, from the Upper Turonian of England. Recently MATSUMOTO & ASAI (1996) have noticed that *I.* (s.l.) *kamuy*, from the Lower Turonian of Hokkaido, resembles in some respects both *I.* (*I.*) *teshioensis* from Japan and *I. perplexus* WHITFIELD, 1877, from the Western Interior, but pointed out distinctions (MATSUMOTO & ASAI, 1996, pp. 382-383). No linking species has been found from the middle Turonian.

JG.H3522 specimen (Pl. 1, Fig. 6), one of the samples from loc.Ik2014d of *I.* (*I.*) *teshioensis* is similar to *I.* (*I.*) *costellatus* in general outline and rib density. This seems to support the previous comments by MATSUMOTO (1959).

OCCURRENCE: *I.* (*I.*) *teshioensis* occurs commonly in the Upper Turonian of various regions in Japan.

1. Nakagawa district of the Teshio Mountains. Abeshinai, Saku area in previous papers, including the type locality, northern Hokkaido; Member IIId3, upper part of the Saku Formation, Middle Yezo Group (MATSUMOTO & OKADA 1973).

2. Obira area, northwestern Hokkaido; Units Mn, Mo, correlative of the upper part of the Saku Formation (MATSUMOTO & OKADA 1973).

3. Mikasa area (Ponbetsu, Ponbetsu-Gono-sawa and the main part of R. Ikushunbetsu areas), central Hokkaido (*see* chapter on stratigraphy); Member IIIa, IIIá, Upper Yezo Group.

4. Hobetsu area, southern Hokkaido, along the R. Hobetsu, near the confluence of the Nutapomanai-zawa; the correlative of the upper part of the Saku Formation, Upper Yezo Group (MATSUMOTO & OKADA 1973).

5. Kajisako area, south Shikoku, loc. M-51; lower part of the Lower Kajisako Formation, Sotoizumi Group (TASHIRO & *al.* 1982).

6. Uwajima area, western Shikoku; upper member of the Ogura Formation, Uwajima Group (TERAOKA & *al.* 1986).

7. Onogawa Basin, eastern Kyushu ; upper member of the Ryozen Formation, Onogawa Group.

I. (*I.*) *teshioensis* is associated with *I.* (*I.*) *tenuistriatus*, *I.* (*I.*) *pedalionoides* , *M. incertus*, rarely with *I.* (*I.*) *hobetsensis* and *I.* (*I.*) *iburiensis*. Various ammonites are associated in some sediments: *Subprionocyclus neptuni* (GEINITZ) , *S. bravaisianus* (D'ORBIGNY), *S. normalis* (ANDERSON) and *Reesidites minimus* (HAYASAKA & FUKADA) are important for interregional correlation.

RANGE: *I.* (*I.*) *teshioensis* is restricted to the Upper Turonian in Japan and adjacent areas, characterising a distinct zone above the zone of *I.* (*I.*) *hobetsensis*. Exceptionally, for example, on the route of the Ganseki-zawa (Ikushunbetsu area, locs.Ik1712, 1715, 1718 in ascending order) (UCHIDA & NODA 1998 *in press*), *I.* (*I.*) *teshioensis* co-occurs with the typical form of *I.* (*I.*) *hobetsensis*. The two specie co-occur also in loc. H2467, in Hobetsu area. The level with co-occurrence of these two species may be regarded, at least tentatively, as the base of the Upper Turonian.

Inoceramus (*Inoceramus*) *iburiensis* NAGAO & MATSUMOTO, 1939
Pl. 2, Figs la-d, 2a, b; Pls 16-17

1939. *Inoceramus iburiensis* NAGAO & MATSUMOTO, pp. 291-293, Pl. 31, Figs 1-2, Pl. 32, Fig. 2.
1965. *Inoceramus iburiensis* NAGAO & MATSUMOTO; VERECHAGIN & *al.*, p. 41, Pl. 30, Fig. 1, Pl. 31, Fig. 1, Pl. 32, Fig. 1.
1971. *Inoceramus iburiensis* NAGAO & MATSUMOTO; PERGAMENT, pp. 120-122, Pl. 69, Fig. 1, Pl. 70, Fig. 1, Pl. 71, Fig. 1, Pl. 72, Fig. 1, Pl. 73, Fig. 1.
1976. *Inoceramus iburiensis* NAGAO & MATSUMOTO; NODA & MATSUMOTO, No. 45-266, Figs 7-8.
1977. *Inoceramus iburiensis* NAGAO & MATSUMOTO; KAUFFMAN, p. 179.
1981. *Inoceramus* (*Inoceramus*) *iburiensis* NAGAO & MATSUMOTO; MATSUMOTO, pp. 18-20; Pl. 2, Figs 1-2; Pl. 4, Figs 1, 3; Pl. 5, Fig. 2.
1982. *Inoceramus* (*Inoceramus*) *iburiensis* NAGAO & MATSUMOTO; MATSUMOTO, pp. 2-3, Pl. 1, figs 1-4.
1982. *Inoceramus* (*Inoceramus*) cf. *iburiensis* NAGAO & MATSUMOTO; MATSUMOTO & *al.*, p. 56, Pl. 9, Fig. 9.

LECTOTYPE: GMH7208 (HK7208 of NAGAO & MATSUMOTO 1939, Pl. 31, Fig. la-c) from the Oyubari area, Hokkaido, designated by MATSUMOTO (1981).

MATERIAL: KMNH.IvP100,004 (LV), GK. H10089 (LV), JG.H40-1040(RV), 40-1041 (LV), 3502 (RV) from the Obira area; JG. H3504 (LV), 3505 (RV) from the Oyubari area, KMNH. TvP100,002 (LV), JG.H3501 (RV) from the Hobetsu area, Hokkaido, OES03067 (LV), 03098 (RV) and 03126 (RV) from the Kajisako area, Shikoku.

MEASUREMENTS: Measurements are shown in Table 2.

DESCRIPTION: Shell large, sometimes huge (H up to 43 cm); subequivalve, inequilateral, considerably inflated from anterior to posterior and also along growth axis, especially so in umbonal region, anterior face broad, angularly bent from the disk and nearly perpendicular or somewhat concave to plane of commissure.

specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
KMNH IvP 100,002	285	185+	92.5	150	290	230	123	70	-	87	0.65+	0.32	0.79	0.81-
KMNH IvP 100,004	228 95.1	220 90.0	100 -	- 63.0	250 -	200 -	123 -	67 -	- -	90 -	0.88 0.95	0.44 -	0.80 -	- 0.60
JG.H3501	106.0	-	33.8	36.2	115.2	-	100	-	-	78	-	0.32	-	-
JG.H3502	113.6	100.0	80.2	67.7	125.5	98.1	104	73	-	78	0.88	0.71	0.78	0.68
JG.H3504	124.9	86.4	64.8	-	129.7	100.4	120	78	-	84	0.69	0.52	0.77	-
JG.H3506	177.6	129.3	86.8	97.9	177.6	142.0	102	74	74	80	0.73	0.49	0.80	0.76
JG. H40-1041	421	289	120	120	483	278	128	72	-	77	0.69	0.29	0.63	0.42
JG. H40-1040	370	320	136	-	390	312	141	72	-	82	0.86	0.38	0.80	-

Table 2. Measurements of *Inoceramus* (*Inoceramus*) *iburiensis* NAGAO & MATSUMOTO from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

Posterior part steep or moderately sloped and passing to broad and flat posterior wing. Anterior hinge angle 90° on average. Outline of shell subtrapezoidal, as high as long in youth, gradually becoming higher with growth, and with nearly straight ventral margin in adult stage. Hinge line longer than two-thirds of shell length. Umbo terminal, large, projected over hinge line and strongly incurved.

Surface ornamented by major concentric ribs and minor concentric rings in combination. The former coarse, round-topped and separated by broad concave interspaces, rapidly weakening towards anterior face and on posterior slope. A shallow groove runs somewhat posteriorly along growth axis. At the intersection between a radial sulcus and concentric ribs, the ribs become somewhat low, irregular and weakly sinuous. Concentric rings superimposed on ribs and interspaces, but sometimes oblique to major ribs. Two radial ridges developed from somewhat behind umbo to the venter, of which the anterior one demarcates the anterior face from the flank, and the other one, along the growth axis, sharply delimits the posterior slope from the disk.

REMARKS: The original definition of *I.* (*I.*) *iburiensis* given by NAGAO & MATSUMOTO (1939, p. 291) on the basis of four syntypes was more or less obscure, as MATSUMOTO (1981) pointed out. MATSUMOTO (1981) clearly redefined the species in Japanese. The morphological characters of the species are distinct, as described above.

COMPARISON: *I.* (*I.*) *iburiensis* is somewhat similar to *I.* (*I.*) *hobetsensis* in its subequivalve character, outline, and surface ornament, but is distinguished from the latter species by its conspicuously inflated umbonal region, strongly incurved umbo, truncate anterior face, which is bent sharply from the disk. *I.* (*I.*) *percostatus* MÜLLER, 1887, from the Coniacian of Germany and Caucasus is also similar to the present species in general outline, shell convexity and the ornament of coarse concentric ribs with a shallow median sulcus. As MATSUMOTO (1981) mentioned, *I.* (*I.*) *percostatus* differs from the present species in its higher stratigraphic occurrence in the Coniacian in comparison to the upper Middle to lower Upper Turonian range of the present species, its indistinct or narrower posterior auricle, minor concentric ornament distinct even in the umbonal region and the conspicuously inflated shell throughout growth; whereas the present species has a well developed posterior auricle which is clearly demarcated from the flank, strongly incurved umbo and broad and truncated anterior face which is sharply bent from the flank. KAUFFMAN (1977a) noted the resemblance between *I.* (*I.*) *iburiensis* and *I.* (*I.*) *lamarcki stuemckei*, HEINZ, 1926, as illustrated by TRÖGER (1967, Pl. 5, Fig. 9; Pl. 6, Fig. 6), and pointed out that the two species may be synonymous. However, the morphological distinction between these species is clear, as has already been pointed out by MATSUMOTO (1981).

PHYLOGENY: *I.* (*I.*) *iburiensis* can be inferred to be derived from *I.* (*I.*) *hobetsensis*, because of the similarity of the ontogenetic development and stratigraphical occurrence. MATSUMOTO (1959) suggested a close relationship between *I.* (*I.*) *iburiensis* and the species *I.* (*I.*) *flaccidus* WHITE, 1874, from the Middle Turonian of the Western Interior. *I.* (*I.*) *flaccidus* is similar to the nodose form of *I.* (*I.*) *hobetsensis* [= *I.* (*I.*) *flaccidus* in KAUFFMAN's sense, 1977a with whom I agree]. This relationship is in harmony with the assumed lineage of *I.* (*I.*) *hobetsensis* to *I.* (*I.*) *iburiensis*.

OCCURRENCE :

1. The type locality is recorded as Hakkin-zawa (so-called Shirakin-zawa) of Oyubari area , Yubari Mountains of central Hokkaido.

2. Obira area, northwestern Hokkaido. Locs. R2114, 2117, Unit Mm-n; upper part of Middle Yezo Group. Loc.Ob2100, Unit Mn-o, upper part of middle Yezo Group along the R. Kamikinenbetsu. At loc.Ob2100 it is associated with huge specimens of *I.* (*I.*) *hobetsensis* and *I.* (*Cr.*) *ernsti*.

3. Oyubari area, central Hokkaido. In addition to the type locality, Loc. Ku0104p. (=Y121023 of HIRANO et al., 1989, p. 29), Isojirono-sawa, Unit Uyl, lower part of the Upper Yezo Group. Associated with large specimens of *I.* (*I.*) *hobetsensis*.

4. Hobetsu area, southern Hokkaido. Locs. H2125, 2123, 2135 along the Nutapomanai-zawa, a tributary of the R.Hobets (MATSUMOTO & OKADA 1973). *I.* (*I.*) *iburiensis* occurs in the upper part of the Zone of *I.* (*I.*) *hobetsensis*.

5. Kajisako area, south Shikoku. Loc. M-03, lower part of the Kajisako Formation, Sotoizumi Group (TASHIRO & *al.* 1982).

RANGE: Upper part of the Middle Turonian to the lower part of the Upper Turonian.

Inoceramus (*Inoceramus*) *pedalionoides* NAGAO & MATSUMOTO, 1939
Pl. 1, Fig. 9; Pl. 3, Figs la-b, 2, 3a-b

1939. *Inoceramus pedalionoides* NAGAO & MATSUMOTO, pp. 277-279, Pl. 26, Figs 8-9.

LECTOTYPE: IGPS22720 (=Sd22720) figured by NAGAO & MATSUMOTO (1939, Pl. 26, Fig. 8a-c) designated herein.

MATERIAL: IGPS22720 (lectotype); JG.H3261 from loc. Ik2013d" of the Ponbetsu area, central Hokkaido, JG.H3519 from Ob0003 and JG.H3520 from NH13c (TANAKA, 1963) of the Obira area, northwestern Hokkaido.

MEASUREMENTS: Measurements are shown in Table 3.

RELATIVE GROWTH: Due to an insufficient number of specimens for statistical analysis of average relative growth, individual relative growth is examined for both valves of specimen JG.H3261. The relative growth between shell length (1) vs. shell height (h) and shell width (b) and shell height (h) are shown in Text-fig. 3. The analysis shows the relative growth between 1 vs. h exhibiting negative allometry in both valves and that between b vs. h, positive allometry in both valves..

DESCRIPTION: Shell small to medium sized, attaining 65 mm in H, inequivalve and inequilateral, much higher than long, considerably inflated from anterior to posterior and moderately and uniformly convex along growth axis. Left valve more inflated than right. Anterior

specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
IGPS22720LV	48.1	30.8	21.4	20.2	50.4	31.0	88°	63°	108°	74°	0.64	0.44	0.62	0.66
IGPS22720RV	46.8	30.8	13.9	19.9	47.0	37.0	92°	-	110°	73°	0.66	0.30	0.79	0.65
JG.H3261LV	59.6	40.2	30.5	22.6	65.8	37.0	96°	80°	112°	80°	0.67	0.51	0.52	0.56
JG.H3261RV	54.6	39.2	20.2	22.6	57.0	43.1	98°	85°	117°	80°	0.72	0.37	0.76	0.58
JG.H3520LV	36.8	25.3	16.6	13.9	38.2	23.2	103°	80°	113°	73°	0.69	0.45	0.61	0.55

Table 3. Measurements of *Inoceramus* (*Inoceramus*) *pedalionoides* NAGAO & MATSUMOTO; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

face truncated, perpendicular to plane of commissure and abruptly or sharply bent from disk, posterior half gradually or steeply sloping to margin, and posterodorsal. part steep, showing distinct boundary with wing-like area. Umbo small, terminal, curved and somewhat twisted forwards, left one more projected over hinge line than right. Anterior margin very long and straight, and narrowly bent at anteroventral margin, ventral one rounded and continuing to broadly convex posterior margin which forms an obtuse angle with hinge line. Hinge line more than half of shell length.

Surface ornamented by major concentric ribs or undulations and minor concentric rings in combination. Major ornament variable in intensity from almost smooth to fairly distinct, and irregular in breadth and shape, minor rings also variable in intensity, being scarcely perceptible to distinct, round-topped, crowded and regular in breadth.

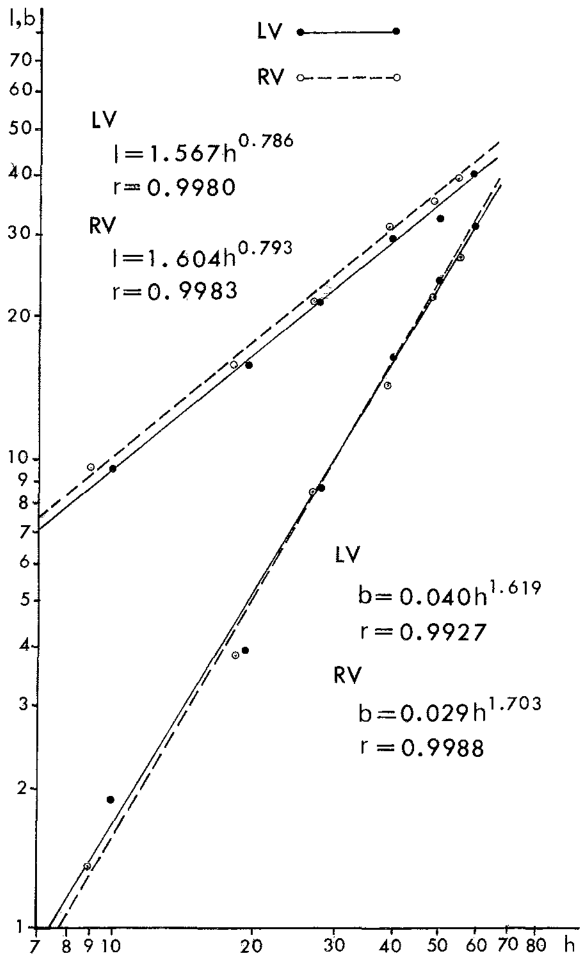


Fig. 3. Diagram showing individual relative growth between l and h, and b and h of *Inoceramus* (*I.*) *pedalionoides* JG.H3261

REMARKS: The present species shows fairly high variability in outline, shell convexity and surface ornament. These apparent morphological variation, however, relates to various growth stages or to secondary deformations. In the lectotype and the topotype specimen JG.H3261 the shell is smooth or only weakly ornamented. In contrast the specimen JG.H3519 and 3520, from the Obira area, possess well developed concentric ribs and rings. In specimen JG.H3519 the ribs are, moreover, enhanced by deformation.

COMPARISON: As originally mentioned by NAGAO & MATSUMOTO (1939), the young shell of *I.* (*I.*) *pedalionoides* closely resembles *I.* (*I.*) *tenuistriatus* in its slightly inequivalve character, umbonal inflation, marginal outline of dorsal part, more or less developed wing and the same type of surface ornament. In later ontogenetic stages, however, *I.* (*I.*) *pedalionoides* becomes distinct from *I.* (*I.*) *tenuistriatus* in its much higher outline, longer and more broadly rounded posterior margin and truncated anterior face. Moreover, in biometric analysis of the relative growth, *I.* (*I.*) *pedalionoides* shows negative allometry between l vs. h, and positive allometry between b vs. h, whereas *I.* (*I.*) *tenuistriatus* shows isometry in both l vs. h and b vs. h (NODA 1988, pp. 586-590).

I. (*I.*) *pedalionoides* is also similar to specimens of *I.* (*I.*) *apicalis* WOODS, 1911, from the Middle and lower Upper Turonian of Europe and the N. American Western Interior, in its small size, vaulted shell and surface ornament with distinct minor rings and blunt major ornament but clearly distinguished from that species in its characteristic pedal-like outline, less prominent umbo, broad anterior face truncated sharply from the disk and anteriorly concave growth axis.

PHYLOGENY: KAUFFMAN (1977a) suggested that the present species belonged to the *I.* (*I.*) *pictus* – *I.* (*I.*) *apicalis* phylogenetic lineage, on the basis of morphological resemblance and stratigraphical occurrence. Unfortunately, *I.* (*I.*) *apicalis* has not been obtained from anywhere in Japan. The resemblance in the early ontogenetic stage between *I.* (*I.*) *pedalionoides* and *I.* (*I.*)

tenuistriatus implies a close relationship between both species. In my opinion, *I.* (*I.*) *pedalionoides* was certainly derived from *I.* (*I.*). *tenuistriatus*.

OCCURRENCE:
1. Type locality: Ponbetsu area, probably loc.Ik2013 on the R. Ponbetsu, central Hokkaido; Member IIIa' of the Upper Yezo Group.

2. Obira area, northwestern Hokkaido. For details see Chapter of Stratigraphy. Loc.NH13c (*see* TANAKA 1963, Map. 11), left bank of the R. Obirashibe about 300m downstream from the confluence with the Jugosen-zawa; Unit Ub of the Upper Yezo Group, associated with *I.* (*I.*) cf. *uwajimensis*. This place is submerged beneath the artificial Lake Obirashibe.

3. Onogawa Basin, eastern Kyushu, loc.ON201, upper member of the Nakakawarauchi Formation, Onogawa Group.

RANGE: As is clear from the stratigraphic positions of the localities and associated species the range of the present species is from the Upper Turonian to the upper Lower Coniacian.

Inoceramus (*Inoceramus*) *tenuistriatus*
NAGAO & MATSUMOTO, 1939
Pl. 3, Figs 4a-c, 5, 6, 9a-c

1939. *Inoceramus tenuistriatus* NAGAO & MATSUMOTO, pp. 272-274, Pl. 24, Fig. 8, Pl. 26, Figs 1-4.
1966. *Inoceramus tenuistriatus* (?) NAGAO & MATSUMOTO; PERGAMENT, pp. 47-48, Pl. 13, Figs 2-4; Pl. 14, Figs 2-4.
1976. *Inoceramus tenuistriatus* NAGAO & MATSUMOTO; NODA & MATSUMOTO, no. 45-265, Fig. 6.
1980. *Inoceramus tenuistriatus* NAGAO & MATSUMOTO; FUTUKAMI & *al.*, Pl. 8, Fig. 9.
1988. *Inoceramus tenuistriatus* NAGAO & MATSUMOTO; NODA, pp. 584-595, Figs 5-8.

LECTOTYPE: GMH7192 (=HK7192 of NAGAO and MATSUMOTO, 1939, p. 262, pl. 26, fig. 1) designated by PERGAMENT (1966, p.47) from the Ponbetsu area, central Hokkaido.

MATERIAL: 91 specimens from localities Ik2012-2014 in the Ponbetsu area, and several specimens from the Ikushunbetsu, Ponbetsu-Gonosawa and Obira areas. For details *see* NODA (1988).

MEASUREMENTS: Measurements are shown in Table 4.

DIAGNOSIS: Shell small (H below 50 mm), inequivalve and inequilateral, considerably inflated from anterior to posterior and also along growth axis. Umbo small, terminal and slightly projected over hinge line. Hinge line more than half of shell length, general outline pentagonal. Surface ornamented with very fine concentric

	specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
left valve	IGPS22751	29.9	26.0	11.0	16.0	33.0	27.0	109°	80°	113°	71°	0.87	0.37	0.82	0.62
	GMH7192	24.0	21.0	11.8	14.0	27.0	23.0	110°	82°	120°	65°	0.88	0.49	0.85	0.67
	GK.H8280b	17.2	14.3	6.0	9.6	20.3	14.0	98°	88°	116°	58°	0.83	0.35	0.69	0.67
	GK.H8284	27.0	21.6	10.5	12.4	28.8	20.6	105°	84°	117°	67°	0.80	0.39	0.72	0.57
	JG.H2862a	31.2	26.5	12.2	15.7	36.0	28.0	107°	76°	115°	76°	0.85	0.39	0.78	0.59
	JG.H2968a	26.0	21.2	10.4	13.8	27.6	23.8	108°	78°	104°	78°	0.82	0.40	0.86	0.65
right valve	IGPS22751	27.0	24.0	9.0	17.2	30.0	25.0	90°	90°	115°	66°	0.89	0.33	0.83	0.72
	GMH7187	22.0	19.0	8.0	12.8	24.0	21.0	99°	89°	112°	68°	0.86	0.36	0.88	0.67
	GK.H8278a	24.3	18.8	6.4	15.0	26.4	23.8	92°	90°	111°	54°	0.77	0.26	0.90	0.80
	GK.H8279b	15.8	12.9	3.9	8.5	16.7	13.3	99°	85°	115°	60°	0.82	0.25	0.80	0.66
	JG.H2863c	24.3	17.5	8.2	8.6	26.0	19.0	106°	85°	106°	70°	0.72	0.34	0.73	0.49
	JG.H2975a	23.7	18.6	8.1	10.0	26.2	20.7	110°	98°	117°	72°	0.78	0.44	0.79	0.54

Table 4. Measurements of *Inoceramus* (*Inoceramus*) *tenuistriatus* NAGAO & MATSUMOTO; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

lirae and low and narrow concentric rings. Low and broad concentric undulations may occur rarely.

REMARKS: This species is quite distinct in its small size (less than 50 mm in H), vaulted shell, pentagonal outline and fine ornament. According to biometric analysis (NODA 1988, pp. 585-589) the extent of variation in shell form is small except for the shell convexity and ratio s/l, and slightly inequivalve.

For the comparison of this species with *I.* (*I.*) *pedalionoides* see the description of that species.

Despite the original description and figures by NAGAO & MATSUMOTO (1939), various forms from the Cenomanian outside Japan have been incorrectly assigned to the present species. The so-called "*I.* (*I.*) *tenuistriatus*" from various horizons of Euramerica and the Pacific Coast of Russia is morphologically distinct from the population sample from the type locality (NODA 1988, p. 588, 591, 593). To settle the above confusion, NODA (1988) redefined the present species. I agree with MATSUMOTO & TANAKA (1988) in their remarks that some specimens of so-called *I.* (*I.*) *tenuistriatus* from outside Japan should be preferably assigned to the species *I. nodai* MATSUMOTO & TANAKA, 1988, from the Upper Cenomanian of the Ikushunbetsu and Oyubari areas, central Hokkaido.

COMPARISON: *I.* (*I.*) *inaequivalvis* SCHLÜTER, 1877, from the upper Turonian of Europe and *I.* (*I.*) *submametensis* ZONOVA, 1982, from the Middle Turonian of the Pacific Coast of Russia are somewhat similar to *I.* (*I.*) *tenuistriatus*. However, *I.* (*I.*) *inaequivalvis* is distinguished from *I.* (*I.*) *tenuistriatus* by its broad wing, well developed major ribs, distinct inequivalveness and longitudinally rectangular outline. *I.* (*I.*) *submametensis* is also distinguished from the present species by its well developed posterior auricle and concentric ribs.

OCCURRENCE:
1. Type locality, loc. Ik2013, see the item of *I.* (*I.*) *pedalionoides*.
2. Ponbetsu – Gono – sawa, loc. Ik2727; Member IIIa' of the Upper Yezo Group, associated with *Lymaniceras planulatum*. For the locality, refer to MATSUMOTO (1984, fig. 4) or MATSUMOTO & NODA (1985, fig. 1).

Occurrences of *I.* (*I.*) *tenuistriatus* have been recorded by a number of researchers from various areas, such as the Soashibetsu, Hatonosu, Manji, Oyubari and Hobetsu areas of central Hokkaido, the Obira area of northwestern Hokkaido and the Uwajima area, western Shikoku. Some specimens from the previously listed localities may, however, need reexamination based on the revised definition.

RANGE : The examined specimens came from the Upper Turonian in the limited area of Hokkaido. The true range and the geographic distribution of the species have yet to be worked out.

Inoceramus (*Inoceramus*) *lusatiae* ANDERT, 1911
Pl. 4, Figs la-c, 2a-c, 3a, b, 4

1911. *Inoceramus lusatiae* ANDERT, pp. 54, 56, Pl. 2, Figs la-b, Pl. 3, Fig. 3, Pl. 8, Figs 3-5.
1934. *Inoceramus lusatiae* ANDERT; ANDERT, p. 126, Pl. 7, Figs 1-3, Text-figs 14a-b.
1967. *Inoceramus lusatiae* ANDERT; TRÖGER, pp. 73-76, Pl. 8, Figs 2-3.
1977. *Mytiloides lusatiae* (ANDERT); KAUFFMAN, pp. 240, 243, Pl. 9, Figs 17, 23.
1992. *Inoceramus lusatiae* ANDERT; WALASZCZYK, pp. 32-33, Pl. 27, Figs 1-3, 5-6.
1996. *Inoceramus* (*Inoceramus*) *lusatiae* ANDERT; NODA, pp. 558-564, Figs 2-1a-e, 2-2a- e, 3-1a-c, 3-2, 3-3, 3-4 (cum synonymy).
non 1971. *Inoceramus lusatiae* ANDERT; PERGAMENT, pp. 94-95, Pl. 23, Fig. 1.

LECTOTYPE: The specimen figured by ANDERT (1911, Pl. 2, Figs la-b) and TRÖGER (1967, Pl. 8, Figs 2a-b) was designated as the lectotype by TRÖGER (1967).

MATERIAL: 7 specimens, JG.H3095, 3096, 3100, 3101, 3102, 3201 and 3202 from the Ashiyachi-zawa in the Ikushunbetsu Valley, central Hokkaido.

MEASUREMENTS: Measurements are shown in Table 5.

DIAGNOSIS: Shell nearly equivalve, highly inequilateral and oblique, with some variation; valves variably inflated. Outline with guitar-like

specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
JG.H3095LV	73.0	62.0	25.0	-	79.0	63.0	-	89°	-	64°	0.85	0.34	0.80	-
JG.H3095RV	81.0	66.0	26.8	-	86.0	68.0	120°	86°	60°	66°	0.81	0.33	0.79	-
JG.H3096LV	70.7	61.4	24.5	33.0	75.0	57.0	120°	79°	-	67°	0.87	0.35	0.76	0.54
JG.H3096RV	70.7	61.4	23.0	33.0	75.0	57.0	114°	84°	-	67°	0.87	0.33	0.79	0.54
JG.H3100RV	76.0	62.7	21.3	43.8	89.0	70.0	100°	76°	87°	57°	0.83	0.28	0.79	0.70

Table 5. Measurements of *Inoceramus* (*Inoceramus*) *lusatiae* ANDERT from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

concaved posterior margin; posterior auricle triangular and sharply delimited from disc (for details *see* NODA, 1996, pp. 558-564).

REMARKS: The available specimens are mainly well preserved, retaining the original outline. The obliquity (δ) ranges from 57 to 67° and the shell convexity (b/h) ranges from 0.28 to 0.33 in the right valve. In JG.H3096 (Pl. 4, Fig. 3), the small anterior auricle develops, but this is an exceptional case not described originally by ANDERT (1911, 1934) or TRÖGER (1967). According to TRÖGER (*personal communication*, 1993) the ontogenetic changes of Na/Ha, Vo/Ha and Wa in the Japanese specimens (JG.H3095, 3096) are in the range of variation of the German ones (*see* NODA 1996, p. 563, fig. 7), but the surface ornament is distinct between the two groups. This may imply the possibility of the existence of geographic subspecies.

PHYLOGENY: TRÖGER (1969, p. 74) suggested that *I.* (*I.*) *lusatiae* may be derived immediately from *I.* (*I.*) *lamarcki stuemckei* HEINZ, 1926 on the basis of morphological resemblance and stratigraphical occurrence. As has been mentioned recently (NODA 1996, p. 563), some specimens comparable with *I.* (*I.*) *lamarcki stuemckei* have been obtained from the Middle Turonian of Hokkaido. Although not described in detail, a specimen is figured herein (Pl. 1, Fig. 8) for reference. PERGAMENT's specimen of *I. lusatiae* (PERGAMENT 1971, Pl. 23, Fig. 1) from the uppermost Turonian of Kamchatka should be referred to *I.* (*I.*) *lamarcki*.

OCCURRENCE: Localities. Ik7000, 7001, 7002 and 7003 along the lower reaches of the Ashiyachi-zawa, a tributary of the R. Ikushunbetsu, Ikushunbetsu area, central Hokkaido, may be submerged beneath the artificial Lake Katsurazawa during the full water season.
Locality Ik7000. Unit IIIa, uppermost part of the lower Upper Yezo Group, associated *with I.* (*I.*) *tenuistriatus* and *Yezoites* sp. For others see the stratigraphy chapter.

RANGE: Uppermost Turonian to Lower Coniacian.

Inoceramus (*Inoceramus*) *uwajimensis* YEHARA, 1924
Pl. 3, Figs 10, 12; Pl. 5, Figs 1a-c, 2a-b, 3, 4a-d; Pl. 6, Figs 1, 3

pars 1924. *Inoceramus uwajimensis* YEHARA, pp. 36-37, Pl. 3, Figs 1-2 [*non* Pl. 4, Figs 1, and 3 which is *Inoceramus* (*Inoceramus*) *hobetsensis* NAGAO & MATSUMOTO].

1939. *Inoceramus uwajimensis* YEHARA; NAGAO & MATSUMOTO, p. 286, Pl. 34, Figs 1, 3-4, 6, Pl. 35, Figs 1-3.

1939. *Inoceramus uwajimensis* YEHARA, *em.* var. *yeharai* NAGAO & MATSUMOTO, pp. 287-291, Pl. 33, Figs 2, 5; Pl. 34, Fig. 4.

1962. *Inoceramus yeharai* NAGAO & MATSUMOTO; SAITO, pp. 66-67, Pl. 1, Figs 19- 20.

1975. *Inoceramus uwajimensis* YEHARA; NODA, pp. 253-256, Pl. 36, Figs 1-8; Pl. 37, Figs 1-2, 4.

1982. *Inoceramus* (*Inoceramus*) *uwajimensis* YEHARA; MATSUMOTO & *al.*, pp. 57-58, Pl. 9, Figs 10-11; Pl. 10, Fig. 2.

1994. Inoceramus (Inoceramus) uwajimensis Yehara; Noda, pp. 17-19, Pl. 4, fig. 2; Pl. 5, fig 1; Pl. 6, figs 1, 2, 4-6.

LECTOTYPE: One of the syntypes of YEHARA (1924, Pl. 3, Fig. 2), from the Furushiroyama shale

specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
JG.H2066LV	63.8	55.6	19.6	-	70.0	56.5	100°	73°	-	79°	0.87	0.31	0.81	-
JG.H2154LV	77.0	65.2	-	-	84.3	62.3	95°	87°	-	68°	0.85	-	0.74	-
JG.H2166LV	67.0	62.8	14.0	27.1	74.6	61.2	95°	73°	139°	53°	0.94	0.21	0.82	0.43
JG.H3017LV	55.3	50.0	13.2	-	57.3	50.0	98°	72°	-	61°	0.90	0.24	0.86	-
JG.H3524LV	69.0	64.8	20.0	24.2	83.0	66.2	96°	79°	131°	54°	0.94	0.29	0.80	0.37
JG.H3525LV	54.4	39.7	13.4	15.2	55.5	38.8	103°	80°	136°	71°	0.73	0.25	0.70	0.38
JG.H3528LV	56.5	47.6	12.6	21.0	62.7	46.1	89°	75°	142°	56°	0.84	0.22	0.74	0.44
JG.H3529LV	45.0	41.8	17.2	16.2	51.5	39.1	88°	78°	137°	51°	0.93	0.38	0.76	0.39
JG.H3530LV	56.0	46.9	13.2	-	59.2	50.0	95°	78°	-	66°	0.84	0.24	0.84	-
JG.H3534LV	71.9	63.1	21.7	33.3	82.5	60.9	91°	73°	148°	53°	0.88	0.30	0.74	0.53
JG.H3071RV	79.0	62.9	16.6	22.2	86.2	67.8	100°	-	137°	60°	0.80	0.21	0.79	0.35
JG.H3522RV	43.7	42.6	14.6	16.7	52.8	37.8	95°	72°	132°	53°	0.97	0.33	0.72	0.39
JG.H3532RV	66.2	58.8	19.2	35.9	67.0	60.0	110°	79°	100°	68°	0.89	0.29	0.90	0.61
JG.H3535RV	46.4	38.4	-	14.7	47.2	38.6	96°	-	133°	64°	0.83	-	0.82	0.38

Table 6. Measurements of *Inoceramus* (*Inoceramus*) *uwajimensis* YEHARA; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

(Furushiroyama Formation), Uwajima Group, western Shikoku, designated by MATSUMOTO *in* TAKAI & MATSUMOTO (1961, p. 273).

MATERIAL: 20 specimens from the Ponbetsu-Gono-sawa, 22 specimens from the Okuhidarimata-zawa, Ikushunbetsu area, central Hokkaido, 22 specimens from the Futaba Group, Fukushima Pref., 12 specimens from the Furushiroyama Formation (Type locality) Uwajima Group, western Shikoku and 46 specimens from Onogawa Group, eastern Kyushu.

MEASUREMENTS: Measurements for some selected specimens are shown in Table 6.

DESCRIPTION: Shell normally medium-sized (H up to and sometimes in excess of 100 mm), slightly inequivalve, inequilateral; moderately and uniformly convex from anterior to posterior and also along growth axis. Umbo small, terminal and slightly projected over hinge line. posterior wing-like area variable in shape and extent. Beak angle (β) variable, ranging from 72° to 87°. General outline highly variable: oval, fan-shaped, pentagonal and elongate ellipse. Surface ornamentation: major concentric ribs commonly predominant, variable in density, crowded or broadening with growth, often irregular in shape, sharply acute-topped to blunt; minor riblets generally hardly perceptible, but distinct near the umbo in well preserved specimens.

REMARKS: The original material of YEHARA (1924) is heterogeneous (see synonym list), containing two specimens of *I.* (*I.*) *hobetsensis* from Kofuji, eastern Kyushu. NAGAO & MATSUMOTO (1939) redefined its specific characters on the basis of a number of specimens from various regions (including south Sakhalin), and separated a form with a distinct wing-like area from the typical form as a variety *yeharai*.

I. (*I.*) *uwajimensis* commonly occurs densely crowded in shell beds, from which large numbers of specimens can be collected. NODA (1975) examined populations of the species from Southwest Japan and analysed biometrically the morphological variation within individual populations and between successive populations. The variation is schematically illustrated in Text-fig. 4. In that paper it was concluded that the range of variation in selected characters gradually increased up section. In addition the form called *yeharai* was found to fall within the range of variability of a single population. Independently from the above biometric studies, TOSHIMITSU (*personal communication*, 1995) pointed out that the posterior wing-like area develops commonly in *I.* (*I.*) *uwajimensis* albeit with a large extent of variation, but it is readily broken off because of the delicate shell structure. In fact, a sample of Ik2710 from the Ponbetsu Gono-sawa, contains apparently variable specimens with or without wing-like areas, the latter being referable to the variety *yeharai*. *I.* (*I.*) *uwajimensis* var. *yeharai* thus describes well preserved specimens of *I.* (*I.*) *uwajimensis* that retain the posterior wing-like area, and its separation is therefore unnecessary.

KAUFFMAN (1977a) stated that, based on the illustrations in YEHARA (1924) and NAGAO & MATSUMOTO (1939) *I.* (*I.*) *uwajimensis* was synonymous with *I* (*I.*) *stantoni* SOKOLOV, 1914 [= *I.* (*I.*) *acuteplicatus* STANTON, 1899] from the Middle Coniacian of Sakhalin. However, YEHARA's original material was heterogeneous, as mentioned above.

So far as can be observed from the illustration of SOKOLOW (1914), the two species closely resemble one other, and a specimen figured by SOKOLOW (1914, Pl. 5, Fig. 7) was collected by JIMBO from south Sakhalin. PERGAMENT (1971) regarded *I.* (*I.*) *uwajimensis* and var. *yeharai* as a junior synonym of *I.* (*I.*) *stantoni*. Although he examined an adequate number of specimens there are, nevertheless, some differences between the Russian and Japanese specimens. In the Russian specimens, the concentric ribs are round-topped with wide interspaces, and are not comparable with the ribs in any form of *I.* (*I.*) *uwajimensis*, regardless of the large extent of variation in the ornament of that species. The ornament of the Russian species more resembles that of *I.* (*I.*) *hobetsensis*. However, although the synonymy between *I.* (*I.*) *stantoni* and *I.* (*I.*) *uwajimensis* is highly probable, the specific name *I.* (*I.*) *uwajimensis* is retained until detailed population studies have been carried out for the former species.

I. (*I.*) *uwajimensis* is allied to *I. kleini* MÜLLER, *I. frechi* FLEGEL, *I. glatziae* FLEGEL, *I. stillei* HEINZ and *I. guerichi* HEINZ, from the Upper Turonian to

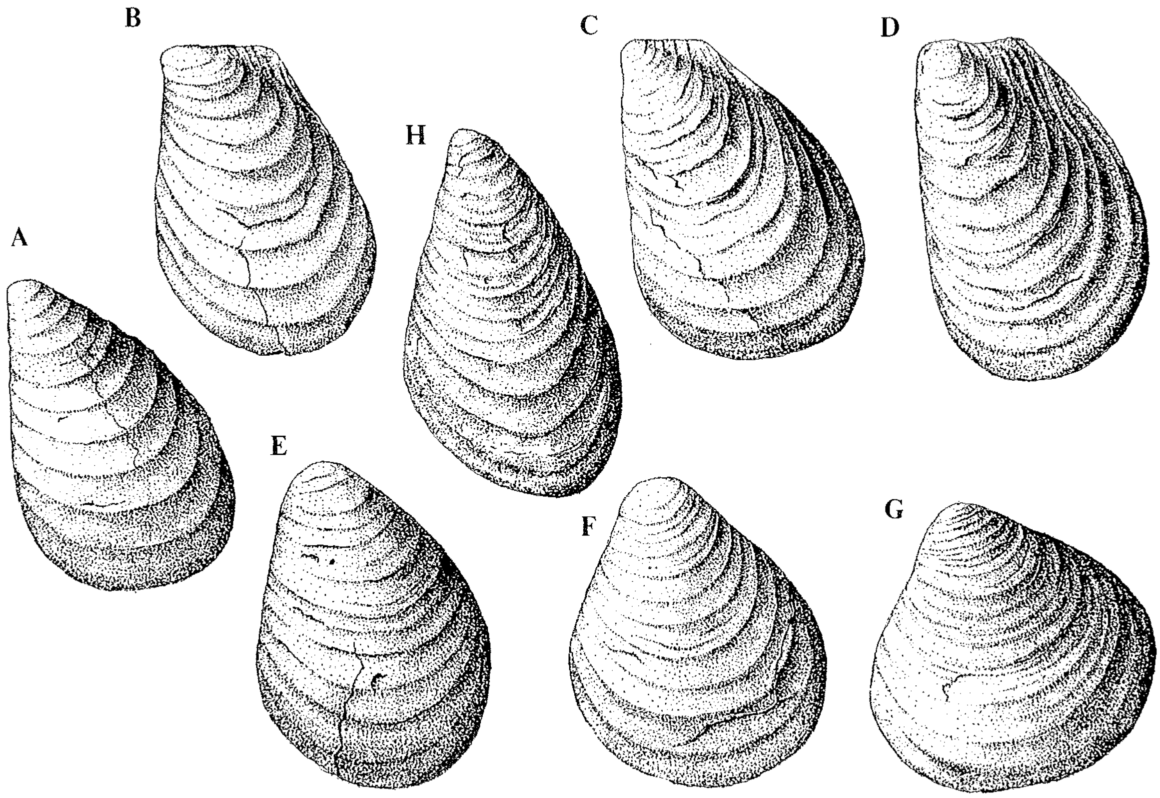


Fig. 4. Variation of outline in *Inoceramus* (*I.*) *uwajimensis*; sample UN101; A, B, and F; smple UF101 – A, B, and F; Sample OI213 – all forms; Sample OI214 – A, B, C, D, and G; Sample AS201 – A, B, D, and G (*after* NODA 1975)

Lower Coniacian of Europe, as pointed out, originally, by NAGAO & MATSUMOTO (1939). However, its actual derivation is not clear. MATSUMOTO (1959) originally assumed as a possible ancestry of *I.* (*I.*) *uwajimensis* the *I.* (*I.*) *teshioensis* – *I.* (*I.*) *costellatus* – *I.* (*I.*) *perplexus* lineage. At loc.Ik2013 on the R. Ponbetsu, a definite Upper Turonian locality, a specimen (JG.H2864) comparable with *I.* (*I.*) *uwajimensis* was exceptionally found together with *I.* (*I.*) *teshioensis*. I have also noted a similar co-occurrence of the two species in the Uwajima Group, western Shikoku.

Undoubted examples of *I.* (*I.*) *costellatus* have not been recorded from Japan, but specimens that can be compared with that species are occasionally included in populations of *I.* (*I.*) *teshioensis*. In addition to the morphological resemblance, the stratigraphic occurrence supports the lineage suggested by MATSUMOTO (1959).

The extent of variation of *I.* (*I.*) *uwajimensis* gradually increases stratigraphically upwards. Various forms linked by intermediates co-exist in a single population from any one horizon.

OCCURRENCE:

1. Type locality. Somewhere in the Uwajima area, western Shikoku.

2. Obira area. northwestern Hokkaido. Unit Ub-d, Upper Yezo Group.

3. Ponbetsu, Ikushunbetsu areas, central Hokkaido; upper part of Member IIIb, b' and lower part of Member IIIc, c', Upper Yezo Group.

4. Oyubari area, central Hokkaido; upper part of Unit U1, Upper Yezo Group (HIRANO 1986).

5. Futaba area, Fukushima Prefecture, northeast Honshu; Ashizawa Formation, Futaba Group (SAITO 1962).

6. Kajisako area, southern Shikoku; Kajisako Formation, Sotoizumi Group.

7. Onogawa Basin, eastern Kyushu; Shibakita and Inukai Formations, Onogawa Group.

For the associated species in Hokkaido, *see* MATSUMOTO 1984, pp. 176-177.

RANGE: Lower to Middle Coniacian.

Subgenus *Cremnoceramus* COX, 1969

TYPE SPECIES: *Inoceramus inconstans* WOODS, 1912, designated by COX (1969).

DIAGNOSIS: See COX (1696, p. N314) and KAUFFMAN *in* HERM & *al.* (1979, p. 58).

REMARKS: *See* KAUFFMAN (*in* HERM & *al.* 1979, p. 59) and NODA (1996, p. 571).

The geniculation in shell convexity is an essential criterion for *I.* (*Cremnoceramus*) as HEINZ (1932) and COX (1969) originally pointed out. TRÖGER (1981a), however, suggested that the geniculation should not be applied for taxonomic purposes, since it is a highly flexible feature varying with the mode of life. As discussed by KAUFFMAN (*in* HERM & *al.* 1979), *I. rotundatus* FIEGE, 1930, and *I. waltersdorfensis* ANDERT, 1911, show transitional characters between *I.* (*Inoceramus*) and *I.* (*Cremnoceramus*).

Inoceramus (*Cremnoceramus*) *ernsti*
HEINZ, 1928
Pl. 6, Figs 4a-c, 5, 6a-b. Pl. 7, Fig. la-c; Pl. 8, Fig. 1

pars 1912. *Inoceramus lamarcki* PARKINSON; WOODS, p. 325, Text-fig. 85.
1928. *Inoceramus ernsti* HEINZ, pp. 73-74.
1934. *Tethyoceramus* (*Protoceramus*) *ernsti* (HEINZ); HEINZ, p. 250, Pl. 19, Fig. 1.
1967. *Inoceramus ernsti* HEINZ; TRÖGER, pp. 128-130, Pl. 14, Figs 1-6.
? 1971. *Inoceramus* cf. *ernsti* HEINZ; PERGAMENT, pp. 119-120, Pl. 33, Fig. 2, Pl. 34, Fig. 3.
1977. *Inoceramus* (*Inoceramus*) *ernsti* HEINZ; KAUFFMAN, pp.242, 244, Pl. 11, Fig. 5.
1992. *Inoceramus* (*Cremnoceramus*) *ernsti* HEINZ;. LOPEZ, pp. 2.245-2.248, Pl. 1, Figs 4, 5a-b.
1992. *Cremnoceramus ernsti* (HEINZ); WALASZCZYK, pp. 55-56, Pl. 32, Figs 1-3.
1996. *Inoceramus* (*Cremnoceramus*) *ernsti* HEINZ; NODA, pp.576-585, Figs 5a-c, 6- 21a-c, 6-2a-d, 7-1a-c, 7-2a-c, 7-3a-d (cum synonymy).

LECTOTYPE: The specimen from the Upper Chalk of England illustrated by WOODS (1912, p. 325, Text-fig. 85) [British Geological Survey BGS GSM 21237], designated by TRÖGER (1967, p. 128). The same specimen was photographed by WALASZCZYK(1992, Pl.32, Figs 2a, b).

MATERIAL: JG.H3017, 3059, 3061 and 3023 from the Obira area, northwestern Hokkaido.
MEASUREMENTS: Measurements are shown in Table 7.

DIAGNOSIS: Shell inequivalve, moderately convex with geniculation, anterodorsal part deeply concave to plane of commissure; growth axis broadly concave to anterior; surface ornamentation fairly variable in breadth, shape and intensity (for details *see* NODA 1996, pp. 578-581).

REMARKS: *I.* (*Cr.*) *ernsti* was established by HEINZ (1928) on the basis of a single specimen (British Geological Survey BGS GSM 21237), figured by WOODS (1912a, Text-fig. 85). The original specimen comprises a well preserved, undistorted right valve that lacks the posterior margin. Therefore, the length of hinge line, development of the posterior wing, curvature of the posterior margin and the variation of the species are actually unknown. Moreover, the stratigraphic position of the original specimen is not known precisely but was cited as ?zone of *Holaster planus*, Upper Chalk [Upper Turonian *Sternotaxis plana* Zone in modern terminology; however, the style of preservation and the type of matrix suggests Lower Coniacian *Micraster cortestudinarium* Zone as a more likely provenance: editor's comment] Consequently, various forms with dissimilar ornament have been assigned to *I.* (*Cr.*) *ernsti* by different authors. The specimens from Japan comprise diverse forms with various types of ornament, but they are all referable to some form previously assigned to that species. JG.H3023 (Pl. 7, Fig. 1) from the upper Upper Turonian somewhat resembles *I.* (*I.*) *hobetsensis*, but its deeply concave anterior face is too well developed for that species, and rather similar to that of *I. (Cr.) ernsti*. JG.H3017 (Pl. 6, Figs 5, 6a-b; Pl. 8, Fig. 1) from the Lower Coniacian consists of separated valves: the left valve is in ornament different from that of JG.H3023 but its right valve compares well in outline and shell convexity with the type. WE.P1321 (Pl. 6, Fig. 4), from the Lower Coniacian, is an immature right valve with a nearly smooth surface; its marginal outline and concave growth axis closely resemble those of the lectotype.

PHYLOGENY: The species is closely related to *Inoceramus* (*I.*) *lamarcki* and it was actually regerded as variety of this species by WOODS (1912a). TRÖGER (1969) proposed the following lineage: *I.* (*I.*) *lamarcki lamarcki* – *I.* (*I.*) *lamarcki stuemckei* – *I.* (*Cr.*) *ernsti* – *I.* (*V.*) *koeneni*. This scheme was accepted by NODA (1996, p. 581) who suggested further, that *I.* (*Cr.*) *ernsti* may be regarded as ancestral form of *I.* (*Cordiceramus*).
OCCURRENCE:

specimen	h	l	b	s	H	L	α	γ	δ	$\delta_{H=60mm}$
JG.H3017LV	140.0	109.2	46.2	38.4	141.0	102.5	120°	140°	87°	83°
JG.H3017RV	109.0	95.9	33.8	35.9	111.6	90.0	121°	138°	81°	78°
JG.H3059LV	52.1	45.3	25.5	19.8	57.6	36.4	136°	90°	86°	-
WE.P1321RV	34.7	30.1	19.1	15.0	35.4	29.5	117°	128°	80°	-
JG.H3023LV	340.0	282.0	115.0	122.0	355.0	290.0	100°	-	58°	78°

specimen	l/h	$l/h_{H=60mm}$	b/h	$b/h_{H=60mm}$	L/H	s/l	remarks
JG.H3017LV	0.78	0.93	0.33	0.26	0.73	0.35	
JG.H3017RV	0.88	0.89	0.31	0.28	0.81	0.37	
JG.H3059LV	0.87	-	0.49	-	0.63	0.34	somewhat deformed less than 60mm in H
WE.P1321RV	0.86	-	0.55	-	0.83	0.50	less than 60mm in H
JG.H3023LV	0.83	0.83	0.34	0.33	0.82	0.43	

Table 7. Measurements of *Inoceramus* (*Cremnoceramus*) *ernsti* HEINZ; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

1. Obira area, northwestern Hokkaido. Locs. Ob0011, 0013, 0020, along the main course of the R. Obirashibe, now submerged beneath the artificial Lake Oberashibe; Unit Ub of the Upper Yezo Group. Loc.Ob2100, a cliff along the R. Kamikinenbetsu, a tributary of the R. Obirashibe; Unit Mn-o uppermost part of the Middle Yezo Group, associated with huge specimen of *I.* (*I.*) *iburiensis*.

2. Upper reaches of the R. Ikushunbetsu, central Hokkaido. Loc.Ik8617a, forestry road along the Okuhidarimata-zawa; Unit IIIb of the Upper Yezo Group, associated with *I.*(*I.*) *uwajimensis*.

RANGE: Upper Turonian to Lower Coniacian.

Inoceramus (*Cremnoceramus*) *rotundatus* FIEGE, 1930
Pl. 8, Figs 3, 4a-b, 5, 7a, b, 8a-c

1930. *Inoceramus inconstans rotundatus* em. FIEGE, p. 42, Pl. 7, Fig. 32; Pl. 8, Fig. 11, Text-fig. 3.
1967. *Inoceramus rotundatus* FIEGE; TRÖGER, pp. 110-114, Pl. 12, Figs 5-6; Pl. 13, Figs 10-13.
1979. *Cremnoceramus* ? *rotundatus* (FIEGE); KAUFFMAN (*in* HERM & *al*., p. 68, Pl. 9, Figs A, C.).
1985. *Inoceramus rotundatus* FIEGE; MATSUMOTO & NODA, pp. 264-271, Pl. 41, Figs 1-4; Pl. 42, Figs 1-6; Pl. 43, Figs 1-11; Pl. 44, Figs 1-7.
1996. *Cremnoceramus rotundatus* (TRÖGER, 1967 *non* FIEGE); WALASZCZYK, p. 377, fig. 3G-J.
1996. *Cremnoceramus rotundatus* (FIEGE); WALASZCZYK, pp. 377-378, fig. 4D, E.

LECTOTYPE: The specimen illustrated by FIEGE (1930, Pl. 7, Fig. 32) was designated by BRÄUTIGAM (1962).

MATERIAL: 27 specimens from the Ponbetsu-Gono-sawa. For details *see* MATSUMOTO & NODA (1985, pp. 264-265).

MEASUREMENTS: Measurements for selected specimens are shown in Table 8. For full list of the specimens *see* MATSUMOTO & NODA (1985, p. 266).

REMARKS: The specimens of *I.* (*Cr.*) *rotundatus* described by MATSUMOTO & NODA (1985) are fairly variable in form and surface ornamentation. WALASZCZYK (1996) noted the distinction between the lectotype of *I.* (*Cr.*) *rotundatus* and the species referred to *I.* (*Cr.*) *rotundatus* by TRÖGER (1967). According to WALASZCZYK (1996), TRÖGER's forms are characterized by subregular, closely spaced and relatively high concentric ribs, occasionally including low and widely spaced concentric ribs with flat interspaces and with irregularly spaced riblets. These forms occur in the basal Coniacian, not ranging to the upper part of the Lower Coniacian, whereas *I.* (*Cr.*) *rotundatus* FIEGE *sensu stricto* seems

specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
JG.H2857LV	51.7	49.8	20.2	25.0	54.1	52.0	105°	-	134°	62°	0.96	0.41	0.96	0.50
JG.H2869LV	40.5	37.4	15.2	24.5	44.4	40.8	103°	-	-	62°	0.92	0.38	0.92	0.66
JG.H2897dLV	25.0	24.0	9.9	12.9	27.8	23.8	102°	-	131°	63°	0.96	0.40	0.86	0.54
GK.H10131LV	62.2	52.0	22.8	29.0	69.4	60.3	108°	-	126°	66°	0.84	0.37	0.87	0.56
GK.H10137LV	20.6	18.2	8.2	11.5	22.0	19.9	102°	-	135°	66°	0.88	0.40	0.90	0.63
GK.H10135LV	22.5	21.7	9.3	11.7	25.9	21.8	102°	-	132°	62°	0.96	0.41	0.84	0.54
JG.H2856RV	25.0	24.3	10.8	11.0	26.0	25.3	128°	-	115°	73°	0.97	0.43	0.97	0.45
JG.H2866RV	23.0	22.4	7.5	12.5	26.0	23.5	105°	-	133°	63°	0.97	0.33	0.90	0.56
JG.H2868RV	37.6	33.7	12.0	17.4	38.2	35.6	107°	-	130°	62°	0.90	0.32	0.93	0.52
GK.H10131RV	23.7	22.9	8.0	14.1	25.3	23.0	100°	-	128°	61°	0.97	0.34	0.91	0.59
GK.H10136RV	17.1	16.8	5.2	10.0	17.6	16.0	107°	-	117°	59°	0.98	0.30	0.91	0.60
GK.H10138RV	19.5	18.4	7.4	11.3	20.7	19.3	115°	-	137°	62°	0.94	0.38	0.93	0.61

Table 8. Measurements of *Inoceramus* (*Cremnoceramus*) *rotundatus* FIEGE from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2; for details *see* MATSUMOTO & NODA (1985, p. 266, Table 1)

to appear in the upper Lower Coniacian. From the above evidence, WALASZCZYK proposes that TRÖGER's form should probably be referred to a separate species. Some specimens of MATSUMOTO & NODA (1985) were regarded as *I.* (*Cr.*) *brongniarti* MANTELL, 1822, by WALASZCZYK (1992, p. 48), which was considered a synonym of *I.* (*Cr.*) *rotundatus* TRÖGER (*non* FIEGE) by him (1996, p. 377). A rich material of *I.* (*Cr.*) *rotundatus*, from the Ponbetsu-Gono-sawa, allowed the statistical evaluation of its variation. The study showed that in thc population sample from that locality these two species co-occur. The typical specimens of *I.* (*Cr.*) *rotundatus* FIEGE, as well as intermediate to *I.* (*Cr.*) *rotundatus sensu* TRÖGER, predominate in the basal part of the Lower Coniacian. TRÖGER's forms dominate the higher in the succession, where it is accompanied by *I.* (*I.*) *uwajimensis*. It is very difficult to discriminate these two forms as there is a number of intermediate morphotypes.

PHYLOGENY: KELLER (1982, p. 116) pointed out the distinction between *I.* (*Cr.*) *rotundatus* and *I.* (*Cr.*) *waltersdorfensis hannovrensis* HEINZ, 1932. At the same time he mentioned the existence of a transitional form. In the Ponbetsu-Gono-sawa area, central Hokkaido, an *I.* (*Cr.*) *waltersdorfensis hannovrensis*-like form co-occurs with *I.*(*Cr.*) *rotundatus*. As MATSUMOTO & NODA (1985, p.271) mentioned, a few specimens of the *hannovrensis*-like form are not separable from the forms that they identified with *I.* (*Cr.*) *rotundatus*.

A few specimens compared with *I.* (*Cr.*) *waltersdorfensis hannovrensis* occur in Unit Ua1, somewhat below the horizon of *I.* (*Cr.*) *rotundatus* (Unit Ua2), associated with an Upper Turonian fauna in the Obira area, northwestern Hokkaido. This would support the above inferred lineage of *I.* (*Cr.*) *rotundatus*.

OCCURRENCE:

1. Obira area, northwestarn Hokkaido.
Loc. Ob0003 along the main course of the R. Obirashibe; Unit Ua2 of the Upper Yezo Group.

2. Ponbetsu-Gono-sawa, locs. Ik2786, 2726, 2716, 2714 and 2710 along the rivulet of the Ponbetsu-Gono-sawa, central Hokkaido; Member IIIb' of the Upper Yezo Group.

3. Ikushunbetsu area, central Hokkaido. Locs.Ik966a-c, 965a-c and 964b along the main course of the R. Ikushunbetsu, now submerged beneath the artificial Lake Katsurazawa; Unit IIIb of the Upper Yezo Group.

RANGE: Lower Coniacian.

Inoceramus (*Cremnoceramus*) *lueckendorfensis* TRÖGER, 1967
Pl. 9, Figs la-c, 2a-c

1959. *Inoceramus inconstans* WOODS; DOBROV & PAVLOVA, p.137, Pl. 5, Figs la, b.
1967. *Inoceramus inconstans lueckendorfensis* TRÖGER, pp. 102-105, Pl. 11, Figs la-c.
1981b. *Inoceramus "inconstans" lueckendorfensis* TRÖGER; TRÖGER, pp. 102, 106-107, Pl. 1, Figs 8-11.
1989. *Inoceramus* (*Cremnoceramus*) *inconstans lueckendorfensis* TRÖGER; TRÖGER, p. 197-198; list.
1991. *Inoceramus inconstans lueckendorfensis* TRÖGER; TARKOWSKI, p. 109, Pl. 13, Fig. 8.
1996. *Inoceramus* (*Cremnoceramus*) *lueckendorfensis* TRÖGER; NODA, pp. 585-587, Figs 11-la-c, 11-2a-c.

HOLOTYPE: Specimen No. 92F (TRÖGER, 1967, Pl. 11, Fig. 1a-c) by original designation.

MATERIAL: Two specimens, JG.H3097 and 3098, from the Obira area, northwestern Hokkaido.

MEASUREMENTS: Measurements are shown in Table 9.

DESCRIPTION: The specimens are both right valves and fairly well preserved. With respect to morphological characters, such as the inflated shell with geniculation, concave anterior part, blunt elevation of the valves along the growth axis and the outline with subangular bend at mid-venter, the above two specimens agree well with the holotype of *I.* (*Cr.*) *lueckendorfensis*; whereas the posterior auricle is well developed in the holotype, it is obscure in the Obira specimens. Minor concentric ornament is clearly perceptible near the umbo in both the holotype and in the Obira specimens. In the holotype there are major concentric undulations up to the geniculated stage. In the examined Obira specimens the

specimen	h	l	b	s	H	L	α	γ	δ	$δ_{H=60mm}$
JG.H3097LV	105.7	89.2	45.4	45.0	107.6	87.5	118°	120°	77°	72°
JG.H3098LV	102.8	89.1	42.0	37.8	106.1	86.4	118°	-	73°	66°

specimen	l/h	$l/h_{H=60mm}$	b/h	$b/h_{H=60mm}$	L/H	s/l	remarks
JG.H3097LV	0.84	0.90	0.43	0.24	0.81	0.50	
JG.H3098LV	0.87	0.93	0.41	0.29	0.81	0.42	

Table 9. Measurements of *Inoceramus* (*Cremnoceramus*) *lueckendorfensis* TRÖGER from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

undulations are blunt in JG.H3098 and perceptible only on the ventral slope of JG.H3097.

According to TRÖGER (*personal communication*, 1993), the Japanese specimens correspond well to the German type specimen in shell shape but are distinct in surface ornamentation. The Japanese specimens may be ranked as a subspecies of *I.* (*Cr.*) *lueckendorfensis*, but the establishment of a new taxon is postponed at present because of insufficient material.

The two Obira specimens an onion-like putline, which is clearly different from that of the typical form of *I.* (*Cr.*) *inconstans*. For the above reason *lueckendorfensis* should be ranked as a separate species from *I.* (*Cr.*) *inconstans* (*see also* NODA 1996, p. 587). In order to clarify this problem the specific distinction of the two taxa should be examined at population level on the basis of European material.

PHYLOGENY: NODA (1996, p. 587) assumed that *I.* (*Cr.*) *lueckendorfensis* was probably a descendant of *I.* (*Cr.*) *rotundatus*, based on the morphological resemblance and stratigraphic occurrence of the German and Japanese material. This inference is supported by new stratigraphical data from the Obira area, in that it is now confirmed that the horizon of the two specimens of *I.* (*Cr.*) *lueckendorfensis* is about 6 m higher than that of *I.* (*Cr.*) *rotundatus* within the succession of locality Ob0003.

As an evolutionary successor of *I.* (*Cr.*) *lueckendorfensis*, NODA (1996, p. 587) suggested previously *I.* (*Cordiceramus*) *cordiformis purus* SEITZ, 1961. However, the latter taxon occurs in the Upper Santonian of Germany. There is, therefore, a considerable time gap between the occurrences of the two taxa. Fortunately, a very well preserved specimen which is closely similar to, or possibly identical with *I.* (*Co.*) *cordiformis purus* has been obtained at loc. Ik2708 from the Upper Coniacian of the Ponbetsu-Gono-sawa. This would strongly support the inferred lineage, although there remains a missing link in the Middle Coniacian.

OCCURRENCE: Loc.Ob0003, a cliff along the R. Obirashibe, about 450m upstream from the bridge called Tengu-bashi, Obira area, northwestern Hokkaido; Unit Ua2 of the Upper Yezo Group, about 6 m above the horizon of *I.* (*Cr.*) *rotundatus*.

RANGE: Upper part of the Lower Coniacian.

Inoceramus (*Cremnoceramus*) *deformis* MEEK, 1871
Pl. 10, Fig. 1a-d

1871. *Inoceramus deformis* MEEK, p. 296.
1875. *Inoceramus deformis* MEEK; WHITE, pp. 179-180, Pl. 15, Fig. 1.
1877. *Inoceramus deformis* MEEK; MEEK, p. 146, Pl. 14, Figs 4a, b.
1977. *Inoceramus* (?) *deformis deformis* MEEK; KAUFFMAN, p. 245, Pl. 12, Fig. 3.
1978. "*Inoceramus*" *deformis deformis* MEEK; KAUFFMAN, p. IV.8, list.
1978. "*Inoceramus*" *deformis* n. subsp.; KAUFFMAN, p. IV.8, list.
1978. *Inoceramus* ? *deformis* MEEK; KAUFFMAN, p. XIII.2, list.
1986. *Inoceramus* (*Cremnoceramus*) *deformis* MEEK; SEIBERTZ, p. 1177.
1992. *Cremnoceramus deformis* (MEEK); WALASZCZYK, pp. 52-53, Pl. 29, Fig. 4; Pl. 30, Fig. 4.
1996. *Inoceramus* (*Cremnoceramus*) *deformis* MEEK; NODA, pp. 572-576, Figs. 1-1a-d, 1-2a-c, 7-4 (*cum synonymy*).

HOLOTYPE: By monotypy, the specimen illustrated by MEEK (1877, Pl. 14, Fig. 4) from the Niobrara Formation, Pueblo, Colorado, but the precise locality is not recorded.

MATERIAL: Three specimens, JG.H3016, 3058 and 3060 from the Obira area, northwestern Hokkaido.

MEASUREMENTS: Measurements are shown in Table 10.

DIAGNOSIS: Shell nearly equivalve, with comparatively small beak and weakly developed umbo; valves inflated with a geniculation in the late stage; posterodorsal slope steep, without distinct wing-like area; growth axis concave.

REMARKS: For detailed description of the specimens, *see* NODA (1996, pp. 572-576).

The specimen JG.H3016 (Pl. 10, Figs 1a-d) is of articulated valves without secondary deformation apart from minor displacement along the plane of commissure. Three blunt radial elevations are perceptible, the anterior one demarcates the anterior part from the disc, the median one runs along the growth axis, from which the posterior one is separated by an interval of a shallow depression. The concentric ribs are subangularly bent at the intersections with radial the elevations. These characters may imply some relationships with *I.* (*Cordiceramus*).

I. (*Cr.*) *deformis* was established by MEEK (1871), on the basis of a single imperfect specimen from the Lower Coniacian of the Niobrara Formation, Colorado. Subsequent information on this species is very limited, and thus the variation of the species is not yet clear at present. The specimens assigned to *I.* (*Cr.*) *deformis* from the upper Lower to lower Middle Coniacian of various rigions around the world vary considerably in general outline and surface ornamentation. The available specimens from Japan correspond with some forms of *I.* (*Cr.*) *deformis* described or figured previously.

PHYLOGENY: On the basis of the morphological resemblance and stratigraphical occurrence, KAUFFMAN (1978b) suggested the lineage of *I.* (*Cr.*) *deformis* as composed of *I.* (*Cr.*) *rotundatus* – *I.* (*Cr.*) *erectus* – *I.* (*Cr.*) *deformis* – *I.* (*Cr.*) *schloenbachi*. WALASZCZYK (1992) regarded *I.* (*Cr.*) *deformis* as the last representative of the lineage of *I.* (*Cr.*) *waltersdorfensis* ANDERT – *I.* (*Cr.*) *brongniarti* MANTELL – *I.* (*Cr.*) *deformis* MEEK.

OCCURRENCE: Obira area, northwestern Hokkaido, locs. Ob0012 and 0013 along the main course of the R. Obirashibe, now submerged beneath the artificial Lake Obirashibe, at just below about the centre of the Takimi-Ohashi Bridge; Unit Ub of the Upper Yezo Group. Locs. 0012 and 0013 are the outcrops of the same bed on both sides of the river. Associated species; *I.* (*I.*) *uwajimensis* and *I.* (*I.*) aff. *pedalionoides*.

RANGE: Upper Lower and/or lower Middle Coniacian, but the true range of this species in

specimen	h	l	b	s	H	L	α	γ	δ	$\delta_{H=60mm}$
JG.H3016LV	99.2	81.8	39.8	38.3	99.6	87.0	132°	102°	86°	84°
JG.H3016RV	77.4	70.4	29.7	33.0	81.8	74.8	132°	102°	76°	70°
JG.H3058RV	51.8	53.6	14.0	29.2	52.0	59.3	123°	103°	74°	-
JG.H3060LV	53.3	45.1	19.2	18.1	53.3	42.7	136°	104°	87°	-

specimen	l/h	$l/h_{H=60mm}$	b/h	$b/h_{H=60mm}$	L/H	s/l	remarks
JG.H3016LV	0.82	0.94	0.40	0.40	0.87	0.47	
JG.H3016RV	0.91	0.86	0.38	0.31	0.91	0.47	
JG.H3058RV	-	-	-	-	-	-	secondarily deformed
JG.H3060LV	0.85	-	0.36	-	0.80	0.40	less than 60mm in H

Table 10. Measurements of *Inoceramus* (*Cremnoceramus*) *deformis* MEEK from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

Japan should become clear on the basis of further stratigraphic work in various areas.

Subgenus *Platyceramus* SEITZ, 1961

TYPE SPECIES: *Inoceramus mantelli* DE MERCEY, 1877, by original designation (SEITZ 1961, ex HEINZ 1932).

DIAGNOSIS: *See* SEITZ (1961, p, 54).

REMARKS: *I.* (*Platyceramus*) and *I.* (*Cladoceramus*) were originally proposed by HEINZ (1932) as full genera, but they were both *nomina nuda* according to the rules of I.C.Z.N. because they lacked diagnoses. *I. mantelli* and *I. michaeli* HEINZ (=*I. digitatus* SCHLÜTER, revised to *I. undulatoplicatus michaeli* by SEITZ; non *I. digitatus* SOWERBY, 1877) were designated as the type species for *Platyceramus* and *Cladoceramus* respectively.

SEITZ (1961) gave diagnoses for *Platyceramus* and *Cladoceramus*, treating both taxa as subgenera of the genus *Inoceramus*. The authorship for these taxa is thus ascribed to SEITZ, as MATSUMOTO & *al.* (1982) have already mentioned. Despite this situation, VOKES (1967, 1980) wrongly regarded these taxa as being invalid, and COX (1969) inadequately recorded *Platyceramus* as a junior synonym of the genus *Inoceramus* and *Cladoceramus* as a junior synonym of the genus *Sphenoceramus*. *Sphenoceramus* is quite distinct from *Cladoceramus* in its acute beak angle, fairly thick umbonal region, moderately inflated shell and posterior wing sharply demarcated from the disc.

In SEITZ's concept the distinction between *Platyceramus* and *Cladoceramus* is subtle. MATSUMOTO & *al.* (1982, p. 63) and also NODA (1983, p. 202) revised SEITZ's definition of *Platyceramus* to include the subgenus *Cladoceramus* SEITZ, 1961, and gave a reason for that assignment.

I. (*Platyceramus*) was probably derived from *I.* (*Inoceramus*) in the Lower Coniacian, as is discussed in the item below.

Inoceramus (*Platyceramus*) *tappuensis* nom. nov.

Pl. 10, Fig. 2a-c; Pl. 11, Figs 1a-d, 2a, b.

1939. *Inoceramus* sp. nov. NAGAO & MATSUMOTO, pp. 280-281, Pl. 27, Figs 1a-b; Pl. 28, Fig. 1.

1977. *Inoceramus* sp. nov. NAGAO & MATSUMOTO; KAUFFMAN, p. 176.

non 1979. *Mytiloides striatoconcentricus trögeri* KAUFFMAN, pp. 65-67, Pl. 10, Figs D-E.

1986. *Inoceramus* sp. indet. (sp. nov.) NAGAO & MATSUMOTO; MATSUMOTO & NODA, p. 416.

1992. *Inoceramus* (*Platyceramus*) *troegeri* NODA, pp. 1315- 1326, figs 3a-d, 4-1a-d, 4-2a- b, 5- 2a, b, 6-1-4.

non 1992. *Mytiloides troegeri* KAUFFMAN; WALASZCZYK, p. 26, Pl. 13, Fig. 8.

SPECIFIC NAME: The species was established by myself (NODA, 1992) under the original name "*Inoceramus* (*Platyceramus*) *troegeri*". But the specific name was preoccupied by *Mytiloides striatoconcentricus troegeri* KAUFFMAN, 1979. Thus the specific name "*troegeri* NODA" is invalid under the I.C.Z.N. A new name "*tappuensis*" is given for "*troegeri*" herein. I would offer an apology to Prof. Dr. K.-A. TRÖGER in view of the need for this correction.

DERIVATIO NOMINIS: After the village of Tappu, close to which the type of this species was found.

HOLOTYPE: JG.H3023 (Pl. 11, Fig. 1), from loc. Ob0003f (close to the village of Tappua), lower part of Unit Ua2, basal part of the Upper Yezo Group, Obira area.

MATERIAL: 38 specimens from the Obira area.

MEASUREMENTS: Measurements for selected specimens are shown in Table 11. For details *see* NODA (1992, pp. 1320-1321).

DIAGNOSIS: Shell medium to large, equivalve; gently and uniformly inflated but moderately convex near umbo with some variation. Umbo small, terminal and slightly projected over hinge line. Anterior part steeply inclined to plane of commissure and posterior half gradually flattened, passing transitionally into wing-like area. Outline somewhat higher than long with considerable variation. Surface ornamentation also variable. Major commarginal ribs low, round-topped and fairly irregular in width and intensity. minor; riblets superimposed on major ribs and interspaces, irregular in shape and intensity.

REMARKS: The specimens from the type

specimen	h	l	b	s	H	L	α	γ	δ	l/h	b/h	$b/h_{H=60mm}$	L/H	s/l
JG.H3010LV	73.5	64.7	13.2	31.8	82.6	65.1	88°	142°	61°	0.88	0.18	0.20	0.79	0.49
JG.H3010RV	72.5	64.5	16.0	31.6	83.3	65.1	90°	143°	60°	0.89	0.22	0.21	0.78	0.49
JG.H3122LV	88.0	82.7	17.0	42.0	97.9	78.6	91°	142°	61°	0.94	0.19	0.22	0.80	0.51
JG.H3022RV	82.0	77.9	16.3	40.5	94.0	76.1	92°	143°	62°	0.95	0.20	0.22	0.81	0.52
JG.H3023LV holotype	103.7	93.0	18.4	43.7	118.7	90.7	91°	139°	59°	0.90	0.18	0.21	0.76	0.47
JG.H3023RV holotype	106.8	95.2	17.9	44.7	118.8	92.0	90°	141°	61°	0.89	0.17	0.22	0.77	0.47
JG.H3037LV	71.4	62.4	20.0	29.0	78.5	59.4	98°	142°	60°	0.87	0.28	0.28	0.76	0.46
JG.H3037LV	62.8	60.0	13.8	29.0	70.3	58.0	94°	142°	56°	0.96	0.22	0.23	0.83	0.48
UMUT. MM6492LV	73.0	64.0	16.0	32.0	79.0	61.7	97°	135°	61°	0.88	0.22	0.23	0.78	0.50
UMUT. MM6492RV	70.3	61.2	15.2	-	79.3	61.0	96°	-	61°	0.73	-	-	0.73	-
IGPS22709LV	126.6	94.0	30.5	50.0	130.0	95.0	86°	145°	59°	0.74	0.24	0.24	0.73	0.53
IGPS22709RV	125.0	91.3	-	-	131.0	95.7	84°	145°	60°	0.73	-	-	0.73	-

Table 11. Measurements of *Inoceramus* (*Platyceramus*) *tappuensis* nom. nov. from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2; for details refer to NODA (1992, pp. 1320-1321, Table 1)

locality are of mainly articulated valves and well preserved without secondary deformation. They are suitable for both biometric analysis as well as for the usual study at population level. The results of such examinations suggest that the specimens are not identical with any other hitherto described species (for details *see* NODA, 1992).

PHYLOGENY: Certain specimens of this species (*e.g.* JG.H3037 and 3065) show in the juvenile stage *I.* (*Inoceramus*)-like characters, such as a moderately inflated umbonal region and projected umbo. These early ontogenetic characters can be inferred to be relict adult characters of ancestral species, and thus they may imply a phylogenetic relationship between *I.* (*Inoceramus*) and *I.* (*Platyceramus*). *I.* (*Pl.*) *tappuensis* is inferred to have been derived from *I.* (*I.*) *teshioensis* near the Turonian-Coniacian boundary and is the first representative of the subgenus *I.* (*Platyceramus*). Moreover, in both outline and surface ornamentation JG.H3064a anticipates the succeeding species *I.* (*Pl.*) *mantelli*, while JG.H3011b anticipates *I.* (*Pl.*) *szaszi*. From this viewpoint, *I.* (*Pl.*) *tappuensis* is very important as a link between *I.* (*Inoceramus*) and *I.* (*Platyceramus*) and as a common ancestor of *I.* (*Platyceramus*) spp. on and after the Santonian.

OCCURRENCE: Type locality Ob0003. A large cliff on the left side of the main course of the R. Obirashibe about 450m upstream from the bridge called Tengu-bashi in the village of Tappu, Obira area, northwestern Hokkaido; Unit Ua2, lower part of the Upper Yezo Group. The specimens were obtained from two horizons within an interval of about 60cm, the lower one of which lies about 2 m above the Turonian-Coniacian boundary. Locs.Ob0012 and Ob0020 along the R. Obirashibe, now submerged beneath the artificial Lake Obirashibe; Unit Ub of the Upper Yezo Group.

RANGE: Lower to lower Middle Coniacian.

Inoceramus (*Platyceramus*) *szaszi*
NODA & UCHIDA, 1995
Pl. 12, Figs la-c, 2a-c; Pl. 13, Figs 1-2

1995. *Inoceramus* (*Platyceramus*) *szaszi* NODA & UCHIDA, pp. 142-153, Figs 2-4.

HOLOTYPE: JG.H2901 (Pl. 12, Fig. 2) from loc.Ik2709, Ponbetsu-Gono-sawa, central Hokkaido, Member IIIc', Upper Yezo Group.

MATERIAL: Paratypes: JG.H2794, 2898, 2901, 2903 and 2909 from the type locality, JG.H3099 a,b and 3505 from loc.Ik1623, Kumaoi-zawa, Ikushunbetsu area, central Hokkaido. JG.H3079 from loc.ObOOO2, Obira area, northwestern Hokkaido.

MEASUREMENTS: Measurements are shown in Table 12.

REMARKS: For the specific characters refer to NODA & UCHIDA (1995, pp. 146-148). The specimens examined are mainly well preserved articulated valves without secondary deformation but for slight displacement along the plane of commissure. The specimens were originally referred to *I.* (*Pl.*) *mantelli* DE MERCEY, but a population sample from the type locality Ik2709 is clearly discriminated morphologically from the other samples by means of STUDENT's *t*-test and other biometric analyses. (NODA & UCHIDA 1995, p. 151, Tables 3,4).

This species differs from *I.* (*Pl.*) *mantelli* in the considerably inflated umbonal region, comparatively steep posterodorsal slope, nearly straight growth axis which symmetrically divides the main part of the disc and fan-shaped general outline, whereas *I.* (*Pl.*) *mantelli* has a less convex umbonal part, gradually flattened posterodorsal half, anteriorly concave growth axis and a much higher outline.

This species resembles a certain form (e.g. JG.H3011b) of the variable species *I.* (*Pl.*) *tappuensis* in its small convexity and weak ornament, but the latter is more elongated along the growth axis, by which the disc is divided asymmetrically. Moreover, the morphological distinction is clear from the statistic examination at population level (NODA & UCHIDA 1995, p. 151, Tables 3-4). In addition to the morphological resemblance mentioned above, a specimen JG.H3079 (Pl. 13, Figs 1-2) has been obtained from loc.Ob0002, from an horizon about 20 m higher than that of *I.* (*Pl.*) *tappuensis*. It is a large shell with articulated valves and shows typical shell shape and ornament. This occurrence of *I.* (*Pl.*) *szaszi* from a somewhat higher horizon than *I.* (*Pl.*) *tappuensis* in the continuous succession in a limited area supports the inference of a phyletic lineage from *I.* (*Pl.*) *tappuensis* to *I.* (*Pl.*) *szaszi* (*see* NODA & UCHIDA 1995, p. 152). No successive species have been, however, obtained from higher horizons. *I.* (*Pl.*) *mantelli* is inferred to be an immediate descendant of *I.* (*Pl.*) *tappuensis* and the various species of *I.* (*Platyceramus*) from subsequent stages may be directly or indirectly derived from *I.* (*Pl.*) *mantelli*. *I.* (*Pl.*) *szaszi* may represent a side branch from the main stem of the *I.* (*Platyceramus*) lineage.

OCCURRENCE:

1. The type locality Ik2709. Ponbetsu-Gonosawa, central Hokkaido; upper part of the Member IIIb' of the Upper Yezo Group (for the locality *see* MATSUMOTO & NODA 1985, fig. 1).

2. Locs. IkI623p and 1626p, upper reaches of the Kumaoizawa, Ikushunbetsu area, central Hokkaido, probably Unit IIIc of the Upper Yezo Group (*see* NODA & UCHIDA 1995, p. 152).

3. Loc. Ob0002 along the main course of the R. Obirashibe, Obira area, northwestern Hokkaido; Unit Ub-c of the Upper Yezo Group.

specimen	h	l	b	s	H	L	α	γ	δ	l/h	$l/h_{H=60mm}$	b/h	L/H	s/l
JG.H2794LV	66.0	61.3	17.4	-	74.5	62.0	101°	-	67°	0.93	0.98	0.26	0.83	-
JG.H2794RV	62.2	57.4	14.9	32.0	68.7	59.8	101°	-	64°	0.92	0.98	0.24	0.87	0.56
JG.H2898LV	87.8	82.0	20.6	39.1	92.8	83.0	99°	127°	66°	0.93	0.93	0.23	0.89	0.48
JG.H2898RV	95.2	89.6	22.0	42.6	110.8	87.0	98°	127°	65°	0.94	0.97	0.23	0.86	0.48
JG.H2901LV holotype	104.4	92.0	22.0	-	112.1	97.9	98°	128°	65°	0.88	0.87	0.21	0.87	-
JG.H2901RV holotype	91.5	84.2	21.4	42.1	102.1	89.3	96°	131°	63°	0.92	0.94	0.23	0.87	0.50
JG.H2903LV	64.8	60.6	15.0	33.2	71.8	61.5	99°	131°	64°	0.94	0.96	0.23	0.86	0.55
JG.H2909LV	51.8	47.0	12.1	23.8	53.6	47.0	103°	132°	64°	0.91	-	0.23	0.88	0.51
JG.H3079LV	145.2	135.0	31.0	57.2	153.6	136.5	112°	140°	67°	0.93	0.99	0.21	0.89	0.42
JG.H3079RV	125.3	-	27.4	53.8	138.7	-	112°	-	67°	-	-	0.22	-	-

Table 12. Measurements of *Inoceramus* (*Platyceramus*) *szaszi* NODA & UCHIDA from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

RANGE: Upper part of the Middle Coniacian, upper part of the Zone of *I.* (*I.*) *uwajimensis*.

Subgenus *Volviceramus* STOLICZKA, 1871

TYPE SPECIES: *Inoceramus involutus* SOWERBY, 1828, designated by STOLICZKA (1871, p. 394).

DIAGNOSIS: *See* STOLICZKA (1871), MEEK (187?) and COX (1969).

REMARKS: *See* NODA (1996, pp. 564, 566).

Inoceramus (*Volviceramus*) *koeneni*
MÜLLER, 1887
Pl. 13, Fig. 3a-c

1887. *Inoceramus* (*Volviceramus*) *koeneni* MÜLLER, pp. 412-413, Pl. 17, Fig. 1.
pars 1912a. *Inoceramus lamarcki* PARKINSON; WOODS, Pl. 52, Figs 4, 6.
1912b. *Inoceramus* connecting *Inoceramus lamarcki* PARKINSON with *Inoceramus involutus* SOWERBY; WOODS, p. 9, Text-figs 42-43.
1934. *Cymatoceramus* (*Cymatoceramus*) cf. *koeneni* (MÜLLER); HEINZ, pp. 253-254, Pl. 19, Fig. 3.
1969. *Inoceramus koeneni* MÜLLER; TRÖGER, pp. 67-87, Pls 1-2.
1977. *Inoceramus* (*Cremnoceramus*) *koeneni* MÜLLER; HATTIN & COBBAN, pp. 191- 192, Fig. 9-3.
1978. *Volviceramus koeneni* (MÜLLER); KAUFFMAN, P. XIII.2, list.
1996. *Inoceramus* (*Volviceramus*) *koeneni* MÜLLER; NODA, pp. 566-570, Fig. 10a-d (*cum synonymy*).

LECTOTYPE: The specimen figured by MÜLLER (1887, Pl. 17, Fig. 1) was designated by TRÖGER (1969, p. 70).

MATERIAL: A single specimen JG.H3019 from loc. Ob0013 in the Obira area, northwestern Hokkaido.

MEASUREMENTS: Measurements are shown in Table 13.

DESCRIPTION: The specimen JG.H3019 (Pl. 13, Fig. 3) comprises a well preserved left valve without secondary deformation and a fragment of the right valve, in a single nodule, and probably belonging to the same individual. The left valve has a strongly incurved umbo, considerably inflated shell with three radial elevations and a spirally twisted growth axis; the anterior face is sharply bent from the disc and is deeply concave to the plane of commissure. The shell is highly inequivalve, with a less convex right valve. These are the characters of *I.* (*Volviceramus*), except for the development of three radial elevations. The radial median and posterior elevations, in particular, and the shallow intervening depression, are similar to those figured by TRÖGER (1969, p. 72, fig. 4), while the sharply concave anterior face closely resembles that of the specimen figured by TRÖGER (1969, Pl. 2, Fig. 5). Moreover, the ontogenetic change of shell convexity of JG.H3019 (NODA, 1996, p. 569, fig. 13) agrees well with those of the type 1 of TRÖGER (1969, p. 72, fig. 3). From the above comparison, this specimen is undoubtedly referred to *I.* (*V.*) *koeneni*, regardless of a somewhat smaller convexity than in the German specimens.

The development of three radial elevations in the specimen is a character that is also found in *I.* (*Cordiceramus*). As mentioned previously (NODA (1996, p. 596), *I.* (*V.*) *koeneni* and *I.* (*Co.*) *kawashitai* are probably derived from the common ancestor, *I.* (*Cr.*) *ernsti*. The essential distinction is that the subgenus *Volviceramus* becomes highly inequivalve with time whereas the subgenus *Cordiceramus* is nearly equivalve.

specimen	h	l	b	s	H	L	α	γ	δ	$\delta_{H=60mm}$
JG.H3019LV	130.3	127.7	60.0	46.0	135.6	93.6	152°	121°	108°	96°

specimen	l/h	$l/h_{H=60mm}$	b/h	$b/h_{H=60mm}$	L/H	s/l
JG.H3019LV	0.98	0.97	0.46	0.37	0.69	0.34

Table 13. Measurements of *Inoceramus* (*Volviceramus*) *koeneni* MÜLLER from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

OCCURRENCE: Loc.Ob0013, Obira area, northwestern Hokkaido; Unit Ub of the Upper Yezo Group, now submerged under the artificial Lake Obirashibe.

RANGE: Upper part of the Lower and/or lower Middle Coniacian. Stratigraphical range uncertain.

Genus *Mytiloides* BRONGNIART, 1822

TYPE SPECIES: *Ostracites labiatus* SCHLOTHEIM, 1813, was originally designated by BRONGNIART (1822).

DIAGNOSIS: Shell medium sized, equivalve, inequilateral, moderately to gently convex. Umbo terminal and slightly projected over hinge line, obliquely elongate, oval or fairly broad. Hinge line short, wing-like area narrow. Concentric ribs and minor rings variably developed.

REMARKS: *Mytiloides* was originally erected by BRONGNIART (1822) as a full genus. Subsequently COX (1969) regarded the taxon as a subgenus of *Inoceramus* without any comment. KAUFFMAN & POWELL (1977, pp. 71-78) ranked *Mytiloides* as a full genus, by reason of having no pedalbyssal muscle scars or byssal notch (KAUFFMAN 1969a, b; KIRKLAND 1996). These characters are not found in the genus *Inoceramus* and they collectinely form an essential criterion in separating the taxon *Mytiloides* from *Inoceramus* as an independent genus.

Mytiloides incertus (JIMBO, 1894)
Pl. 14, Figs 1a-d, 2, 5a-d; Pl. 15, Figs 1-5

1894. *Inoceramus incertus* JIMBO, p. 189, Pl. 24(8), Fig. 7.
1940. *Inoceramus incertus* JIMBO; NAGAO & MATSUMOTO, pp. 10-13, Pl. 3, Figs 1-3, 5; Pl. 10, Fig. 2.
non 1940. *Inoceramus incertus* var. *yubariensis* NAGAO & MATSUMOTO, pp. 11-12, Pl. 6, Fig. 1 [=*Inoceramus (Platyceramus) mantelli* DE'MERCEY . *See* NODA & TOSHIMITSU 1990]
1959. *Inoceramus incertus* JIMBO; MATSUMOTO, p. 85.
1963. *Inoceramus incertus* JIMBO; MATSUMOTO, part 10, p. 45, Pl. 67, Fig. 7.
1967. *Inoceramus fiegei fiegei* TRÖGER, pp. 105 and 108, Pl. 11, Fig. 3; Pl. 13, Figs 14-15, 17, 20.
1976. *Inoceramus incertus* JIMBO; NODA & MATSUMOTO, No. 45-270, Fig. 7.
1977. *Mytiloides incertus* (JIMBO); KAUFFMAN, p. 179.
1978. *Mytiloides fiegei fiegei* (TRÖGER); KAUFFMAN, p. 9, Pl. 15, Fig. 1; Pl. 16, Fig. 4.
1983. *Mytiloides incertus* (JIMBO); MATSUMOTO & NODA, p. 111, Figs 2-4.
1984. *Mytiloides incertus* (JIMBO); NODA, pp. 458-469, Pl. 84, Figs 1-10; Pl. 85, Figs 1-2; Pl. 86, Figs 1-8.
1992. *Mytiloides incertus* (JIMBO); WALASZCZYK, pp. 22-23, Pl. 12, Figs 11-12.

LECTOTYPE: UMUT.MM7535 (Pl. 15, Fig. 1), one of the original syntypes, designated subsequently by MATSUMOTO & NODA (1983, p. 111). The syntypes are contained in a nodule, which may be fallen or transported on the bed of the R. Ponbetsu, hence the precise stratum is unknown.

MATERIAL: UMUT.MM7535 (=MM7481 = TK.I-151), including four specimens: the lectotype 7535-3, two paralectotypes 7535-1, 7535-2 and one other specimen; GK.H10041, 10048, 10056, 10061-64, 10066-68, 10087 (Pl. 15, Fig. 5), 10108, 10109 (Pl. 15, Fig. 4), 10111-10129, GMH (=HK)7242, 7246, JG.H2128, 2850-1, 2852 (Pl. 14, Fig. 4), 2853-4, 2855 (Pl. 14, Fig. 2), 3461 (=TTC0001) (Pl. 14, Fig. 1) and 3462 (=TTC0002).

MEASUREMENTS: Measurements are shown in Table 14.

REMARKS: The present species shows a large extent of variation in shell shape and some variation in surface ornamentation as illustrated in Text-fig. 5.

The syntypes are three poorly preserved specimens from a single nodule and the restoration of *M. incertus* based on them by JIMBO (1894, Pl. 8, Fig. 7; Noda 1984, p. 463, Text-fig. 8) was inadequate, because no actual specimens of this species agree with JIMBO's illustration, in spite of the high variability ofthe species. A revised diagnosis of *M. incertus* was given by MATSUMOTO & NODA (1983, p. 111).

NODA (1984) examined biometrically three population samples from Ik2011, 2013 and 2014, one of which localities is presumed to be the source of JIMBO's material. NODA evaluated the significance of differences amongst the samples by means of STUDENT's *t*-test. The results are not significant in all characters exemined i.e., α, γ, δ, l/h, L/H, and s/l, between samples Ik2011 and

specimen	h	l	b	s	H	L	α	δ	l/h	$l/h_{H=40mm}$	L/H	b/h	s/l
GK.H10087	70.2	85.0	-	-	94.5	75.1	108°	55°	1.21	1.04	0.79	-	-
GK.H10093	32.5	37.0	23.9	20.7	39.2	33.9	122°	60°	1.14	-	0.86	0.60	0.56
GK.H10094	28.9	34.9	20.0	-	37.0	33.6	113°	43°	1.21	-	0.91	-	-
GK.H10117	61.6	69.1	-	28.6	69.2	67.7	119°	59°	1.12	1.03	0.97	-	0.41
GK.H10118	54.4	52.5	26.4	28.5	58.0	50.7	119°	55°	0.97	1.09	0.87	0.49	0.54
GK.H10121	78.0	73.9	31.4	-	94.1	64.8	115°	57°	0.95	0.95	0.69	0.40	-
GK.H10127	40.0	38.3	23.0	17.4	41.5	38.0	108°	57°	0.96	0.96	0.92	0.58	0.45
JG.H2850	57.8	49.3	-	29.0	64.4	52.6	116°	53°	0.85	0.91	0.82	-	0.59
JG.H2851	64.0	60.0	26.8	-	73.3	52.0	112°	55°	0.94	1.00	0.71	0.42	-
JG.H2852	55.4	47.7	29.8	27.6	63.0	50.6	105°	55°	0.86	0.93	0.80	0.54	0.58
JG.H2853	54.0	58.9	-	27.0	66.0	53.0	116°	47°	1.09	1.08	0.80	-	0.46
JG.H2854	54.0	55.5	24.6	27.4	61.5	49.3	116°	46°	1.03	1.12	0.80	0.46	0.49
TTC.0001	63.6	61.9	31.8	25.0	74.1	58.6	106°	54°	0.97	0.98	0.79	0.50	0.40
TTC.0002	65.1	65.5	30.0	30.9	69.0	67.0	119°	52°	1.01	1.13	0.97	0.46	0.47

Table 14. Measurements of *Mytiloides incertus* (JIMBO) from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

2013, and significant in some characters between Ik2011 vs. 2014 and also Ik 2013 vs. 2014 (for details *see* NODA 1984, pp. 460-461). Consequently the samples Ik2011 and 2013 were combined statistically as a single population from the presumed type locality. The sample Ik2014 includes some specimens with extremely elongate outline, which is an atypical form statistically and should be omitted from this population.

M. incertus closely resembles *M. fiegei fiegei* (TRÖGER, 1967). The result of STUDENT's *t*-test is not significantly different in any characters exemined. The two taxa, therefore, are not discriminated morphologically on the basis of statistics and are synonymised.

PHYLOGENY: *M. incertus* has generally a relatively long outline with little obliquity and gentle convexity. *M. subhercynicus* (SEITZ, 1934), from the upper-lower Turonian of Hokkaido, *M. hercynicus* (PETRASCHECK, 1903), from probably the uppermost Lower Turonian of Hokkaido, and *M. teraokai* (MATSUMOTO & NODA, 1968) from the Middle Turonian of Kyushu are also relatively broad forms with gently convex shells (*see* MATSUMOTO & NISHIDA 1995 and MATSUMOTO 1995 for the stratigraphical occurrences of *Mytiloides* species from Hokkaido).

KAUFFMAN (1977a, b) stated that *M. subhercynicus*, *M. hercynicus* and *M. "latus"*, which occur within the Middle Turonian of the Western Interior USA and England, closely resemble *M. teraokai*. MATSUMOTO & NISHIDA (1995, p. 6) have noted the affinities between *M. teraokai* and *M. opalensis* (BÖSE), the latter of which has been reported from the Middle Turonian Zone of *Collignoniceras woollgari* in N. America. Although there may be some time gap between Euramerica and Japan, *M. incertus* may be a descendant of one of the above Middle Turonian species with relatively broad outline.

OCCURRENCE:
1. Type area. Locs. Ik2011, 2012, 2013 and 2014 along the main stream of the R. Ponbetsu, Ponbetsu area, central Hokkaido, some of them may be the inferred type locality. Member IIIa' of the Upper Yezo Group. For the associated fauna see the stratigraphical part.

2. Obira area, northwestern Hokkaido; Unit Mn-o of the Middle Yezo Group.

RANGE: Upper Turonian.

Mytiloides mytiloidiformis (TRÖGER, 1967)
Pl. 15, Figs 6, 7a-c

pars 1930. *Inoceramus inconstans inconstans* em. FIEGE; FIEGE, p. 38, Pl. 6, Fig. 19.

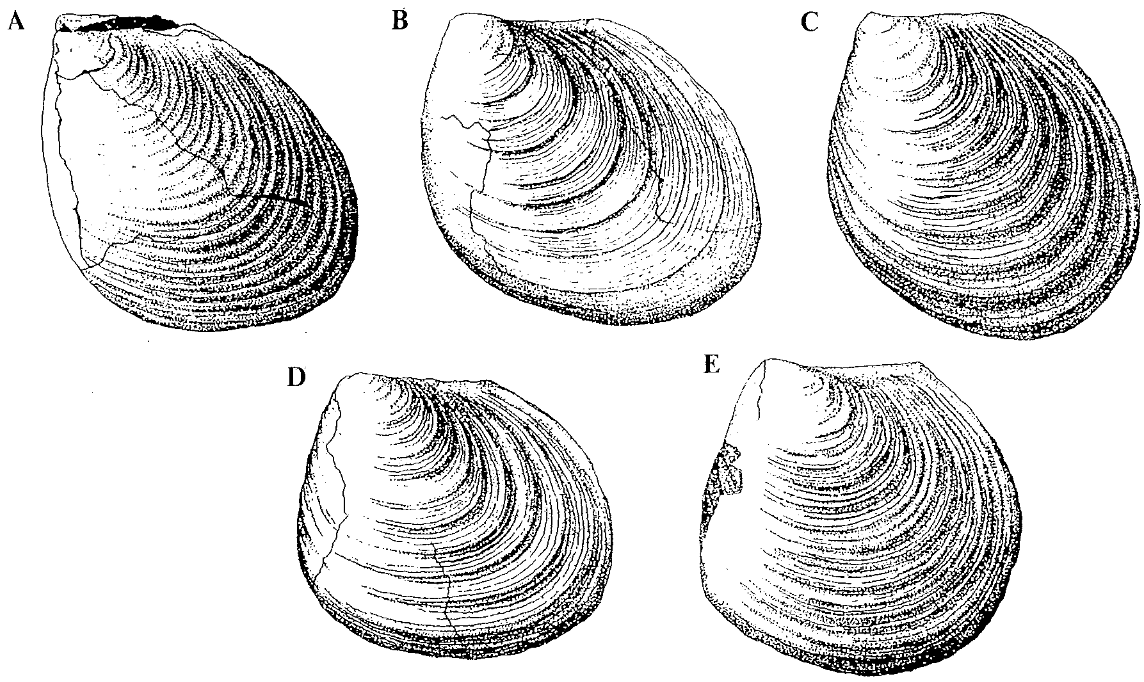


Fig. 5. Variation of shell form in *Mytiloides incertus* (JIMBO) (*after* NODA 1984)

1940. *Inoceramus incertus* JIMBO; NAGAO & MATSUMOTO, pp. 10, 13, Pl. 3, Fig. 4.
1967. *Inoceramus fiegei mytiloidiformis* TRÖGER, pp. 108-110, Pl. 11, Fig. 4; Pl. 13, Figs 16, 18.
1983. *Mytiloides* sp. aff. *M. mytiloidiformis* (TRÖGER); MATSUMOTO & NODA, p. 112, Fig. 5.
1984. *Mytiloides* sp. aff. *M. mytiloidiformis* (TRÖGER); NODA, pp. 467-469, Pl. 86, Fig. 9.
1995. *Mytiloides* aff. *mytiloidiformis* (TRÖGER); MATSUMOTO & NISHIDA, p. 61.
1996. *Mytiloides fiegei mytiloidiformis* (TRÖGER); KAUFFMAN & *al*., p. 83.

HOLOTYPE: The original specimen illustrated by FIEGE (1930, Pl. 6, Fig. 19), and reillustrated by TRÖGER (1967, Pl. 11, Fig. 4) from the Upper Turonian of Lengerich, Germany.

MTERIAL: GK.H10130 and IGPS22738 from the Ponbetsu area and JG.H3505 from loc. Ik1712, from the Ikushunbetsu area. A replica of the holotype, kindly supplied by Prof. Dr. K.-A. TRÖGER.

MEASUREMENTS: Measurements are shown in Table 15.

DIAGNOSIS: Shell elongated along growth axis with considerable obliquity, moderately convex from anterior to posterior and uniformly so along growth axis; wing-like area clearly demarcated. Surface ornamented with concentric ribs and rings in combination, of which former are low, round- or sharp-topped and regular in breadth and intensity and latter are sharp-topped, crowded and continue to wing-like area.

REMARKS: The morphological characters mentioned above (for details refer to NODA 1984, pp. 467-469) are consistent with those of the holotype of *M. mytiloidiformis* (TRÖGER, 1967).

M. mytiloidiformis was originally erected as a subspecies of *I.* (s.l.) *fiegei* TRÖGER, 1967 (= *M. incertus*), by TRÖGER. During the course of study of populations of *M. incertus* it was noticed that the extremely elongate form, GK.H10130 (Pl. 15, Fig. 6) exhibited a h/l ratio that lay outside the possible range ($m \pm 3s$) of the *M. incertus* population. This specimen, therefore, has to be excluded from that sample. Specimen GK.H10130 is contained in a nodule together with typical specimens of *M. incertus*. The co-occurrence of two subspecies is unreasonable from a biological viewpoint. *M. fiegei*

specimen	h	l	b	s	H	L	α	β	γ	δ	l/h	b/h	L/H	s/l
holotype	54.0	47.0	13.8	17.8	64.0	36.0	97°	-	150°	50°-70°	0.87	0.26	0.54	0.36
GK.H10130	61.4	44.9	-	12.7	68.0	34.0	110°	-	160°	60°	0.73	-	0.50+	0.28
JG.H3505	55.8	54.8	15.1	27.4	72.8	41.7	97°	-	149°	47°-57°	0.98	0.27	0.57	0.50

Table 15. Measurements of *Mytiloides mytiloidiformis* (TRÖGER) from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

mytiloidiformis, therefore, should be accorded full specific status as *M. mytiloidiformis* (TRÖGER).

Phylogenetic remarks *see* NODA 1984, p. 469.

OCCURRENCE:
1. Loc. Ik2014, Ponbetsu area, central Hokkaido; lower part of the Member IIIa' ofthe Upper Yezo Group.
2. Loc. Ik1712, upper reaches of the R. Ikushunbetsu, central Hokkaido; lower part of the unit IIIa of the Upper Yezo Group, associated with *I.* (*I.*) *teshioensis*.

RANGE: Upper, but not uppermost, Turonian. The true range of this species should become clear with further field surveys in various areas.

Mytiloides sublabiatus (MÜLLER, 1887)
Pl. 15, Figs 8-9

1841. *Inoceramus mytiloides* ROEMER, p. 60, Pl. 7, Fig. 5 (non *Inoceramus mytiloides* MANTELL, 1822).
1887. *Inoceramus sublabiatus* MÜLLER, p. 411, Pl. 16, Fig. 2.
1929. *Inoceramus sublabiatus* MÜLLER; HEINE, pp. 57-59, Pl. 5, Fig. 27; Pl. 6, Fig. 29.
1979. *Mytiloides sublabiatus* (HEINE); KAUFFMAN (*in* HERM & *al.*, p. 67).

HOLOTYPE: By monotypy the holotype is the specimen figured by MÜLLER (1887, Pl. 16, Fig. 2).

MATERIAL: JG.H3517a, b, and 3518 from the Ponbetsu-Gono-sawa, central Hokkaido. Specimens JG.H3617a and 3618 are both internal moulds of right valves, showing a marginal outline. The prismatic layer remains on the umbonal and ventral regions of JG.H3517a and also on the posterior part of JG.H3518. JG.H3517b is an imperfect left valve. The nodule yields moreover, many shell fragments.

MEASUREMENTS: Measurements are shown in Table 16.

DESCRIPTION: Shell small, probably equivalve, inequilateral, gently and uniformly convex from anterior to posterior and also along growth axis. Anterodorsal part flattened, passing into narrow wing-like area without sharp boundary. Umbo small, terminal and scarcely projecting over hinge line. Anterodorsal to anterior margins long and stright, ventral one narrowly arcuate, postero- to posterodorsal ones broadly convex, forming an obtuse angle with hinge line about 132°. Hinge line short, slightly longer than one third of shell length. Outline considerably elongated along growth axis, which is straight and fairly oblique, δ 61° to 69°.

Surface ornamented with concentric ribs and concentric rings in combination. Concentric ribs low, round-topped, fairly crowded and gradually broadened with growth, concentric rings superimposed on ribs and interspaces.

REMARKS: The available specimens resemble *M. labiatus* and *M. submytiloides* in elongate outline, shell convexity and surface ornamentation, but are discriminated morphologically

specimen	h	l	b	s	H	L	α	γ	δ	l/h	b/h	L/H	s/l
JG.H3517a	43.4	28.3	-	10.4	46.0	27.8	92°	132°	68°	0.63	-	0.59	0.36
JG.H3518	38.0	27.7	-	9.4	42.1	22.7	90°	132°	61°	0.73	-	0.54	0.34

Table 16. Measurements of *Mytiloides sublabiatus* (MÜLLER) from Hokkaido; linear dimensions in mm; symbols as for Table 1 and Text-fig. 2

from the above species by the less prominent umbo, the long and straight anterodorsal margin and the lesser obliquity. Moreover, they are distinct in stratigraphical position occurring in the Lower Coniacian, Zone of *I.* (*Cr.*) *rotundatus*. The specimens also resemble *M. mytiloidiformis*, from the Upper Turonian, in the elongate outline and less prominent umbo, but differ in the straight anterodorsal margin and lesser obliquity. From the also similar *M. labiatoidiformis* (TRÖGER, 1967), from the Upper Turonian, they differ in the straight anterodorsal margin, narrower elongate outline and lesser obliquity.

The variation of *M. sublabiatus* was not clear in the original description by MÜLLER (1887) because of insufficient material. The material of this species illustrated by HEINE (1929) is heterogenous; the specimens figured by him in figs 28 and 29 should be exluded from the synonymy of MÜLLER's species. I agree with KAUFFMAN (*in* HERM & *al.* 1979, p. 67) in his remarks on this species.

The two specimens available are closest to the specimen figured by HEINE (1929, Pl. 5, Fig. 27). If the extent of variation of the species is clarified by population samples in the future, some allied species may be united into *M. sublabiatus* as junior synonyms.

PHYLOGENY: The specimens of *M. sublabiatus* and allied species do not occur in a continuous sequence of strata along a particular route in Hokkaido. However, *M. sublabiatus* is probably a descendant from the elongate forms of *Mytiloides* in the Upper Turonian, such as *M. mytiloidiformis* and/or *M. labiatoidiformis*, because *M. mytiloidiformis* occurs in the Upper Turonian of the Ponbetsu and Ikushunbetsu areas, which are not widely separated from the locality of *M. sublabiatus* at Ponbetsu-Gonosawa. *M. mytiloidiformis* and *M. labiatoidiformis* may have descended indirectly from *M. mytiloides* of the Lower Turonian, although there is an interval without data in the Middle Turonian.

OCCURRENCE: Loc. Ik2799, upper reaches of the Ponbetsu-Gono-sawa, central Hokkaido (for location *see* Noda & Uchida 1995, p. 143, Fig. 1). Member IIIb' of the Upper Yezo Group, associated with *I.* (*Cr.*) *rotundatus*.

RANGE: Lower part of the Lower Coniacian.

Part 2. Stratigraphic Succession

by MASAYUKI NODA & TATSURO MATSUMOTO

INTRODUCTION

Upper Cretaceous marine sediments are distributed fairly extensively in Japan and adjacent areas. For some reason, however, the inoceramid biostratigraphy of the Turonian – Coniacian interval has been studied in only a relatively few areas. They are, as indicated in Text-fig. 1, (1) the Obirashibe Valley (simply called the Obira or Tappu area), northwestern Hokkaido, (2a-c) the Ikushunbetsu Valley (recently called the Mikasa district), central Hokkaido, including three localities, as explained later, (3) Kajisako in Shikoku and (4) the Onogawa Basin, eastern Kyushu. Other areas, such as, (5) Oyubari, (6) Hobetsu, (7) Futaba and (8) Uwajima are too poorly known for the purpose of the present study and are only briefly mentioned in connection with the main description.The descriptions of stratigraphic successions in this paper derive mainly from a number of published papers (listed below), supplemented by some new observations. The sites of the.numbered localities of inoceramid species were mostly indicated in the maps and stratigraphic sections of the previous papers. Some of them, especially the graphic sections and sketches of important outcrops, are reproduced in this paper, with necessary amendments.

Among the fossils associated with the inoceramids, certain species of ammonites are useful for international correlation and are, therefore, mentioned in the description of the stratigraphical successions. Their taxonomic names relate to those used in the cited papers and are not necessarily altered, even where they need to be updated and/or revised in the light of subsequent knowledge.

Before going further, a comment should be made regarding the substages used here. The substage boundaries of the Turonian and the Coniacian are not formally defined internationally, although some proposals were made at the Brussels 1995 Conference on Cretaceous stage boundaries (*cf.* BENGTSON 1996, KAUFFMAN & *al.* 1996). The substages used in both parts of this paper are taken from the scheme of

TOSHIMITSU & *al.* (1996). They must be regarded as only approximate equivalents of substages used elsewhere and are used in Japan on a provisional basis.

SELECTED SECTIONS IN HOKKAIDO

Obirashibe valley

The Cretaceous stratigraphy of the Obirashibe valley (simply called the Obira area or Tappu area, by some authors) was previously described by TSUSHIMA &. *al.* (1958), TANAKA (1963), TANABE & *al.* (1977), SEKINE & *al.* (1985), MAEDA (1987) and ASAI & HIRANO (1990). The lithostratigraphical subdivisions defined by TANAKA (1963) have been used by subsequent authors, sometimes with slight modification. For instance, Unit Mj and Mk are hardly distinguishable in some parts and, in such cases, Mj-k is used as a single composite unit. The unit Mn-o may be used in a likewise manner, where appropriate.

Subsequent to the above works, one of us (MN), sometimes together with TM, investigated the succession along two selected parts of the main course of the river Obirashibe. One of them is near the Obira dam in the middle course. Before construction of the dam, the strata belonging to Units Ml and Mm-o, the upper part of the Middle Yezo Group, and Units Ua, Ub and Uc, the lower part of the Upper Yezo Group, were well exposed there. In 1988, during cutting and dredging in connection with dam construction, various species of inoceramids were found to occur in abundance in strata ranging from the upper part of Unit Mn-o to Unit Uc. Since 1991 this important T/C boundary section has been mostly submerged under the artificial lake. The other section is somewhat downstream from the Obira Dam. It is located on the curved part of the R. Obirashibe, about 450m upstream from the Tengu-bashi bridge. The outcrop is shown in a sketch (Text-fig. 6). Units Ua to Ud can be observed here. The results of previous and subsequent work are summarized in a graphic section (Text-fig. 7), together with data on stratigraphic occurrences of inoceramid species.

The lower part of Mj-k contains *Mytiloides mytiloides* (MANTELL) and *Inoceramus* (*I.*) aff. *tuberosus* KELLER (*see* MATSUMOTO 1996) which indicate the lower part of theTuronian. *I.* (*I.*) *hobetsensis* NAGAO & MATSUMOTO, a zonal index of the middle part of the Turonian, appears in the upper part of Unit Mj-k and ranges to Mn. Huge individuals of this species (H>40 cm) occur commonly in Mm-n and Mn-o, where *I.* (*I.*) *iburiensis* and *I.* (*Cremnoceramus*) *ernsti* coexist. *Subprionocyclus* cf. *neptuni* (GEINITZ), an index

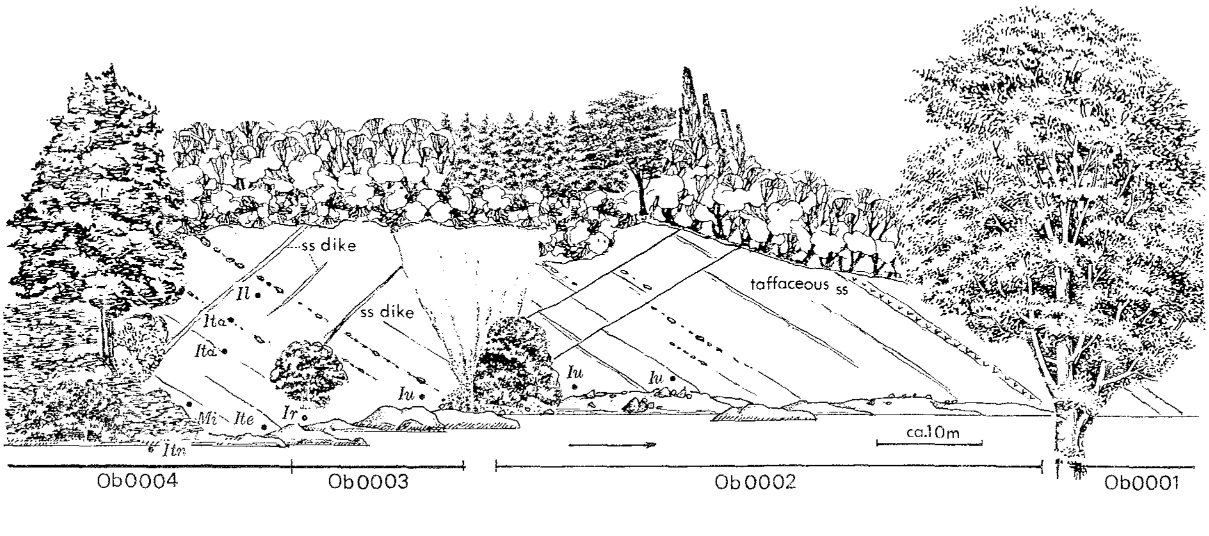


Fig. 6. Sketch of the outcrops Ob0001-0004 on the left side of the R. Obirashibe (adapted from Noda 1992, p. 1325, Fig. 10); **Il** – *I.* (*Cr.*) *lueckendorfensis*, **Ir** – *I.* (*Cr.*) *rotundatus*, **Ite** – *I.* (*I.*) *teshioensis*, **Ita** – *I.* (*Pl.*) *tappuensis*, **Itn** – *I.* (*I.*) *tenuistriatus*, **Is** – *I.* (*Pl.*) *szaszi*, **Iu** – *I.* (*I.*) *uwajimensis*, **Mi** – *Mytiloides incertus*

of the Upper Turonian, enters at loc.R2114. where *I.* (*I.*) *iburiensis* first appears. The uppermost horizon with *I.* (*I.*) *iburiensis* is loc. Ob0004g of Unit Ual, which contains *I.* (*I.*) *teshioensis* and *S. neptuni* at somewhat different levels. *Mytiloides incertus* ranges from NH84 and NH85 of Unit Mo to Ob0004 of Unit Ual, and is associated with *I.* (*I.*) *tenuistriatus* at Ob0004, which must be uppermost Turonian.The lower part of loc.Ob0003 (Ua2) yields *I.* (*Cr.*) *rotundatus*, the widespread Lower Coniacian index. Various species of inoceramids, namely *I.* (*Platyceramus*) *tappuensis*, *I.* (*Cremnoceramus*) *lueckendorfensis* and *I.* (*I.*) *pedalionoides* occur in the 0b0003 section. Unit Ub contains *I.* (*Cr.*) *ernsti*, *I.* (*Pl.*) *tappuensis*, *I.* (*I.*) *pedalionoides*, *I.* (*Cremnoceramus*) *deformis* and *I.* (*Volviceramus*) *koeneni*. *I.* (*V.*) *koeneni* seems to appear earlier here than in Europe and N.

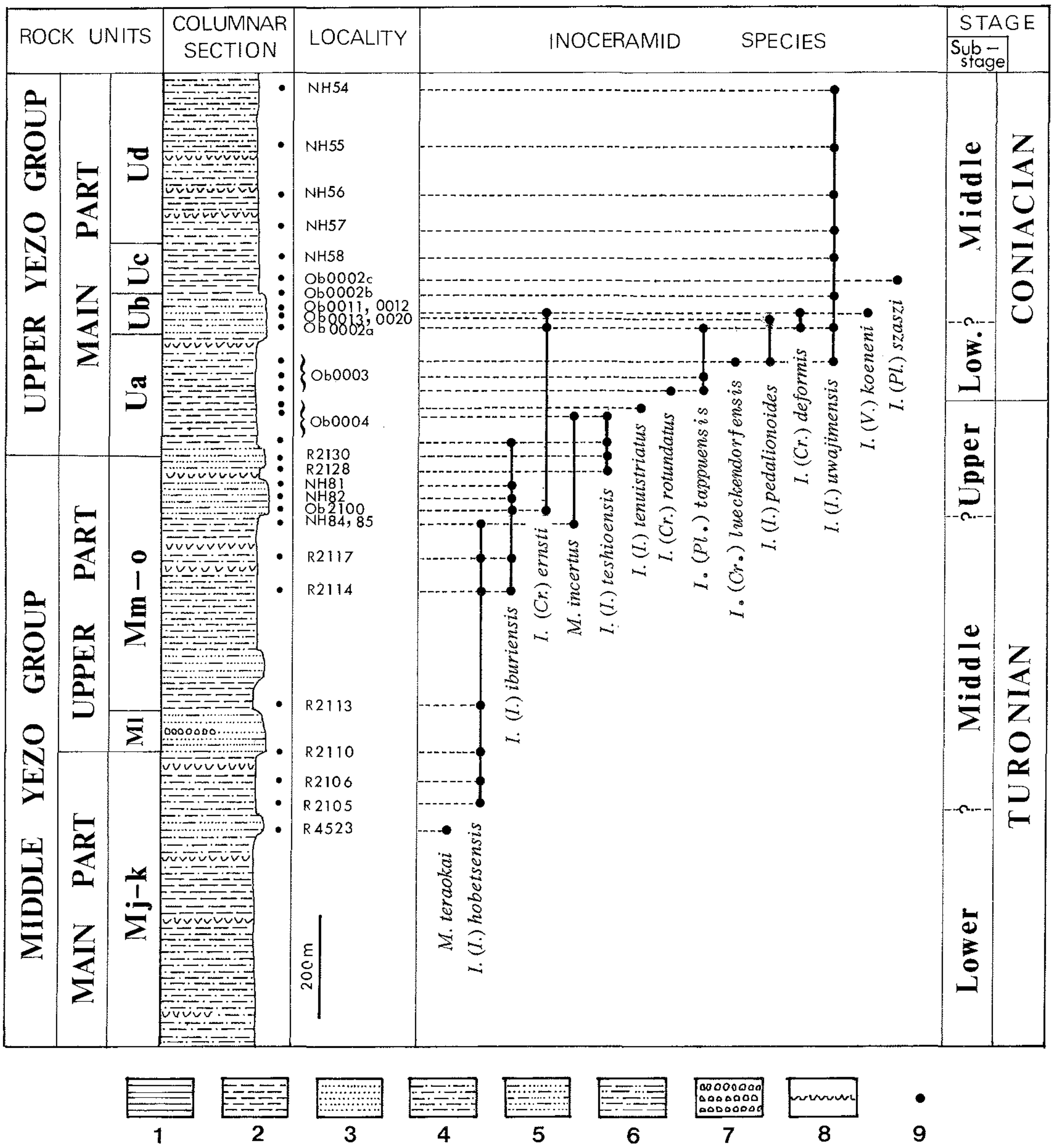


Fig. 7. Stratigraphical section of the Turonian/Coniacian boundary succession along the R. Obirashibe, Hokkaido, showing occurrences of inoceramid species

1 – shale, 2 – siltstone, 3 – sandstone, 4 – alternation of mudstone and sandstone, 5 – sandstone predominant, 6 – mudstone predominant, 7 – conglomerate, 8 – tuff or tuffaceous rick

America. MATSUMOTO & *al.* (1981) obtained *Barroisiceras* (*B.*) *onilahyensis* BASSE from loc.R2638J along the R. Obirashibe in a unit which is assigned to the upper part of Unit Ub or to the lower part of Unit Uc. The strata of loc.ObOOO2b shown in Text-fig. 6 are probably correlated with that part, because *B.* (*B.*) *onilahyensis* is a characteristic species of the Middle Coniacian in Madagascar. *I.* (*Platyceramus*) *szaszi* is first found at loc. ObOOO2c in Unit Uc-d. Here again, Units Uc and Ud are hardly separable lithologically. The species *I.* (*Cr.*) *deformis*, important form for inter-regional correlation, was recently reported from the Obirashibe section (NODA 1996). KENNEDY & COBBAN (1991) regarded *I.* (*Cr.*) *deformis* as a zonal index of the lower Middle Coniacian in the Western Interior. KAUFFMAN & *al.* (1996, p. 84) pointed out that *I.*(*Cr.*) *deformis* occurs in the Lower Coniacian but above the horizon of the first occurrence of *I.* (*Cr.*) *rotundatus*. The stratigraphical range of *I.* (*Cr.*) *deformis* in the Obira area is limited to the lower part of Unit Ub, but it is difficult to ascribe that part (*i.e.* lower Ub) to either the Lower or Middle Coniacian substages, because no index ammonites, such as *Forresteria* (*Harleites*) *petrocoriensis* (COQUAND) have been found there.

Ikushunbetsu valley

The Ikushunbetsu valley (recently called the Mikasa district) is noteworthy for good exposures of the Cretaceous and overlying Lower Tertiary strata, which have been studied by a number of investigators. The main part of this Cretaceous area was shown in a geological map and section by MATSUMOTO & *al.* (1978, Figs 6-7). There is a major anticline and accompanying thrust trending NE-SW. The best outcrop was on the eastern flank of the anticline, along the main course of the R. Ikushunbetsu, before the construction of the Katsurazawa Dam. This section is numbered here as 2a.

The Cretaceous strata in the Ikushunbetsu valley, as in other adjacent areas of the Yubari Mountains, central Hokkaido, are characterised by lateral facies changes. Near-shore facies occur in the west and offshore facies occur in the east. The section of the main course of the R. Ikushunbetsu, described below under 2a, represents sediments of moderate water depths, whereas section 2b, along the lower course of the R. Ponbetsu, and section 2c of the Ponbetsu-Gono-sawa, are of near-shore facies. The section in the upper reaches of the R. Ikushunbetsu, described under 2a, shows rather an offshore facies.

The stratigraphical succession of the sections 2a, 2b and 2c are described below separately.

Main course of the river Ikushunbetsu

The Upper Albian through Santonian succession was formerly very well exposed along the main course of the R. Ikushunbetsu before the construction of the Katsurazawa Dam on Upper Turonian strata. At present the younger strata above the dam are submerged under the artificial Lake Katsurazawa. The Cretaceous biostratigraphy of this area, investigated before the construction of the dam, was described by MATSUMOTO (1954, 1965, 1984) and MATSUMOTO & *al.* (1978). These papers, as well as the results of recent work (UCHIDA & NODA, *in press*), are summarised here, with some supplementary comments where necessary. Owing to the meandering of the river and horizontal displacements by wrench faults, the fossiliferous strata are repeated along the river. Text-fig. 8 shows the generalised stratigraphic succession of this area, together with data on ranges and occurrences of inoceramids after MATSUMOTO (1965, 1984). *I.* (*I.*) *hobetsensis* occurs abundantly in the upper part of the "middle Turonian" in various areas of Japan. In the Ikushunbetsu route it ranges upwards to loc.Ik977. During recent fieldwork along the nearby forestry *I. (I.) hobetsensis* was collected in association with *I.* (*I.*) *teshioensis* and *Mytiloides mytiloidiformis* at loc.Ik1705 (UCHIDA & NODA, *in press*). The co-occurrence of the first two species is taken here as the marker of the base of the Upper Turonian.

I. (*I.*) *teshioensis* characterizes the upper part of the Turonian in Hokkaido and other areas of Japan. In the Ponbetsu section (see below) it is accompanied by *Mytiloides incertus* and *M. mytiloidiformis*. The latter form was described from the Upper Turonian of Germany (TRÖGER 1967, with revision of chronostratigraphical assignement by SEIBERTZ 1979), and recently was also reported from the uppermost Turonian to lowermost Coniacian of the US Western Interior (KAUFFMAN & *al.* 1996). In Hokkaido *M. mytiloidiformis* seems to range more down within the Turonian than in the cited Euramerican records. Here again, the range of *I.* (*I.*) *hobetsensis* extends upwards to the Upper Turonian, as in the Hobetsu area. The first green sandstone (GSl) at loc.Ik971 contains *I.* (*I.*) *teshioensis* together with *Subprionocyclus normalis* and *Reesidites minimus*. Loc.Ik938, stratigraphically somewhat above loc. Ik971, contains the same three species and also *Ryuella ryu* (MATSUMOTO & MURAMOTO). (*see* KLINGER & KENNEDY 1997) The last occurrence of *I.* (*I.*) *teshioensis* is at loc.Ik937b, where the top of the Turonian can be placed. At loc.Ik966d, immediately above loc.Ik937b, the second green sandstone (GS2) crops out. No inoceramid species has been found in this sandstone. However, *Baculites yokoyamai* TOKUNAGA & SHIMIZU occurs abundantly in this bed and ranges upwards to loc. Ik964a. This ammonite is associated with *Inoceramus* (*I.*) *uwajimensis* in various other localities in Hokkaido, as well as at its type locality Futaba (no. 7 in Text-fig. 1), whereas *B. undulatus* D'ORBIGNY occurs in the upper Turonian (*e.g.* loc.Ik1181) in the first green sandstone (GSl) together with *I.* (*I.*) *teshioensis* and *Subprionocyclus normalis* (*see*

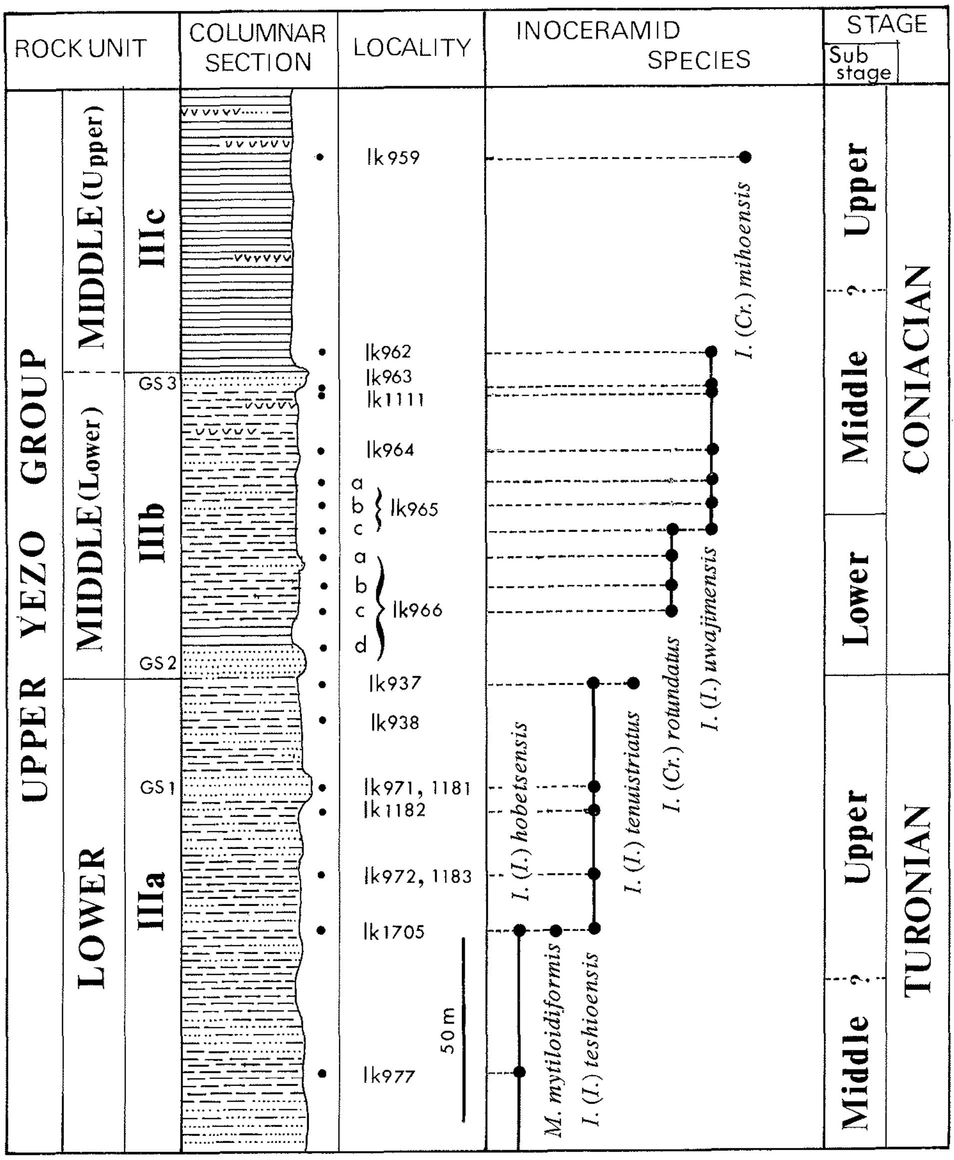


Fig. 8. Stratigraphical succession from the mid-Turonian through Upper Coniacian along the main course of the R. Ikushunbetsu, Hikkaido, showing occurrences of inoceramid species (*adapted from* MATSUMOTO 1965)
(legend as for Text-fig. 7)

MATSUMOTO & OBATA, 1963), as well as in the upper Turonian of France (*see* ROMAN & MAZERAN 1913). Also, in New Mexico, COBBAN (1986) reported *B. yokoyamai* from the Coniacian and *B. undulatus* from the Turonian, although *B. yokoyamai* is said to range downwards to the Turonian in other areas of the N. American Western Interior. Thus, the second green sandstone, GS2, represents the basal Coniacian in the main course of the Ikushunbetsu. Incidentally, a gigantic, endemic ammonite species, *Grandidiericeras nagaoi* MATSUMOTO & SAITO occurs occasionally in GS2 and in fact its type locality is Ik966d. *I.* (*I.*) *uwajimensis* occurs abundantly at loc.Ik963 immediately below the third greensand bed (GS3). At loc.Ik1111 and certain other localities at or below GS3 (*see* MATSUMOTO 1965, fig. 2 for the location), *I.* (*I.*) *uwajimensis* is associated with *Prionocycloceras sigmoidale* MATSUMOTO. Also at loc.Ik964b, somewhat below GS3, *I.* (*I.*) *uwajimensis* is associated with *Prionocycloceras* aff. *guayabanum* (STEINMANN). This ammonite genus is cosmopolitan in the Coniacian. It should be noted that the above two species occur in the middle of the Coniacian, where *I.* (*I.*) *uwajimensis* is most prolific. This part is certainly mid-Coniacian. *Kossmaticeras theobaldianum* (STOLICZKA) was obtained at loc. Ik931, together with *I.* (*I.*) *uwajimensis*. The horizon of loc. Ik931 may have been interpreted too low previously (MATSUMOTO 1965, fig. 3), but it is within the acme-zone of *I.* (*I.*) *uwajimensis*. At loc. Ik2748 of Ponbetsu Gono-sawa, this ammonite species is also found in the Zone of *I.* (*I.*) *uwajimensis* together with *Forresteria* (*Forresteria*) *alluaudi* (BOULE & *al.*), a widespread Middle Coniacian (KENNEDY 1984) *K. theobaldianum* was originally recorded from South India, where its horizon is regarded as mid-Coniacian (SASTRY & *al.* 1968). Furthermore, COLLIGNON (1965) established a Zone of *K. theobaldianum* – *F.* (*F.*) *alluaudi* in the Middle Coniacian of Madagascar. The genus *Kossmaticeras* itself enters earlier, as is shown by occurrences of *K. flexuosum* MATSUMOTO in the Middle Turonian of Japan and of *K.* aff. *recurrens* (KOSSMAT) in the Upper Turonian of Madagascar (*see* MATSUMOTO 1993). As the strata at successive levels from locality Ik966c to loc. Ik965a inclusive contain *I.* (*Cr.*) *rotundatus*, this part of the Ikushunbetsu main section represents the Lower Coniacian. On the eastern flank of a gentle syncline in the upper reaches of the R. Ikushunbetsu, there are some other localities which expose the T/C boundary. *I.* (*I.*) *lusatiae* has been recently obtained from locs. Ik7000 – Ik7003 (*see* NODA 1996, pp. 558-564 and fig. 9) This species is recorded from the Middle Turonian to Middle Coniacian of various regions of Euramerica, although its actual range may vary in different areas. It is mot common in the uppermost Turonian and Coniacian. Hence, stratigraphic occurrence of this species in the Ikushunbetsu area is approximately consistent with that in Euramerica.

It is regrettable that the fine outcrop of the T/C boundary sequence along the main course of the R.Ikushunbetsu is now submerged beneath the artificial lake, but other sections are available along forestry roads and also around the tributary Kami-Ichino-sawa.

Lower course of the R. Ponbetsu

The Cretaceous biostratigraphy of this valley was recorded by MATSUMOTO (1965, 1984), FUTUKAMI & *al.* (1980), MATSUMOTO & *al.* (1981) and NODA (1984).This area is situated on the western flank of the Ikushunbetsu anticline. Good sections are exposed successively along the River Ponbetsu for a considerable distance, of which a length of about 200 m is relevant to the present study. The route map, sketch of the outcrop and stratigraphic occurrence of inoceramid species are shown in Text-figs 9-10 and 11. Upper Turonian strata and a small part of the overlying Coniacian are exposed below the unconformity at the base of the Eocene coal-bearing Ikushunbetsu Formation. We regard the base of the green sandstone represented by Ik2012a in Text-fig. 9, and Ik2011b in Text-fig. 10 (of this report) as the base of the Coniacian stage as the base of the Coniacian Stage on account of the association of *I.* (*I.*) *uwajimensis* and *Baculites yokoyamai* in part of the green sandstone and in the overlying siltstone of the Member IIIb'. Immediately below the green sandstone, in the uppermost part of IIIa', as represented by loc. Ik2012, occur *M. incertus* and *I.* (*I.*) *tenuistriatus*, *Lymaniceras planulatum* MATSUMOTO and *Prionocyclus abberrans* MATSUMOTO. Locs. Ik2013 and 2014 yield fairly common *I.* (*I.*) *teshioensis*, *I.* (*I.*) *tenuistriatus*, *I.* (*I.*) *pedalionoides*, *M. incertus*, *M. mytiloidiformis*, *Lymaniceras planulatum* and *Reesidites minimus*. *Damesites ainuanus* MATSUMOTO, *Subprionocyclus neptuni* and *S.*

normalis were found rarely at loc. Ik2014d. These species together indicate a Late Turonian age. The rare occurrence of *M. mytiloidiformis* at loc. Ik2014 is noteworthy. A specimen with an *Actinoceramus*-like morphotype (= *I.* sp. aff. *I. inaequivalvis* SCHLÜTER *in* MATSUMOTO 1984) from loc. Ik2014 is also notable and should be investigated further. A few specimens which show *I.* (*I.*) *uwajimensis*-like characters are rare elements in the assemblages at localities Ik2013 and 2014 the undoubted *I. (I.) uwajimensis* of the Coniacian. We should, however, examine this idea more carefully. At the horizon of loc.Ik2016a, in the lower part of Member 11d', *S. neptuni* was obtained by MATSUMOTO together with *I.* (*I.*) *hobetsensis*. *S. neptuni* is a cosmopolitan Upper Turonian index, whereas *I.* (*I.*) *hobetsensis* is very common in the middle part of the Turonian in Japan, but may range upwards. In fact, on a route of the Hobetsu River, south-central Hokkaido, *I.* (*I.*) *hobetsensis* occurs commonly at its type locality, but it is also found rarely at an higher horizon, together with *I.* (*I.*) *teshioensis*. In our opinion, the nectonic species, *S. neptuni* is more widespread and more suitable as a zonal index than the benthic *I.* (*I.*) *hobetsensis*.

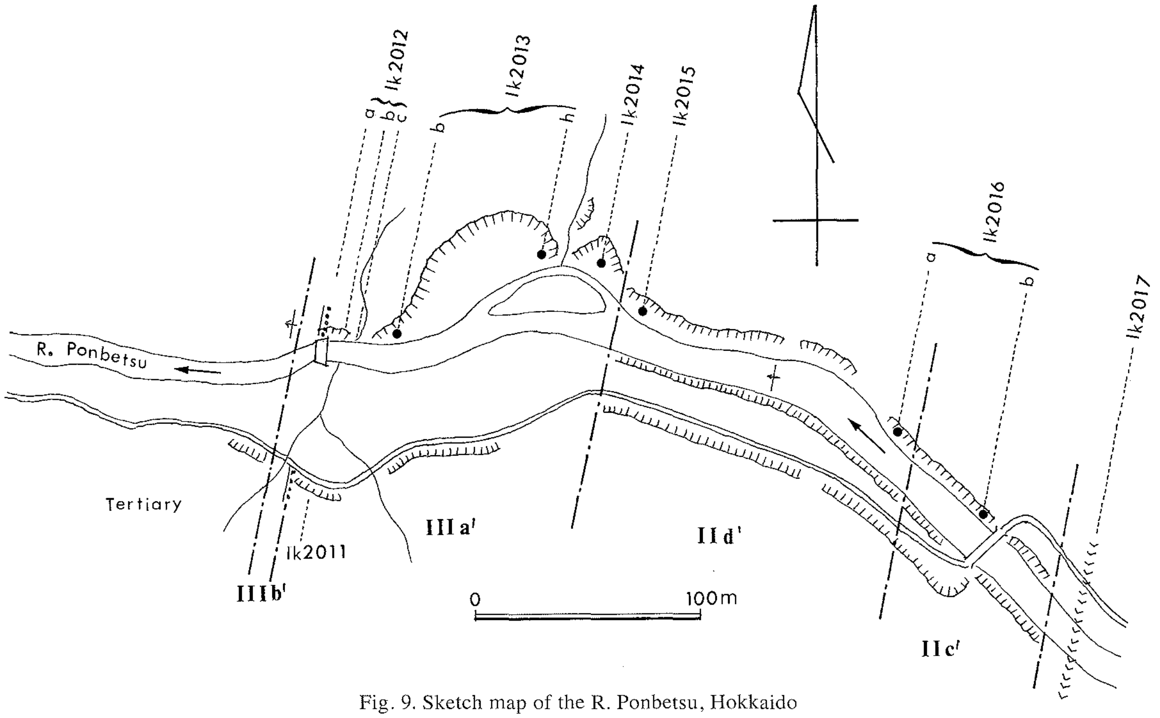


Fig. 9. Sketch map of the R. Ponbetsu, Hokkaido

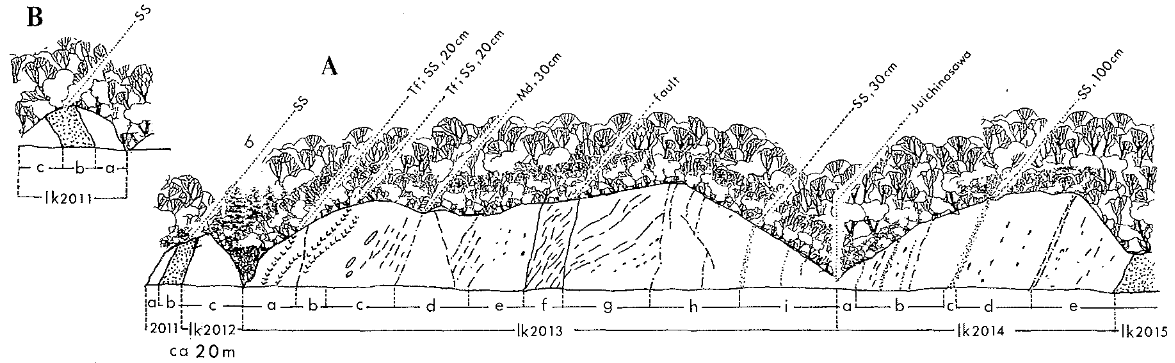


Fig. 10. Sketch of the outcrops along the lower course of the R. Ponbetsu (*adapted from* MATSUMOTO & *al.* 1981)

We regard loc.Ik2016a as falling in the lower part of theUpper Turonian. In other words *I. (I.) hobetsensis* ranges up to this horizon.

Ponbetsu-Gono-sawa

The Ponbetsu-Gono-sawa is a branch of the R. Ponbetsu, which itself is a long tributary of the main River Ikushunbetsu The sections described in items 2a to 2c are part of the celebrated Cretaceous exposures of the Ikushunbetsu Vallcy (*i.e.* the Mikasa district). There is a major anticline in this area. Sections 2b and 2c belong to the western flank of this anticline, that of 2a belongs to the eastern flank (*see* MATSUMOTO & *al.*, 1978, Figs 6-7).The stratigraphy along the Ponbetsu-Gono-sawa was precisely recorded by MATSUMOTO (1984) MATSUMOTO & NODA (1985) and NODA & UCHIDA (1995). The T/C boundary succession in this part is subdivided into Members IIIa', IIIb' and IIIc', which correspond lithostratigraphically to Units IIIa, IIIb and IIIc of the succession along the main course of the R. Ikushunbetsu in the east (see item 2). The fossiliferous strata are well exposed along a particular section of the Ponbetsu-Gono-sawa. Text-fig. 12 shows the general succession and occurrence of inoce-

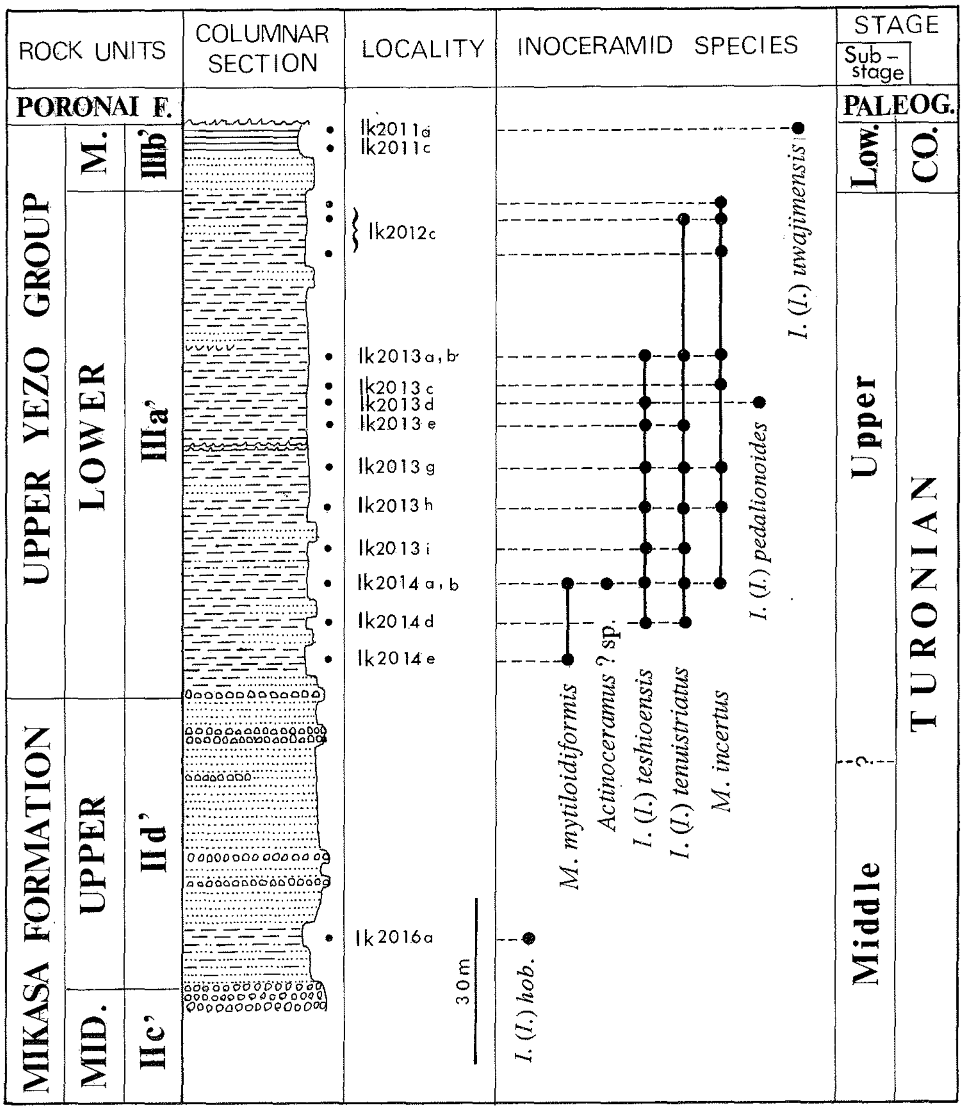


Fig. 11. Stratigraphical succession from the mid-Turonian to the basal Coniacian along the lower course of the R. Ponbetsu, showing occurrences of inceramid species; legend as in Text-fig. 7

ramid species in this section. The green sandstone bed which characterizes the basal part of Member IIIb' is thinner and more silty than that in sections 2a and 2b. The main part of Member IIIb' is a fine sandy siltstone, which is followed by a more sandy unit at the top of the member. Member IIIa', which is conformably overlain by Member IIIb', consists of thick-bedded sandy siltstone. Owing to NW-SE wrench faults and an anticline, the sequence of strata is repeated.

In this section of Ponbetsu-Gono-sawa, inoceramids are abundant and are associated with ammonites at some horizons. Loc. Ik2727, which represents the uppermost part of Member IIIa', contains *I.* (*I.*) *teshioensis* and *I.* (*I.*) *tenuistriatus* together with the ammonites *Lymaniceras planulatum* and *Reesidites minimus*. In Japan, all of these species are taken to indicate Upper Turonian. At loc. Ik2726, 2716a-q, a weakly-ribbed form of *I.* (*Cr.*) *rotundatus* occurs abundantly. Among the associated ammonites, *Forresteria* (*Harleites*) *petrocoriensis* (COQUAND) from loc. Ik2716 and *F.* (*Harleites*) cf. *harlei* (DE GROSSOUVRE) from

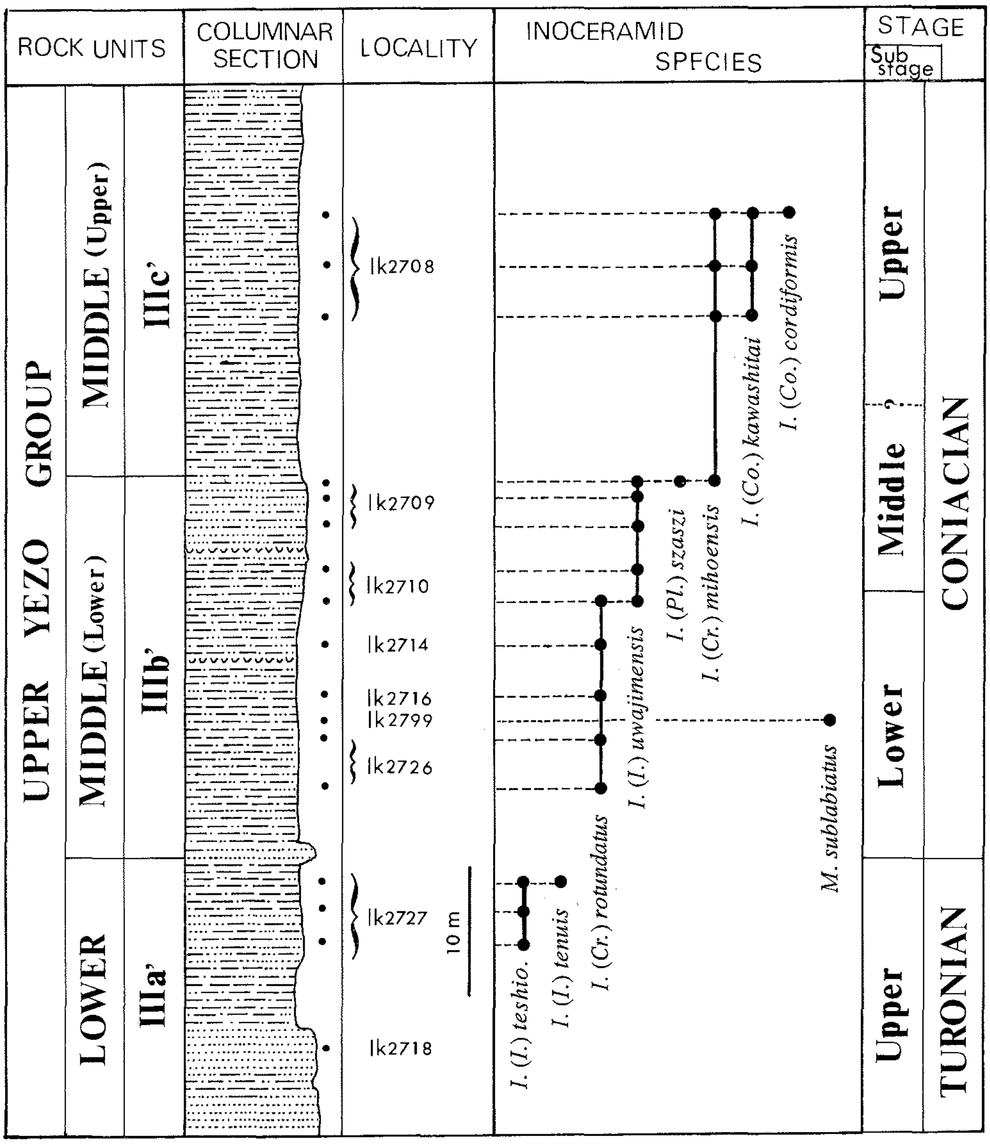


Fig. 12. Stratigraphical chart of the Turonian/Coniacian boundary succession along the Ponbetsu-Gono-sawa, Hokkaido, showing occurrences of incoeramid species; legend as in Text-fig. 7

loc. Ik2786 are good Lower Coniacian indices. At loc. Ik2714 and in the upper part of the cliff of loc. Ik2710, a distinctly ribbed form of *I.* (*Cr.*) *rotundatus* is found. These localities can be confidently assigned to the Lower Coniacian. *I.* (*I.*) *uwajimensis* first appears in the middle part of loc. Ik2710, together with *I.* (*Cr.*) *rotundatus* and is abundant at loc. Ik2709. The base of the Middle Coniacian is inferred to lie in the middle part of loc. Ik2710. The first appearance of *I.* (*Cr.*) *mihoensis* is marked by a few specimens at the top of loc. Ik2709. *I.* (*Pl.*) *szaszi* appears at the highest horizon of the same locality. Associated ammonites are *F.* (*Forresteria*) *alluaudi* (BOULE, LEMOINE & THEVENIN), *Barroisiceras* (*Baseoceras*) *inornatum* MATSUMOTO and *Kossma-ticeras theobaldianum*. The base of the Upper Coniacian could be placed between horizons Ik27091 and Ik2109m, because the first occurrence of *I.* (*Cr.*) *mihoensis* conventionally marks the upper Coniacian in Japan. Loc. Ik2708 yields *I.* (*Cr.*) *mihoensis*, *I.* (*Cordiceramus*) *kawashitai* NODA and *I.* (*Co.*) *cordiformis* subsp. These inoceramids are commonly found in one and the same nodule. *I.* (*Cr.*) *mihoensis* and *I.* (*Co.*) *kawashitai* are conventionally regarded as Upper Coniacian indices in Japan and south Sakhalin. *I.* (*Co.*) *cordiformis* subsp. from loc. Ik2708 is hitherto undescribed in Japan. Summarizing the succession in Text-fig. 12, the Coniacian succession along this route is clearly divisible into lower, middle and upper parts on the basis of the inoceramid assemblages. Whether or not these three parts can be precisely correlated with the internationally defined substages is a problem to be solved in the future.

KAJISAKO SECTION IN THE MONOBE AREA, SHIKOKU

The Upper Cretaceous Kajisako Formation is exposed along the R. Kajisako, a tributary of the R. Monobe, Shikoku. A revised stratigraphy of this formation was given by TASHIRO & *al.* (1982). The formation is divided into four members, namely, the lower, middle, upper and uppermost ones. The total thickness of the formation is about 180 m. The reference section relevant to this study corresponds to the lower member, which is composed of fine-grained sandstones with numerous acidic tuff or tuffite intercalations in the lower part. Text-fig. 13 shows the succession and the occurrence of inoceramid species of the Kajisako section. It should be noted that the succession of inoceramid-bearing beds is discontinuous in this section and that the inferred Turonian part is much thinner than that of the reference succession in Hokkaido. For these reasons the Kajisako section may be less than ideal for the present study. It represents, however, a tectonically less disturbed part of the Cretaceous area in southwest Japan. In other areas, such as Uwajima, the geologic structure is much too complex for biostratigraphical studies.

The inoceramid species from this section reported by MATSUMOTO & *al.* (1982) are as follows (in ascending order):

(1) *Mytiloides* cf. *goppelnensis* (BADILLET & SORNAY) at M-55. This is an imperfect specimen, but it is comparable with the better preserved ones from several places in Hokkaido, fairly low in the Turonian (see MATSUMOTO & NISHIDA 1995, figs 5-6).

(2) both *Mytiloides teraokai* (MATSUMOTO & NODA) and *I.* (*I.*) *hobetsensis* occur abundantly at loc. M-03, about 5 m higher than M-55. They are associated with, among other ammonites, *Collignoniceras* cf. *woollgari* (MANTELL) and *Mesopuzosia* cf. *indopacifica* (KOSSMAT). This faunule indicates a Middle Turonian age.

(3) *I.* (*I.*) cf. *iburiensis* is rare at loc.M-03', 0.3 m above M-03.

(4) *I.* (*I.*) *teshioensis* occurs fairly abundantly at loc.M-51, about 4 m, above M-03. Some specimens are secondarily deformed. A few fragmentary specimens probably referable to *I.* (*I.*) *iburiensis* are also found.

(5) *I.* (*I.*) *uwajimensis* forms dense accumulations in several layers at locs.M-05 and M-06, which are separated from loc.M-51 by about 20 m of strata in which no macrofossils have been found.

(6) *I.* (*Cremnoceramus*) *mihoensis* is represented in this section by a single specimen from loc.M-60, about 7 m above the bed at loc. M-05.

The six inoceramid-bearing levels mentioned above are comparable with those in the well stud-

& *al.* (1992), and SAKAI & *al.* (1993). The stratigraphic succession is well exposed along the R. Kawarauchi, a tributary of the R. Onogawa, and can be examined in several places in the basin. A composite section, together with inoceramid biostratigraphic data, is shown in Text-fig. 14. Locs. OR242, 234, 233 and 230 are located in ascending order in beds of silty mudstone which are interfingered with conglomerates in the upper part of the

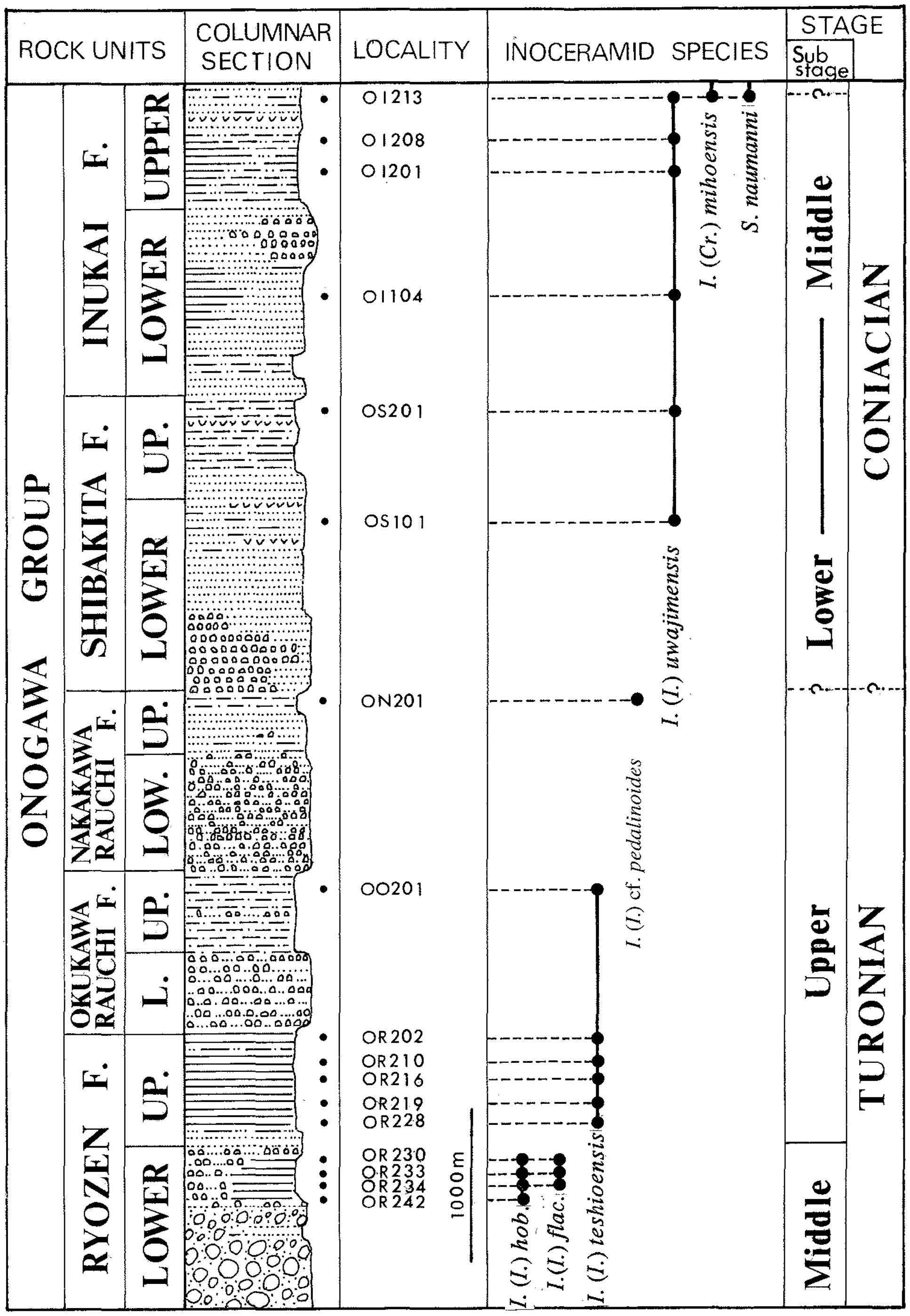
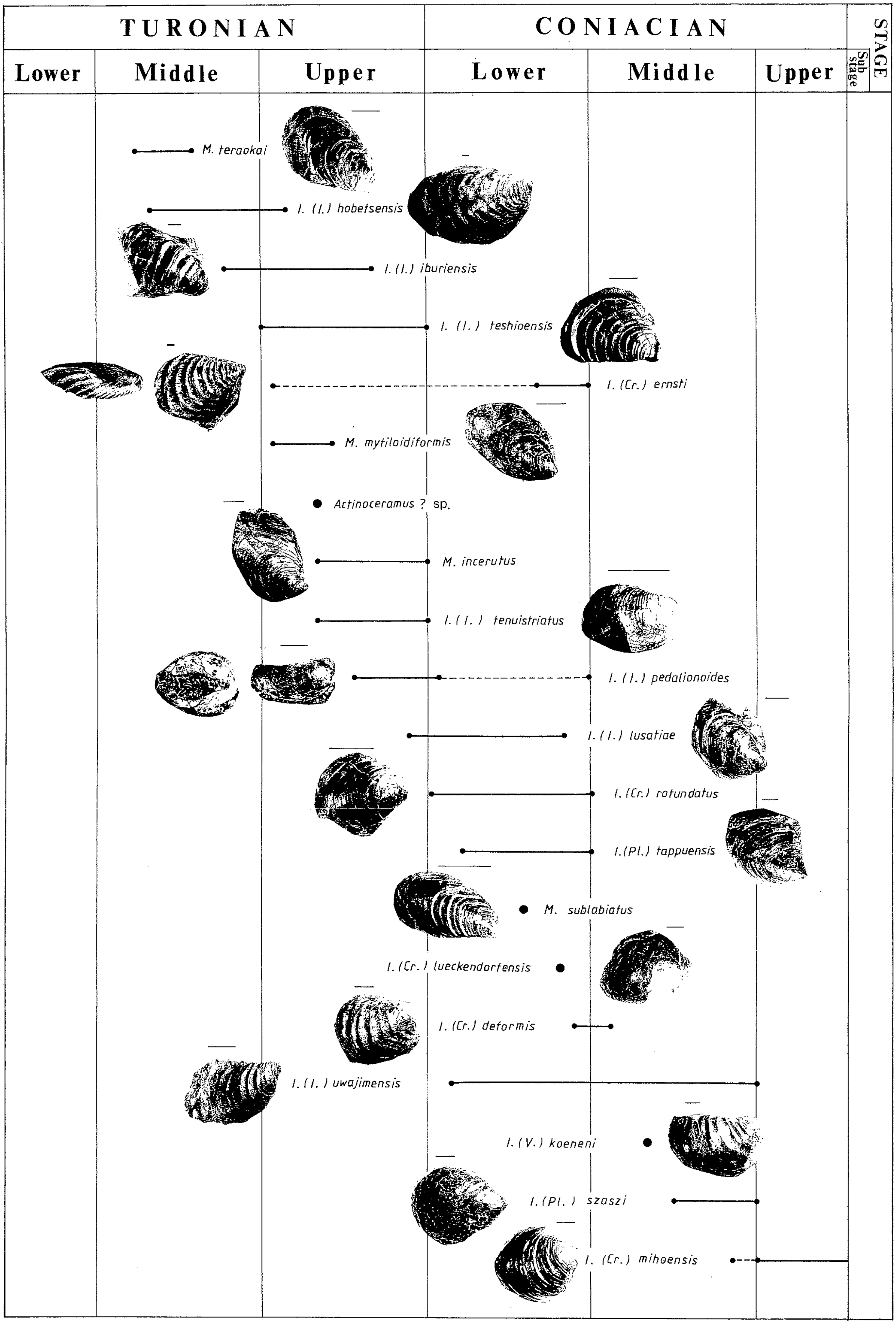
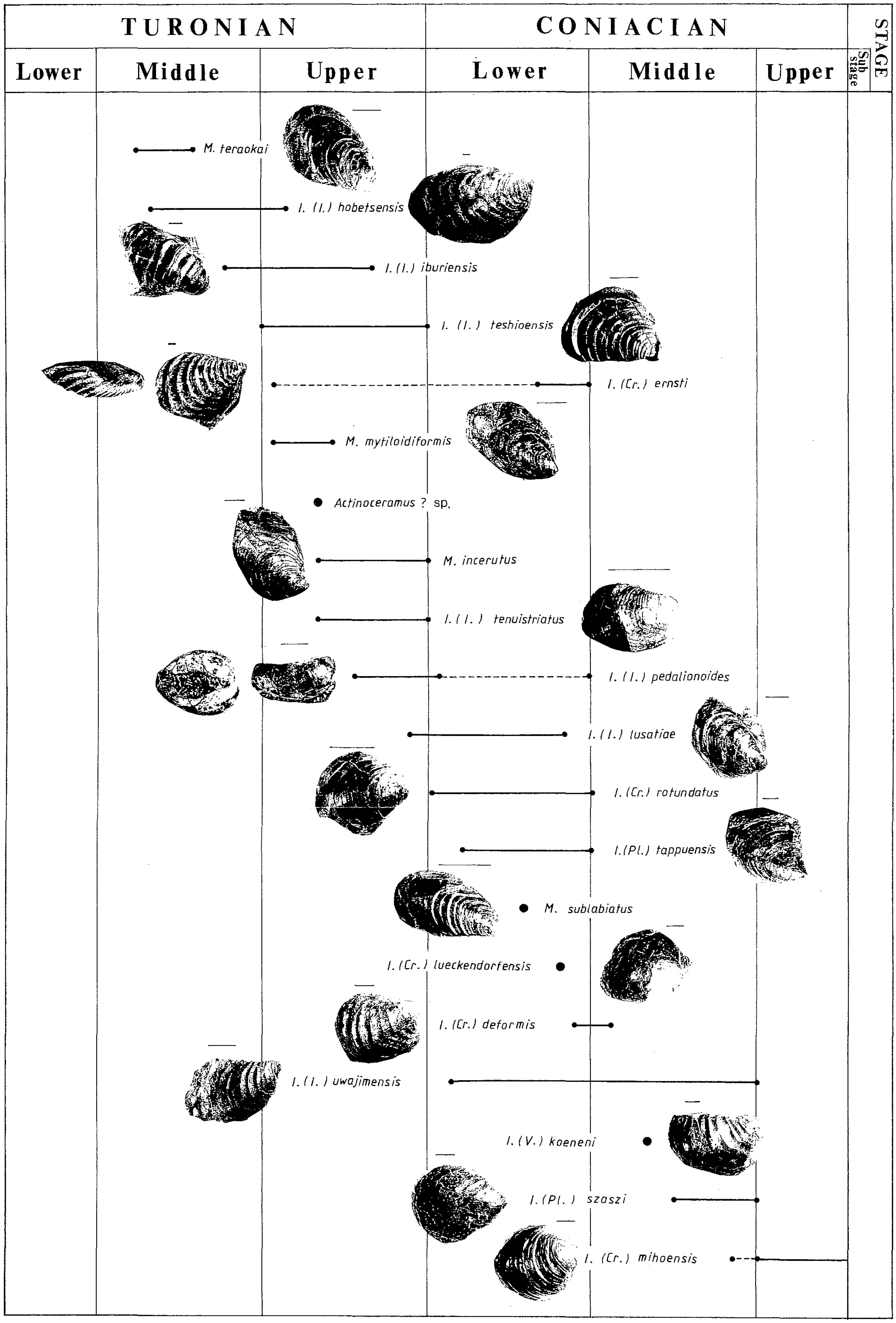


Fig. 14. Stratigraphical profile of the Turonian/Conician boudnary succession of the Onogawa Basin, eastern Kyushu; legend as in Text-fig. 7


STAGE
Sub stage
TURONIAN
CONIACIAN
Lower
Middle
Upper
Lower
Middle
Upper
M. teraokai
I. (I.) hobetsensis
I. (I.) iburiensis
I. (I.) teshioensis
I. (Cr.) ernsti
M. mytiloidiformis
Actinoceramus ? sp.
M. incerutus
I. (I.) tenuistriatus
I. (I.) pedalionoides
I. (I.) lusatiae
I. (Cr.) rotundatus
I. (Pl.) tappuensis
M. sublabiatus
I. (Cr.) lueckendorfensis
I. (Cr.) deformis
I. (I.) uwajimensis
I. (V.) koeneni
I. (Pl.) szaszi
I. (Cr.) mihoensis



Stratigraphical occurrences of inoceramid species in the Turonian and Coniacian of Japan, excluding early Turonian species; the scale bar is 1 cm

APPENDIX Table. Advances in Inoceramid zonation of Japan

STAGE	Substage		Matsumoto (1954)	Matsumoto (1959)	Matsumoto (1969)	Noda & Matsumoto (1976)
L. Paleocene						
HETONAIAN	Upper	K6β	*Inoc. hetonaianus* + *Inoc. awajiensis* *Inoc. shikotanensis*	*Inoc. hetonaianus* – *Inoc. awajiensis* *Inoc. shikotanensis*	*Inoc. hetonaianus* *Inoc.* (?) *awajiensis* *Inoc. shikotanensis*	*Inoc. hetonaianus* *Inoc.* (?) *awajiensis* *Inoc. shikotanensis*
HETONAIAN	Lower	K6α	*Inoc. schmidti*	*Inoc. schmidti*	*Inoc. schmidti*	*Inoc. schmidti*
URAKAWAN	Upper most	K5γ	*Inoc. orientalis*	*Inoc. orientalis*	*Inoc. orientalis*	*Inoc. orientalis*
URAKAWAN	Upper	K5β	*Inoc. japonicus* *I. amakusensis*	*Inoc. japonicus* *I. amakusensis*	*Inoc. japonicus* *I. amakusensis*	*Inoc. japonicus* *I. amakusensis*
URAKAWAN	Lower	K5α	*I. uwajimensis*	*I. mihoensis* *Inoc. uwajimensis*	*I. mihoensis* *I. uwajimensis*	*I. mihoensis* *I. uwajimensis*
GYLIAKIAN	Upper	K4β	*I. hobetsensis* *Inoc. incertus*	*I. teshioensis* *I. hobetsensis* *Inoc.* cf. *labiatus*	*I. teshioensis* *I. incertus* *I. hobetsensis* *Inoc. labiatus*	*I. teshioensis* *I. h. hobetsensis* *I. h. nonsulcatus* *Inoc. labiatus*
GYLIAKIAN	Lower	K4α	*Inoc. concentricus* var. *nipponicus* + *Inoc. yabei*	*Inoc. concentricus nipponicus* + *Inoc. yabei*	*Inoc. concentricus nipponicus*	*I. pennatulus* *I. concentricus costatus* *I. concentricus nipponicus*
MIYAKOAN	Up. most	K3γ	*Inoc.* aff. *crippsi*	*Inoc.* aff. *crippsi*	*Inoc.* aff. *crippsi*	*Inoc.* aff. *crippsi*
MIYAKOAN	Up.	K3β	*Inoc.* aff. *bohemicus*	*Inoc.* aff. *bohemicus*	*Inoc. anglicus*	*Inoc. anglicus*
Range zones (vertical)			*Inoc. ezoensis* – *Inoc. balticus*; *Inoc. naumanni*; *Inoc. teshioensis*; *Sergipia akamatsui*	*Inoc. ezoensis* – *Inoc. balticus*; *Inoc. naumanni*; *Inoc. incertus*; *Inoc.* (*Sergipia*) *akamatsui*	*Inoc. balticus*; *Inoc. naumanni*; *I. yok.*; *Didymotis akamatsui*; *Inoc. yabei*	*Inoc. balticus*; *Inoc. ezoensis*; *Inoc. naumanni*; *I. yo.*; *I. yubariensis*; *I. incertus*; *Didymotis akamatsui*; *I. teraokai*; *Inoc. yabei*

Matsumoto (1977)	Sub-stage	
Inoc. hetonaianus *Inoc. kusiroensis*	K6b	2
Inoc. shikotanensis	K6b	1
I. balticus n. subsp.	K6a	3
Inoc. schmidti	K6a	2
Inoc. orientalis	K6a	1
Inoc. japonicus	K5b	2
Inoc. amakusensis	K5b	1
Inoc. mihoensis	K5a	2
Inoc. uwajimensis	K5a	1
Inoc. teshioensis *Inoc. incertus*	K4b	3
Inoc. hobetsuensis *Inoc. teraokai*	K4b	2
Inoc. labiatus	K4b	1
Inoc. pennatulus	K4a	4
Inoc. yabei *Inoc. costatus*	K4a	3
Inoc. nipponicus	K4a	2
Inoc. aff. *crippsi*	K4a	1
Inoc. anglicus *B. subsulcatus*	K3b	

Matsumoto et al. (1991)	Toshimitsu et al. (1995) [revised]	Substage		STAGE	Age
		L. Paleocene			65.0
	"*Inoc.*" *awajiensis*	K6 b2	Up.	MAASTRICHTIAN	
	Sph. hetonaianus *I.* (*E.*) *shikotanensis*	K6b1	Lower	MAASTRICHTIAN	74.0
	I. (*E.*) aff. *balticus*	K6 a4	Upper	CAMPANIAN	
	M. shimanukii	K6 a3	Upper	CAMPANIAN	
	Sph. schmidti *Sph. orientalis*	K6a2	Lower	CAMPANIAN	
	I. (*P.*) *chicoensis*	K6a1	Lower	CAMPANIAN	
	I. (*P.*) *japonicus*	K5b2	Lower	CAMPANIAN	83.0
	Inoc. amakusensis	K5b1		SANTONIAN	86.6
	I. (*Cr.*) *miho.* *I.* (*Co.*) *kawa.*	K5a2	Up.	CONIACIAN	
	Inoc. uwajimensis	K5a1	Mid	CONIACIAN	
Inoc. rotundatus	*I.* (*Cr.*) *rotund.*	K5a1	Low	CONIACIAN	88.5
I. tenuistriatus- *M. incertus*	*I.* (*I.*) *tenuist.* *M. incertus*	K4b3	Upper	TURONIAN	
Inoc. teshioensis	*I.* (*I.*) *teshioensis*	K4b3	Upper	TURONIAN	
Inoc. hobetsensis – *M. teraokai*	*I.* (*I.*) *hobetsensis* *M. teraokai*	K4b2	Middle	TURONIAN	
Inoc. aff. *hob.*- *Inoc. costatus*	*I.* (*I.*) *costatus*	K4b2	Middle	TURONIAN	
M. subhercynicus	*M. subhercynicus*	K4b1	Lower	TURONIAN	
Inoc. aff. *saxonicus* - *M. mytiloides*	*M. mytiloides* *M.* aff. *columbianus*	K4b1	Lower	TURONIAN	
Mytiloides sp.	*M. sackensis*	K4b1	Lower	TURONIAN	90.4
Inoc. nodai (small form)	*Inoc.* (s.l.) *nodai* (small form)	K4a6	Upper	CENOMANIAN	
I. pictus minus - *M. mikasaensis*	*I. pictus minus* *M. mikasaensis*	K4a5	Upper	CENOMANIAN	
B. nipponica	*A. nipponica*	K4a4	Upper	CENOMANIAN	
B. tamurai	*A. tamurai*	K4a3	Mid.	CENOMANIAN	
Inoc. tenuis – *Inoc. virgatus*	*I.* (*I.*) *tenuis* *Inoc.* (s.l.) *virgatus*	K4a2	Lower	CENOMANIAN	
Inoc. aff. *virgatus* (small form)	*I.* (s.l.) aff. *virgatus*	K4a1	Lower	CENOMANIAN	97.0
Inoc. anglicus *B. subsulcatus*	*I.* (s.l.) *anglicus* *Actinoc. subsulcatus*	K3b	Up.	ALB.	
Range zones (vertical): *I. reduncus*; *I. pennatulus*; *I. ginterensis*; *I. nodai*	Range zones (vertical): *Sph. naumanni*; *I.* (*P.*) *mantelli*; *I.* (s.l.) *kamui*; *I. nodai*; *I. ginterensis*; *I. pennatulus*; *I. reduncus*				

6. Based on the stratigraphic succession of inoceramid species in the intervals from mid-Turonian through the upper part of the Coniacian in Japan, the ranges of the investigated species are summarized in Text-fig. 15.

7. To sum up, in spite of some unfavourable conditions, intensive biostratigraphic research in Japan yields constructive contributions to the problem of the T/C stage boundary and global correlation.

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PLATES 1 – 18

PLATE 1

1-4, 6-7 – *Inoceramus* (*Inoceramus*) *teshioensis* NAGAO & MATSUMOTO, 1939

1 – JG.H3520; loc. IK2013d, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 2
2 – JG.H3519; loc. IK2013d, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1
3 – JG.H3078; loc. IK2014d, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1
4 – JG.H2238; loc. OR220, Nakahaji, Onogawa Basin, eastern Kyushu; upper member of the Ryozen Formation, Onogawa Group; × 1.2
6 – JG.H3520; loc. IK2014 d, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1 [somewhat similar to *I.* (*I.*) *costellatus*]
7 – JG.H3602; loc. OR218, Onogawa Basin, eastern Kyushu; upper member of the Ryozen Formation, Onogawa Group; × 0.9

5 – *Inoceramus* (*Inoceramus*) *uwajimensis* YEHARA, 1924, JG.H3101; loc. UF101, shore of Uwajima Bay, western Shikoku, lower member of the Furushiroyama Formation, Uwajima Group; × 1 [deformed left valve, apparently similar to *I.* (*I.*) *teshioensis*]

8 – *Inoceramus* (*Inoceramus*) cf. *lamarcki stuemkei* HEINZ, 1926, JG.H3504; loc. Ob2042, Nanbuno-sawa, Obira area, northwestern Hokkaido; Unit Mm-n, Middle Yezo Group; × 0.9

9 – *Inoceramus* (*Inoceramus*) *pedalionoides* NAGAO & MATSUMOTO, 1939, JG.H3261, loc. Ik2013d; Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1

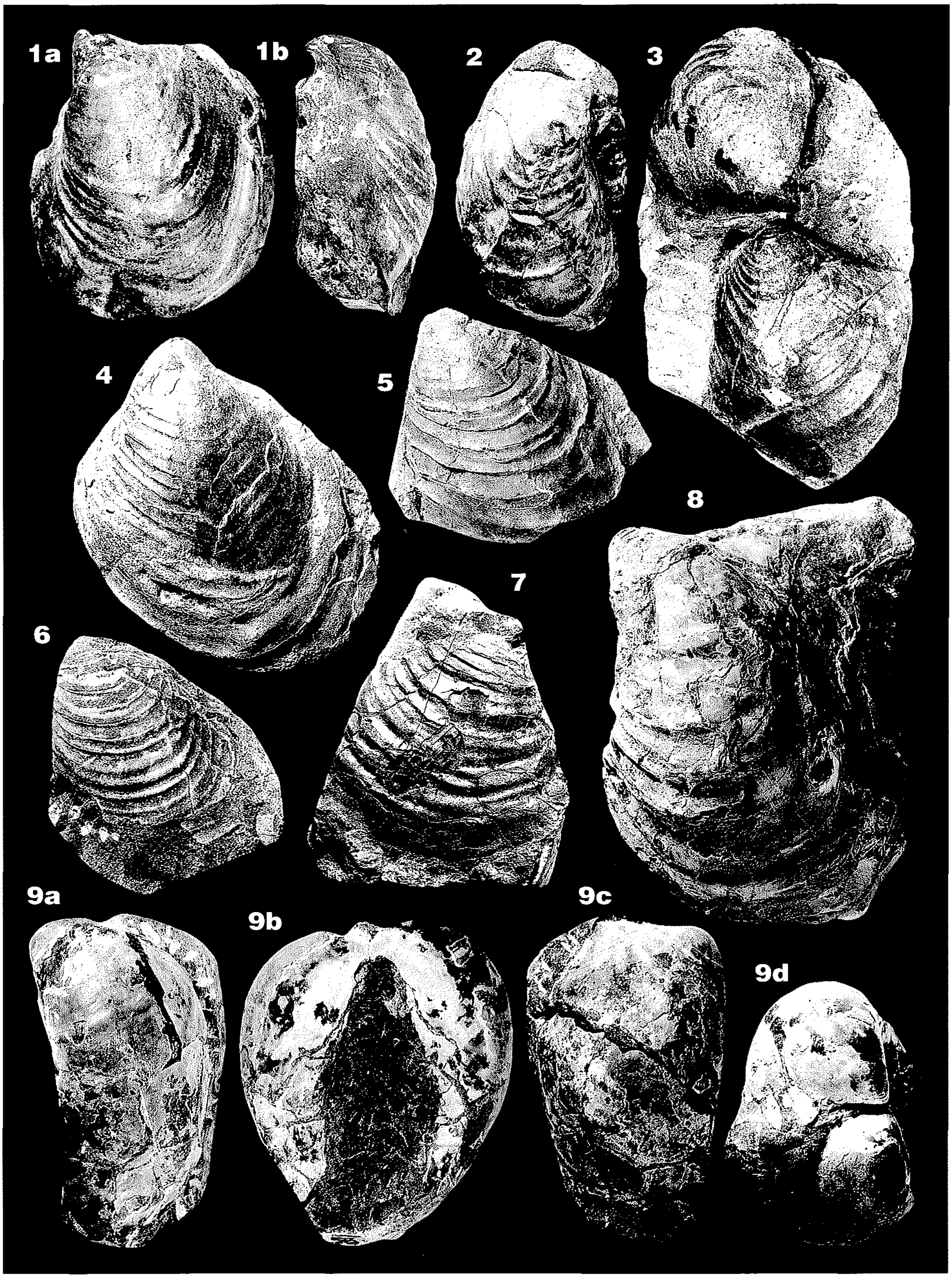
1a
1b
2
3
4
5
6
7
8
9a
9b
9c
9d

PLATE 2

Inoceramus (Inoceramus) iburiensis
NAGAO & MATSUMOTO, 1939

1 – JG.H3506; loc. KU10-0104, Isojirono-sawa, Oyubari area, central Hokkaido; Middle Yezo Group; × 0.6

2 – KMNH.IvP100,002; loc.H2135, a tributary of Nutapomanai-zawa, Hobetsu area, south-cenral Hokkaido; Middle Yezo Group; × 0.37

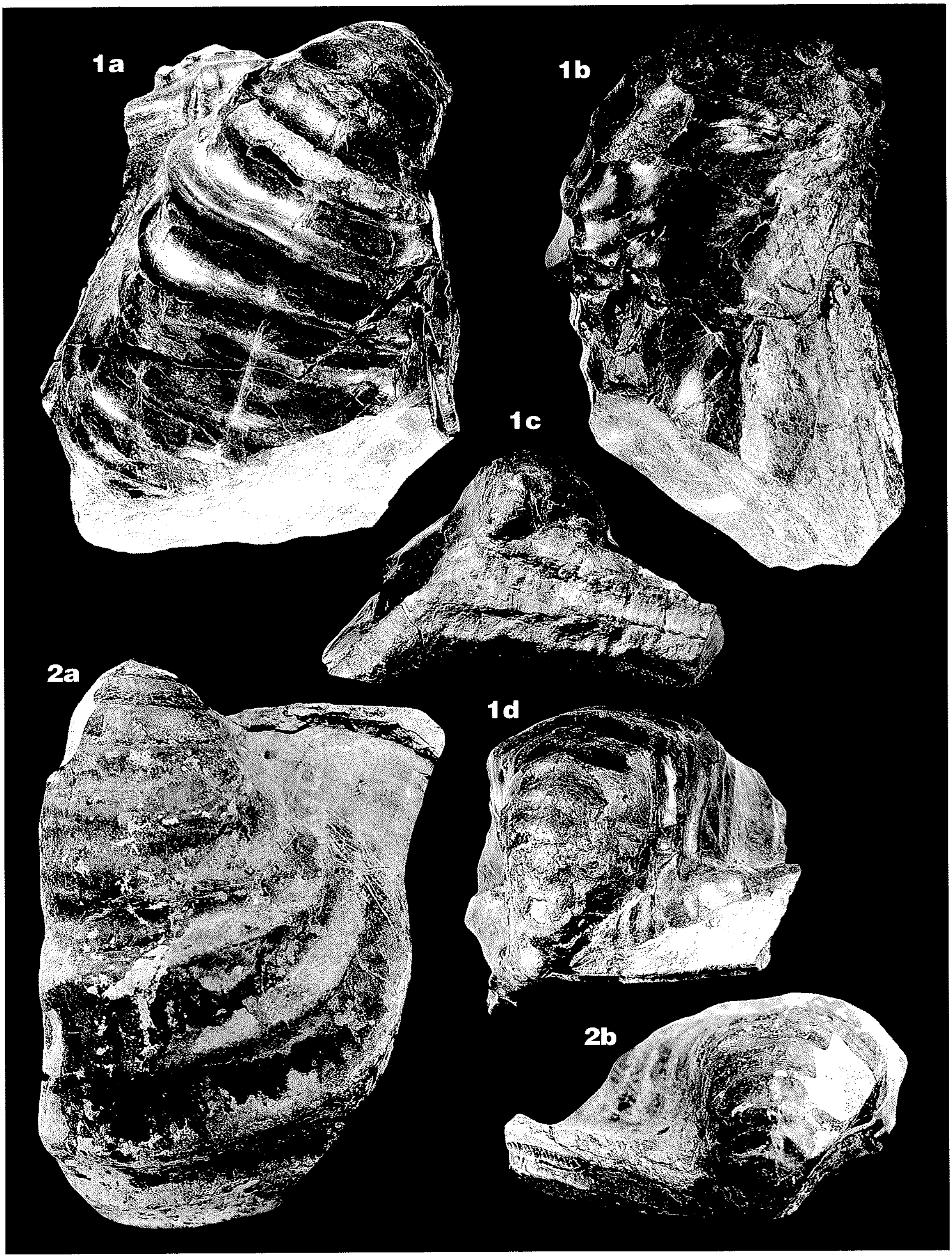
1a
1b
1c
2a
1d
2b

PLATE 3

1-3 – *Inoceramus (Inoceramus) pedalionoides* NAGAO & MATSUMOTO, 1939

1 – Lectotype, LGPS22720; precise locality unknown, probably Ik2013d, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1

2 – JG.H3519; loc. Ob0004, Obira area, northwestern Hokkaido; Unit Ual, Uper Yezo Group; × 1

3 – Paralectotype, GMH5969; Penkemoyuparo, Oyubari area, central Hokkaido; Middle Yezo Group; × 1

4-9 – *Inoceramus (Inoceramus) tenuistriatus* NAGAO & MATSUMOTO, 1939; Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group

4 – syntype, IGPS22751b; precise locality unknown, probably Ik2013; × 1.3

5 – JG.H2970; loc. Ik2013b; × 1.25

6 – IGPS22751-2; precise locality unknown, probably Ik2013; × 1.17

7 – JG.H2968a; loc. Ik2013; × 0.95

8 – JG.H2973b; loc. Ik2013; × 1.35

9 – Syntype, IGPS22751a; precise locality unknown, probably Ik2013; × 1

10-12 – *Inoceramus (Inoceramus) uwajimensis* YEHARA, 1924

10 – JG.H2072; loc. OI213, Onogawa Basin, eastern Kyushu; upper member of the Inukai Formation, Onogawa Group; × 1

11 – JG.H3004; loc. OI213; × 1

12 – JG.H2053; loc. UF101, shore of Uwajima Bay, western Shikoku; lower member of the Furushiroyama Formation, Uwajima Group; × 1

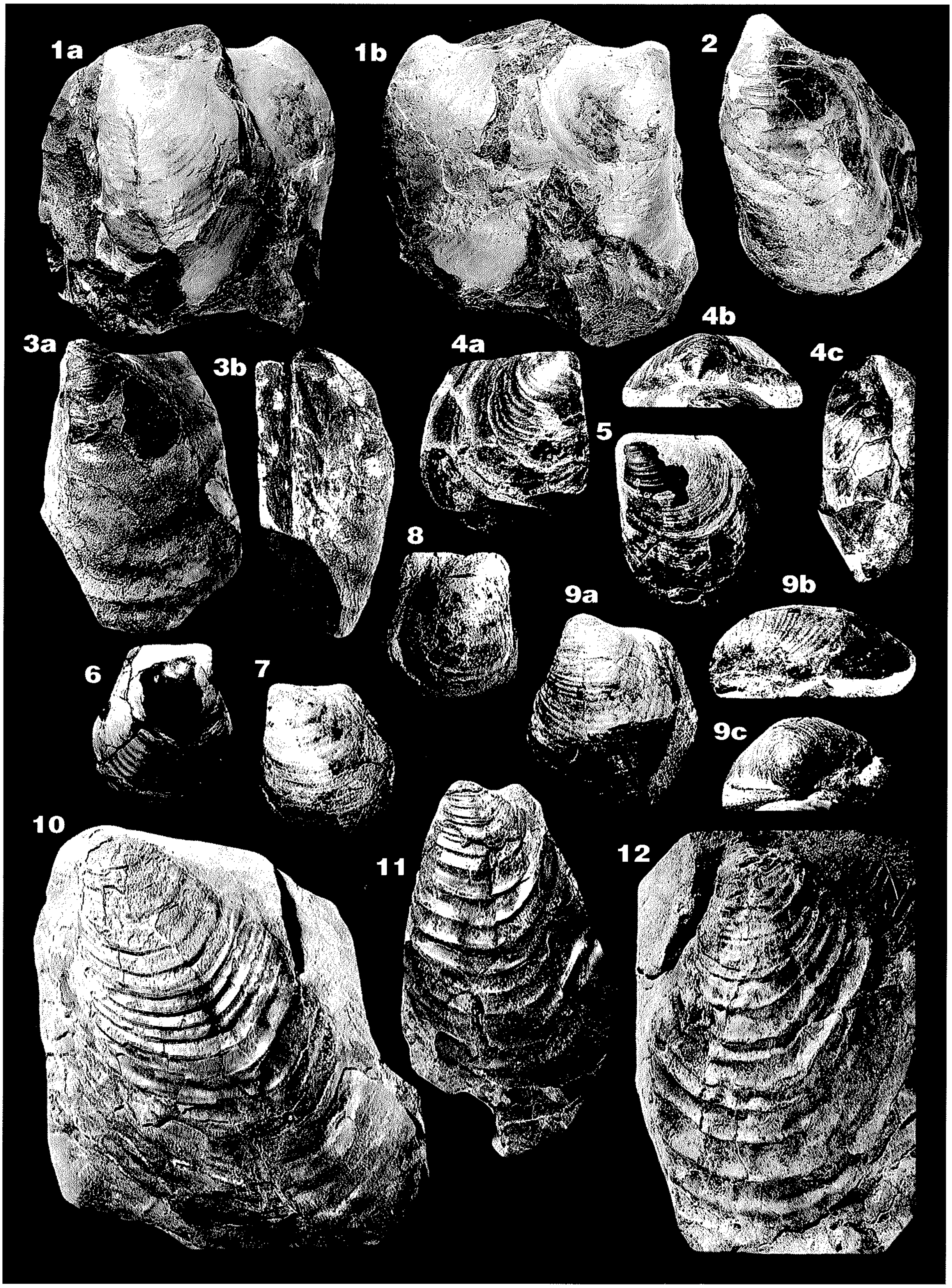
1a
1b
2
3a
3b
4a
4b
4c
5
6
7
8
9a
9b
9c
10
11
12

PLATE 4

1-4 – *Inoceramus* (*Inoceramus*) *lusatiae* ANDERT, 1911
Ashiyachi-zawa, Ikushunbetsu area, central Hokkaido; IIIb member, Upper Yezo Group

1 – JG.H3095; loc. Ik7002; × 0.95
2 – JG.H3100; loc. Ik7003; × 1
3 – JG.H3096; loc. Ik7001; × 0.9
4 – JG.H3202; loc.Ik7000; × 1 (somewhat lower horizon than other, probably near the T/C boundary)

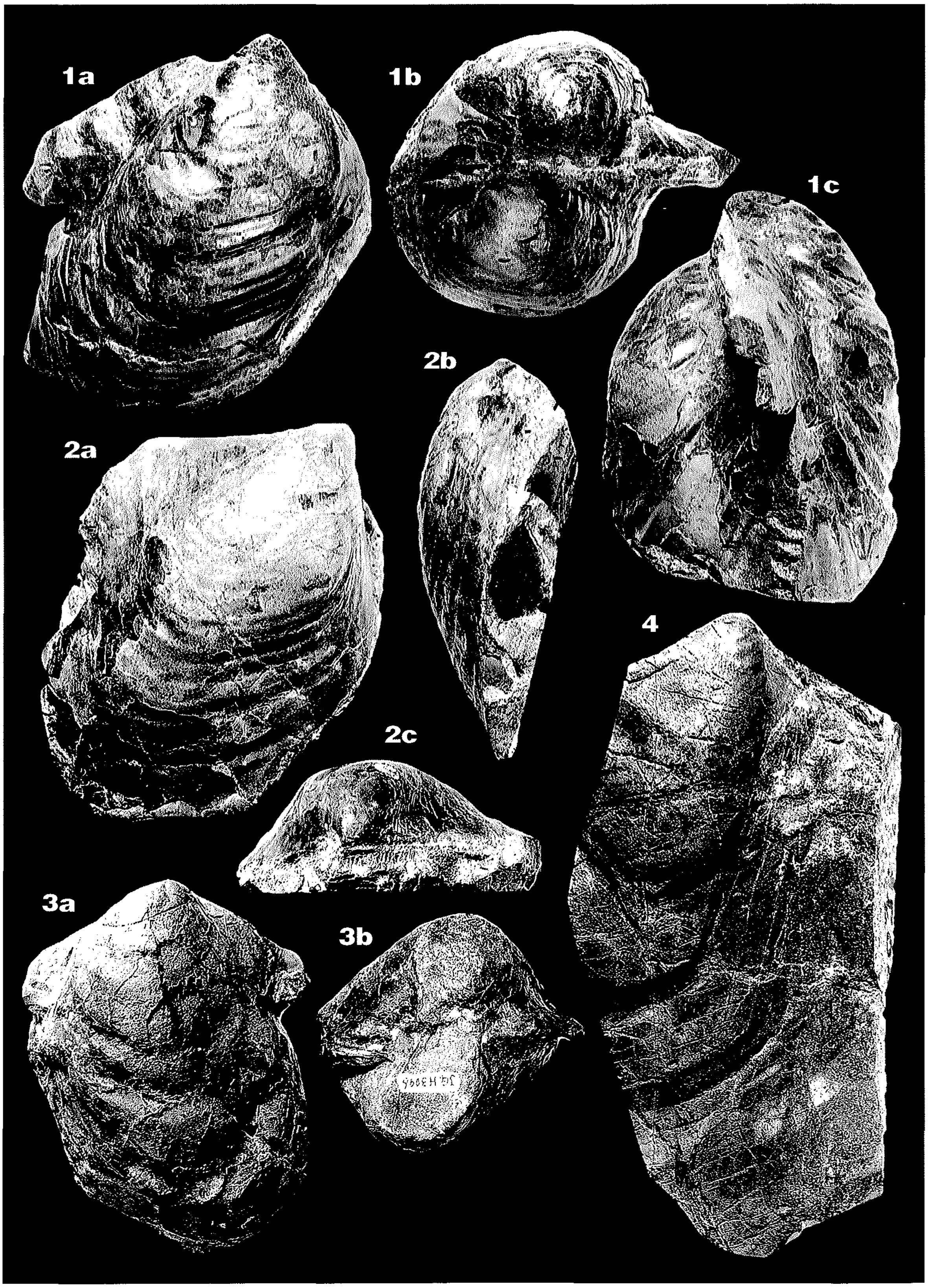
1a
1b
1c
2b
2a
4
2c
3a
3b

PLATE 5

1-4 – *Inoceramus* (*Inoceramus*) *uwajimensis* YEHARA, 1924

1 – JG.H3550; loc. Ik8501, Okuhidarimata, Ikushunbetsu area, central Hokkaido; IIIb member, Upper Yezo Group; × 1
2 – JG.H2071; loc.OI213, Onogawa Basin, eastern Kyushu; upper member of the Inukai Formation, Onogawa Group; × 0.85
3 – JG.H3533; loc.Ik2710, Ponbetsu-Gono-sawa, central Hokkaido; IIIb' member, Upper Yezo Group; × 1
4 – JG.H3532; loc.Ik2710m.; posterior wing well developed, somewhat open valves, so-called *I.* (*I.*) *uwajimensis yeaharai* type

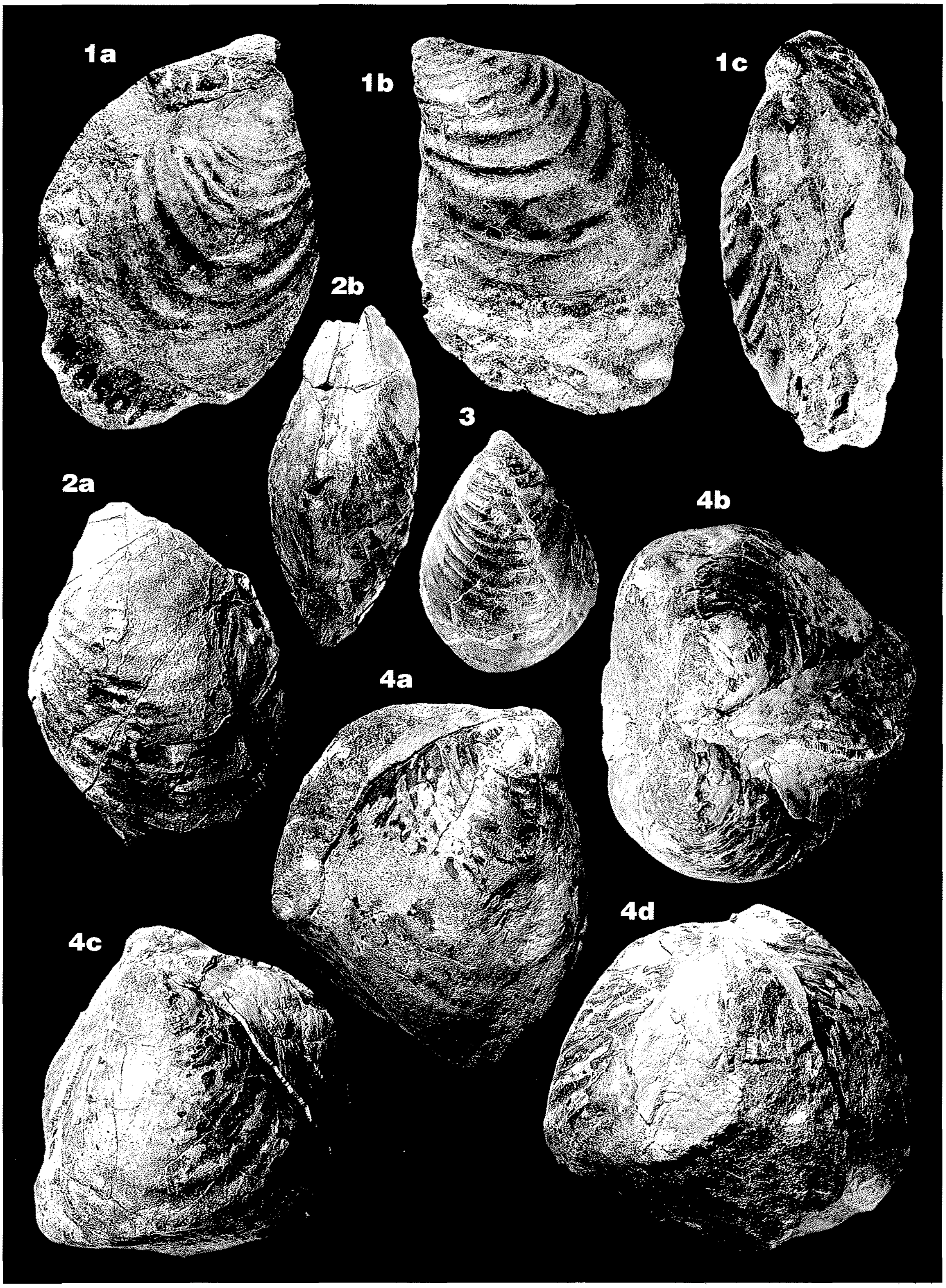
1a
1b
1c
2b
3
2a
4b
4a
4d
4c

PLATE 6

1-3 – *Inoceramus (Inoceramus) uwajimensis* YEHARA, 1924

1 – JG.H3528; loc. Ik7009, Ashiyachi-zawa, Ikushunbetsu area, central Hokkaido; IIIb member, Upper Yezo Group; × 1
2 – JG.H3036; loc. Ik2710r, Ponbetsu-Gono-sawa, central Hokkaido; IIIb' member, Upper Yezo Group; × 0.8
3 – JG.H3071; loc. UN101, Mutsuki, Uwajima area, western Shikoku; upper member of the Narukawa Formation, Uwajima Group; × 0.77 (somewhat crushed)

4-6 – *Inoceramus (Cremnoceramus) ernsti* HEINZ, 1928

4 – WE.P1321; loc. Ik8617a, Okuhidarimata, Ikushunbetsu area, central Hokkaido; IIIb member, Upper Yezo Group; × 1.2
5 – JG.H3017L; loc. Ob0020, Obira area, northwestern Hokkaido; Unit Ub, Upper Yezo Group; × 0.86
6 – JG.H3017R; loc. Ob0020, probably the right valve of the same individual as represented by JG.H3017L (Fig. 5); × 0.86

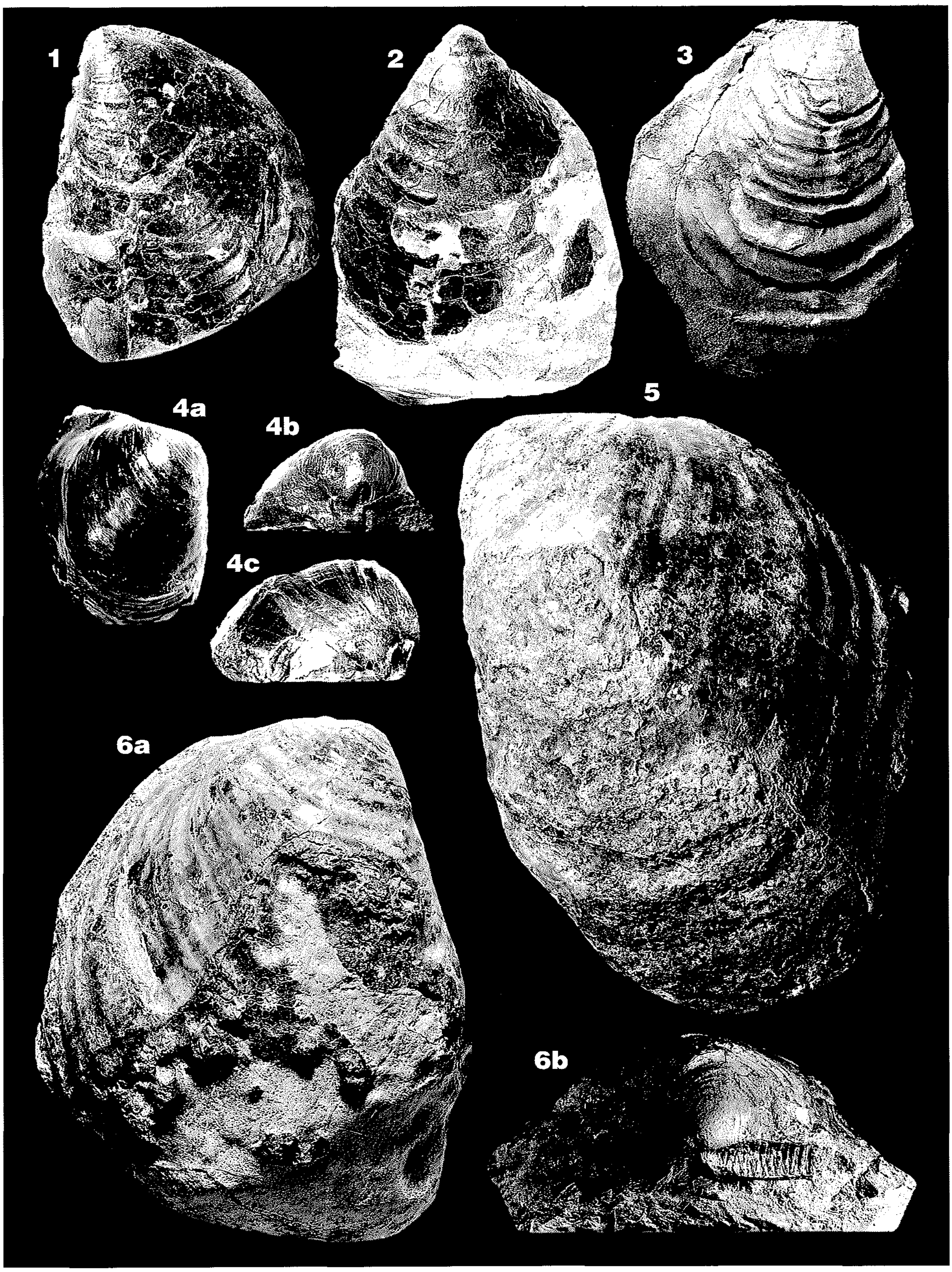
1
2
3
4a
4b
4c
5
6a
6b

PLATE 7

Inoceramus (*Cremnoceramus*) *ernsti* HEINZ, 1928

JG.H3023; loc. Ob2100, Kamikinenbetsu, Obira area, northwestern Hokkaido; Unit Mn-o, Middle Yezo Group; × 0.5

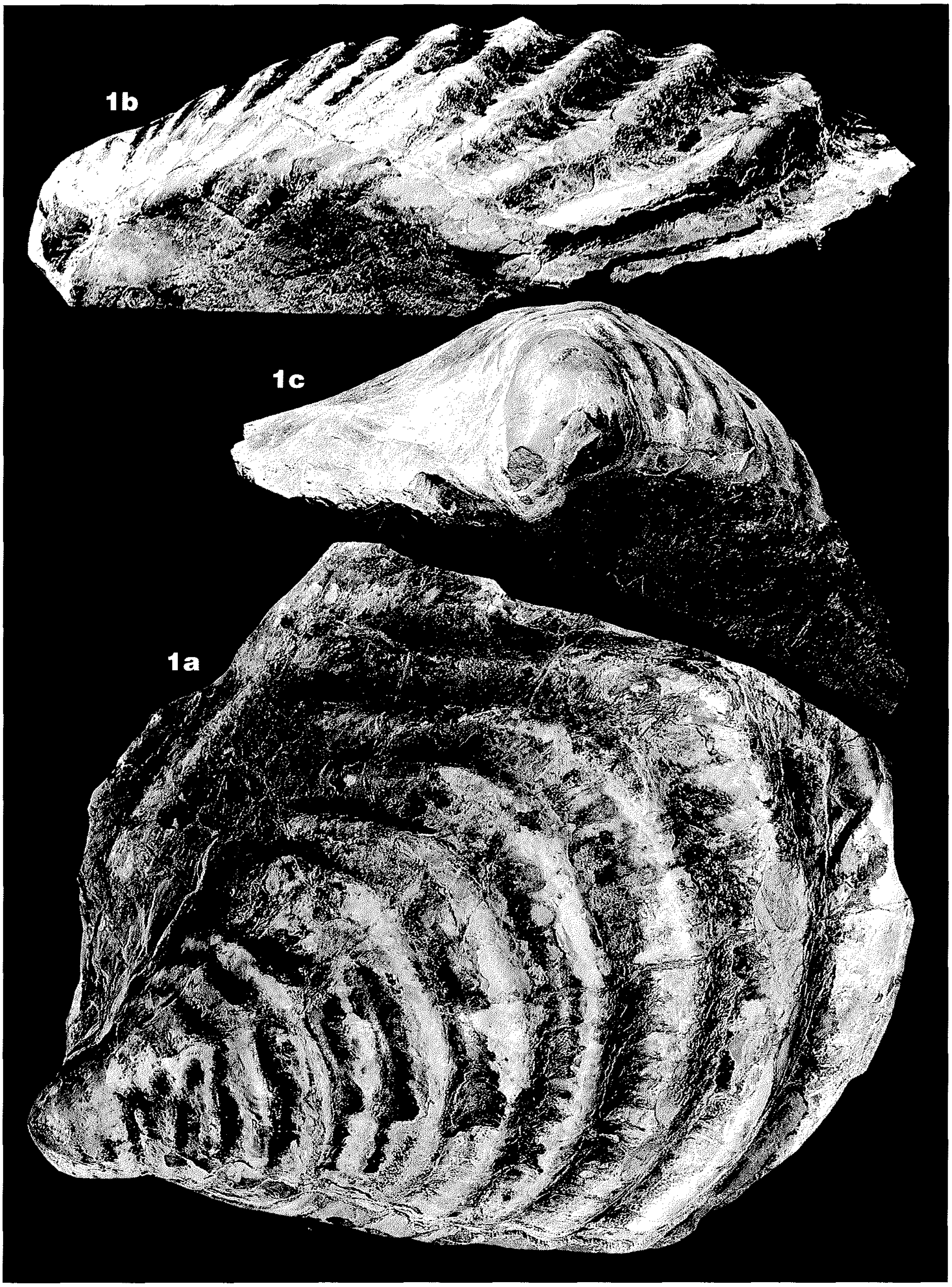
1b
1c
1a

PLATE 8

1 – *Inoceramus* (*Cremnoceramus*) *ernsti* HEINZ, 1928
JG.H3017L; loc. Ob0020, Obira area, northwestern Hokkaido; Unit Ub, Upper Yezo Group; × 0.86

2-8 – *Inoceramus* (*Cremnoceramus*) *rotundatus* FIEGE, 1930

2 – JG.H2857; loc. Ik2710r, Ponbetsu-Gono-sawa, central Hokkaido; IIIb' member, Upper Yezo Group; × 0.8
3 – JG.H2866; loc. Ik2710r, Ponbetsu-Gono-sawa, central Hokkaido; IIIb' member, Upper Yezo Group; × 1.5
4 – GK.H10132; loc. Ik2716h, Ponbetsu-Gono-sawa, central Hokkaido; IIIb' member, Upper Yezo Group; × 1.25
5 – JG.H2897; loc. Ik2716n; × 1
6 – JG.H2894; loc. Ik2716q: × 1.5
7 – JG.H3538; loc. Ik10008p., Kamiichino-sawa, Ikushunbetsu area, central Hokkaido; IIIb member, Upper Yezo Group; × 1
8 – JG.H2860; loc. Ik2710r: × 1

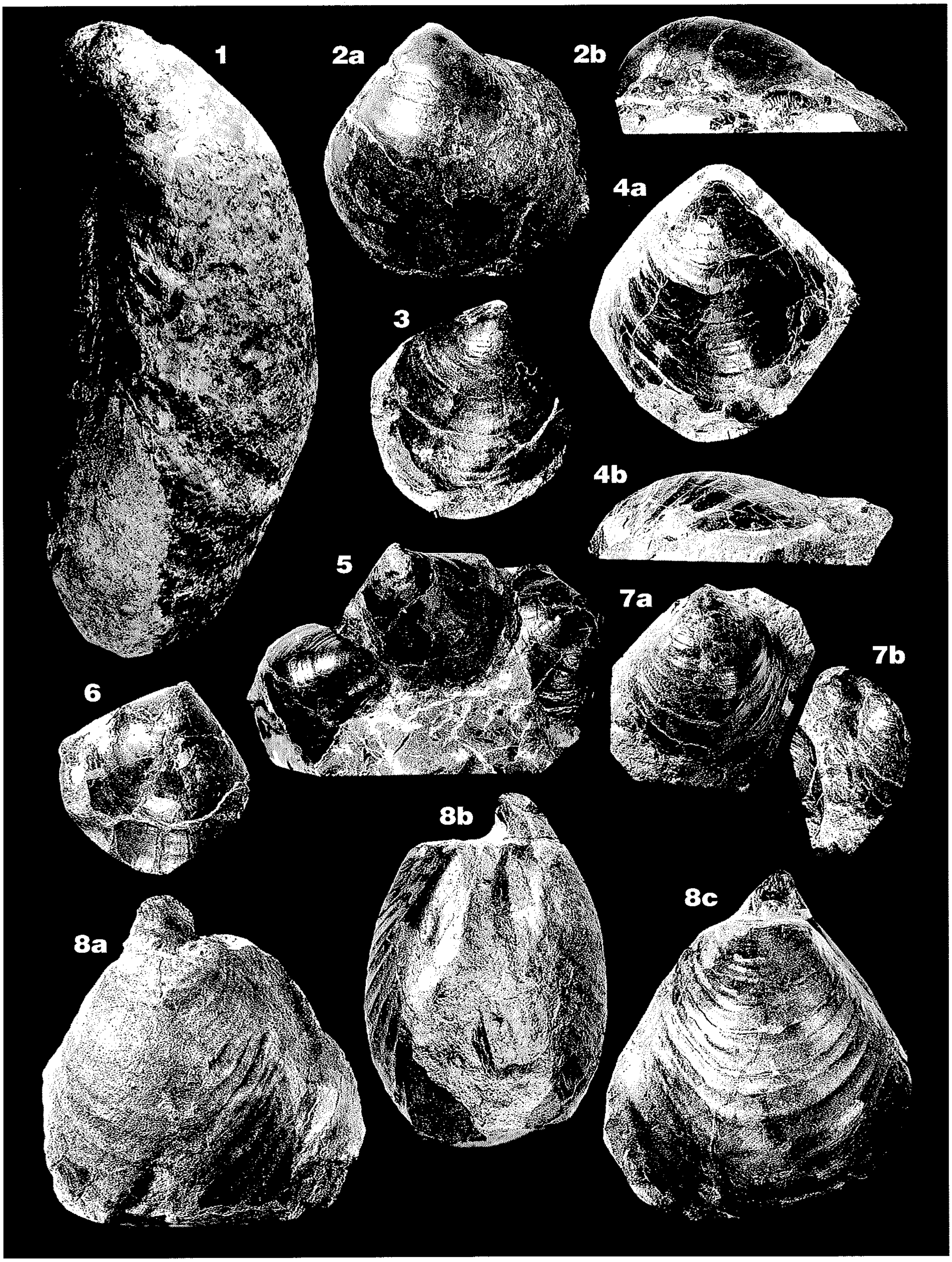
1
2a
2b
3
4a
4b
5
6
7a
7b
8a
8b
8c

PLATE 9

Inoceramus (Cremnoceramus) lueckenforfensis TRÖGER, 1967

loc. Ob0003, Obira area, northwestern Hokkaido; Unit Ua2, Upper Yezo Group

1 – JG.H3098; × 1; 2 – JG.H3097; × 1

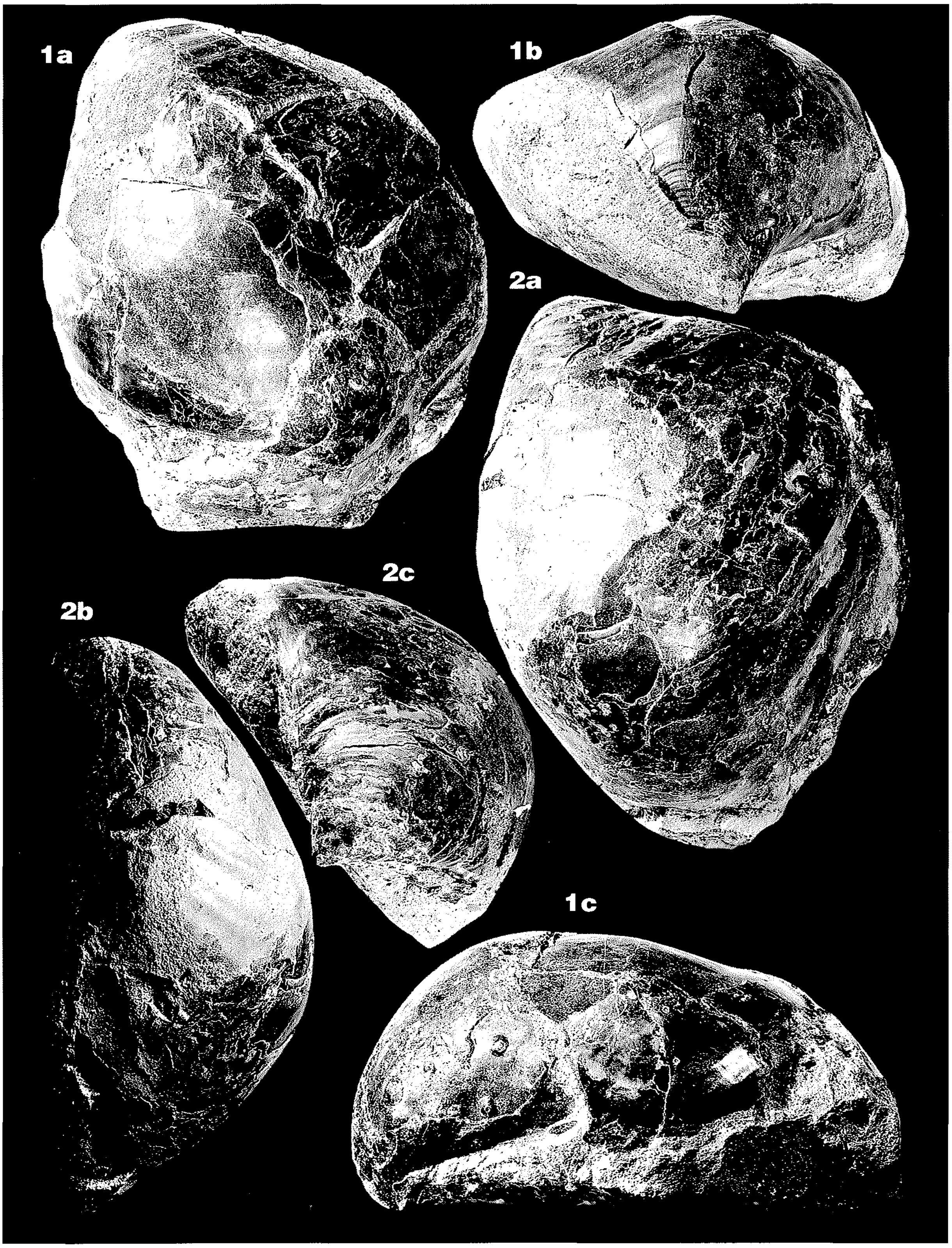
1a
1b
2a
2b
2c
1c

PLATE 10

1 – *Inoceramus (Cremnoceramus) deformis* MEEK, 1871, JG.H3016; loc. Ob0012, Obira area, northwestern Hokkaido; Unit Ub, Upper Yezo Group; × 0.95

2 – *Inoceramus (Platyceramus) tappuensis* nom. nov., UMUT. MM6492; a float of the R. Obirashibe, precise locality unkown, probably from loc. Ob0003; × 1

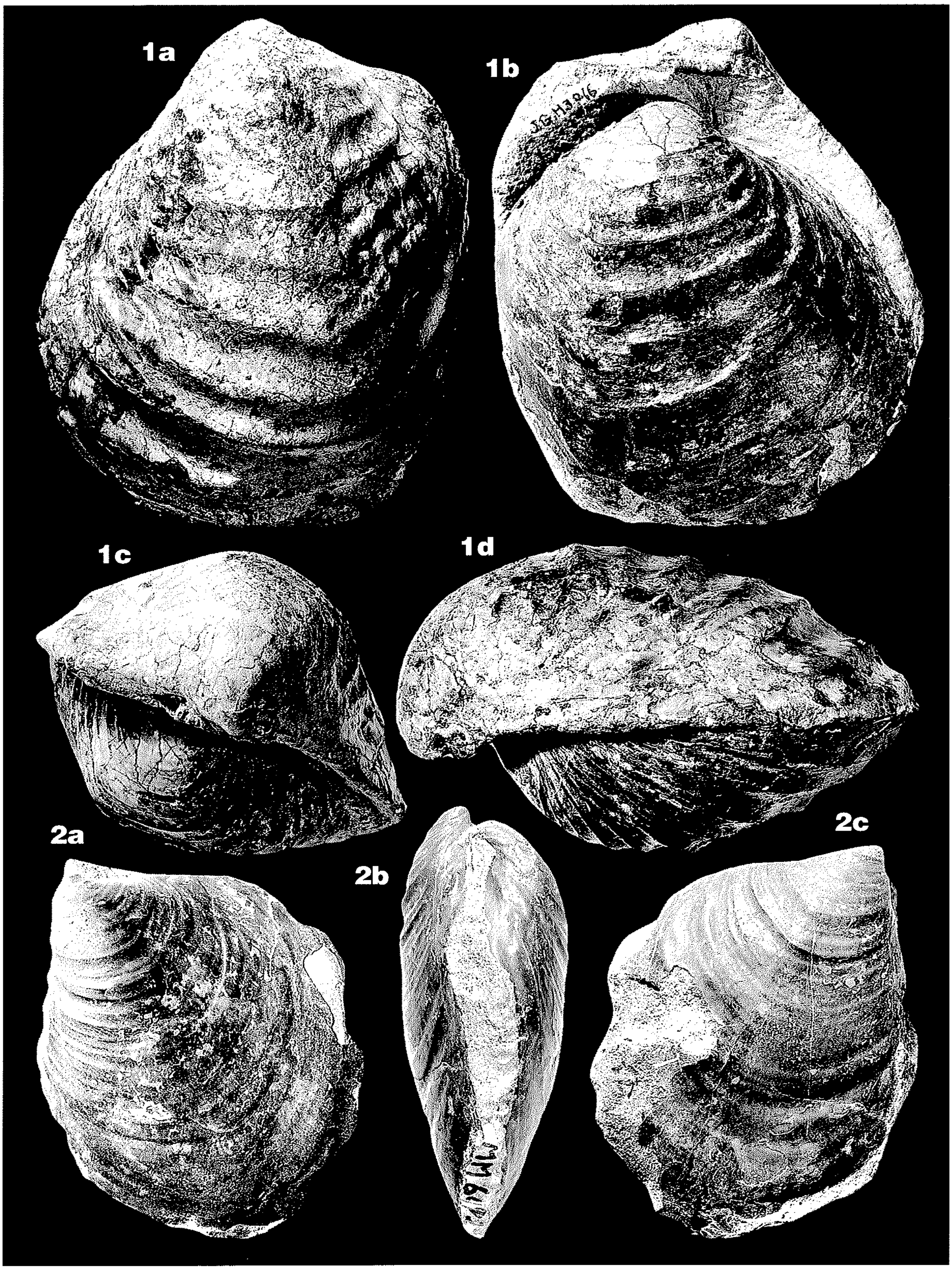
1a
1b
1c
1d
2a
2b
2c

PLATE 11

Inoceramus (*Platyceramus*) *tappuensis* nom. nov.

1 – Holotype, JG.H3023; loc. Ob0003, Obira area, northwestern Hokkaido; Unit Ua2, Upper Yezo Group; × 0.9

2 – IGPS22709; a float of the R. Obirashibe, precise locality unknown, probably from loc. Ob0003; × 0.86

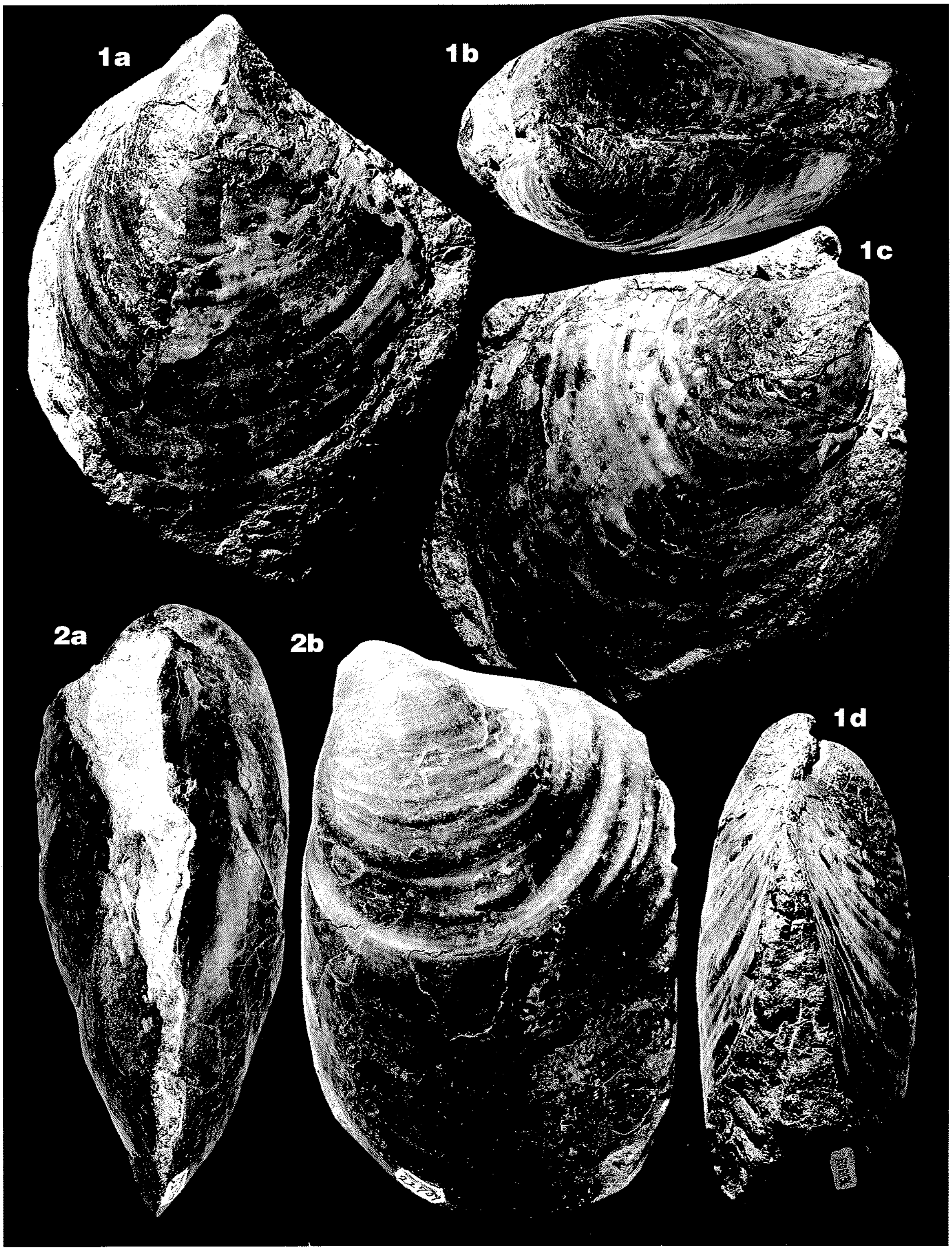
1a
1b
1c
2a
2b
1d

PLATE 12

Inoceramus (Platyceramus) szaszi NODA & UCHIDA, 1995

Loc. Ik2709, Ponbetsu-Gono-sawa, central Hokkaido, upper part of IIIb' member, Upper Yezo Group

1 – Paratype, JG.H2898; × 0.87
2 – Holotype, JG.H2901; × 0.84

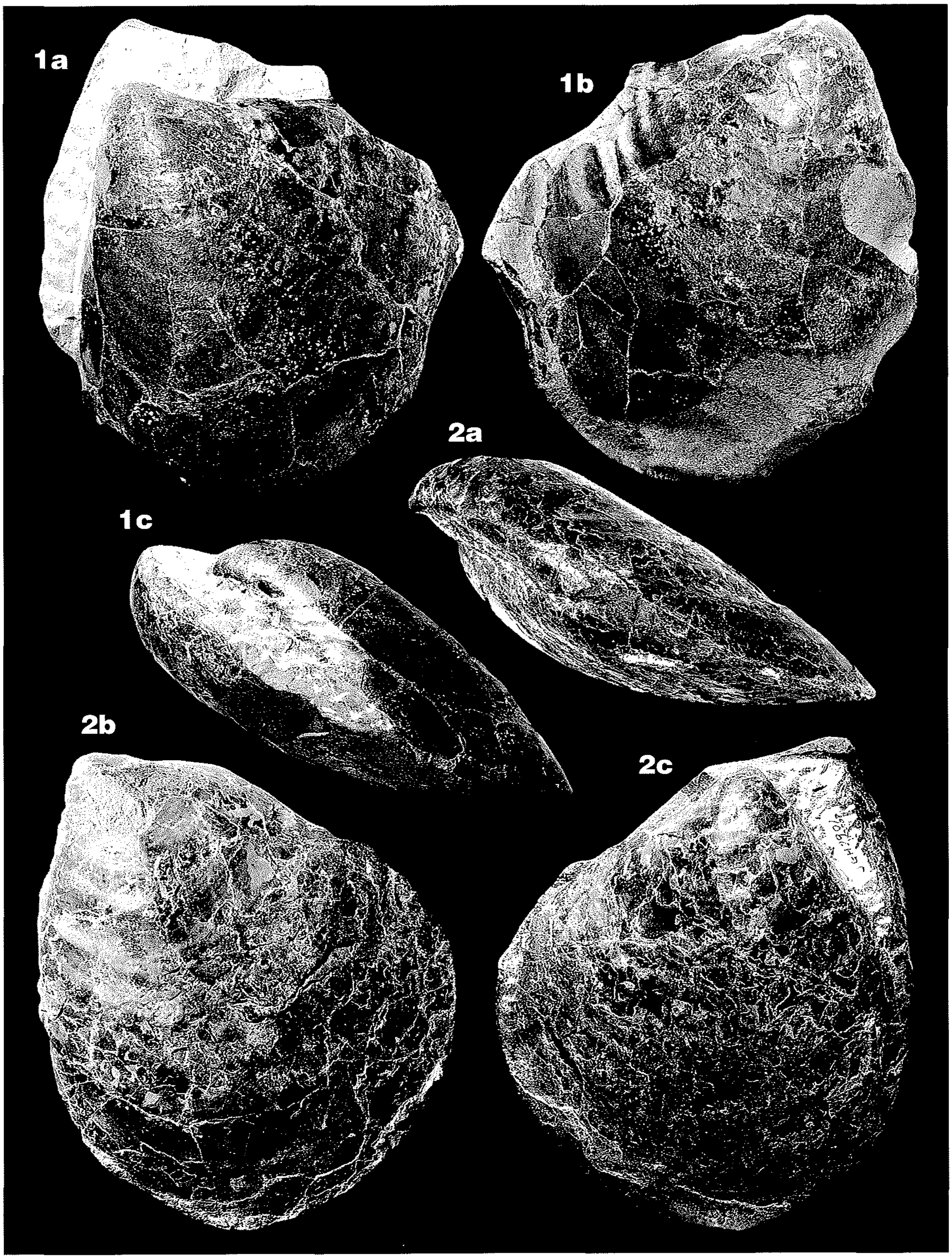
1a
1b
2a
1c
2b
2c

PLATE 13

1-2 – *Inoceramus* (*Platyceramus*) *szaszi* NODA & UCHIDA, 1995

1 – JG.H3079; loc. Ob0002, Obira area, northwestern Hokkaido; Unit Uc, Upper Yezo Group; × 0.59

2 – JG.H2898; loc. Ik2709, Ponbetsu-Gono-sawa, central Hokkaido; IIIb' member, Upper Yezo Group; × 0.87

3 – *Inceramus* (*Volviceramus*) *koeneni* MÜLLER, 1887, JG.H3019; loc. Ob0013, Obira area, northwestern Hokkaido; Unit Ub, Upper Yezo Group; × 0.93

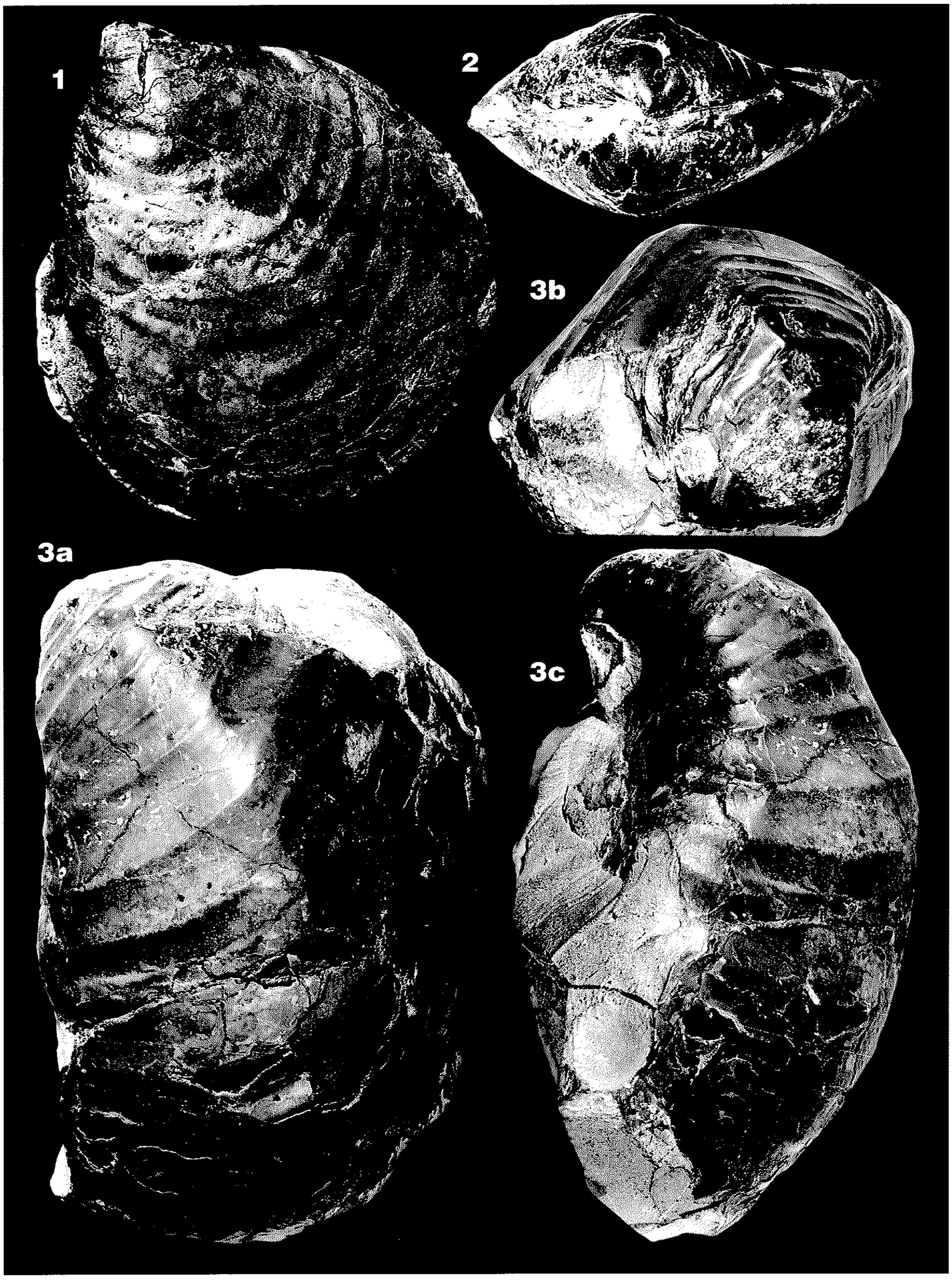
1
2
3b
3a
3c

PLATE 14

Mytilodes incertus (JIMBO, 1894)

Loc. Ik2013, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group

1 – TTC0001; × 1.07; 2 – JG.H2855; × 1; 3 – GK.H10123; × 1; 4 – JG.H2852; × 1; 5 – TTC0002; × 0.87

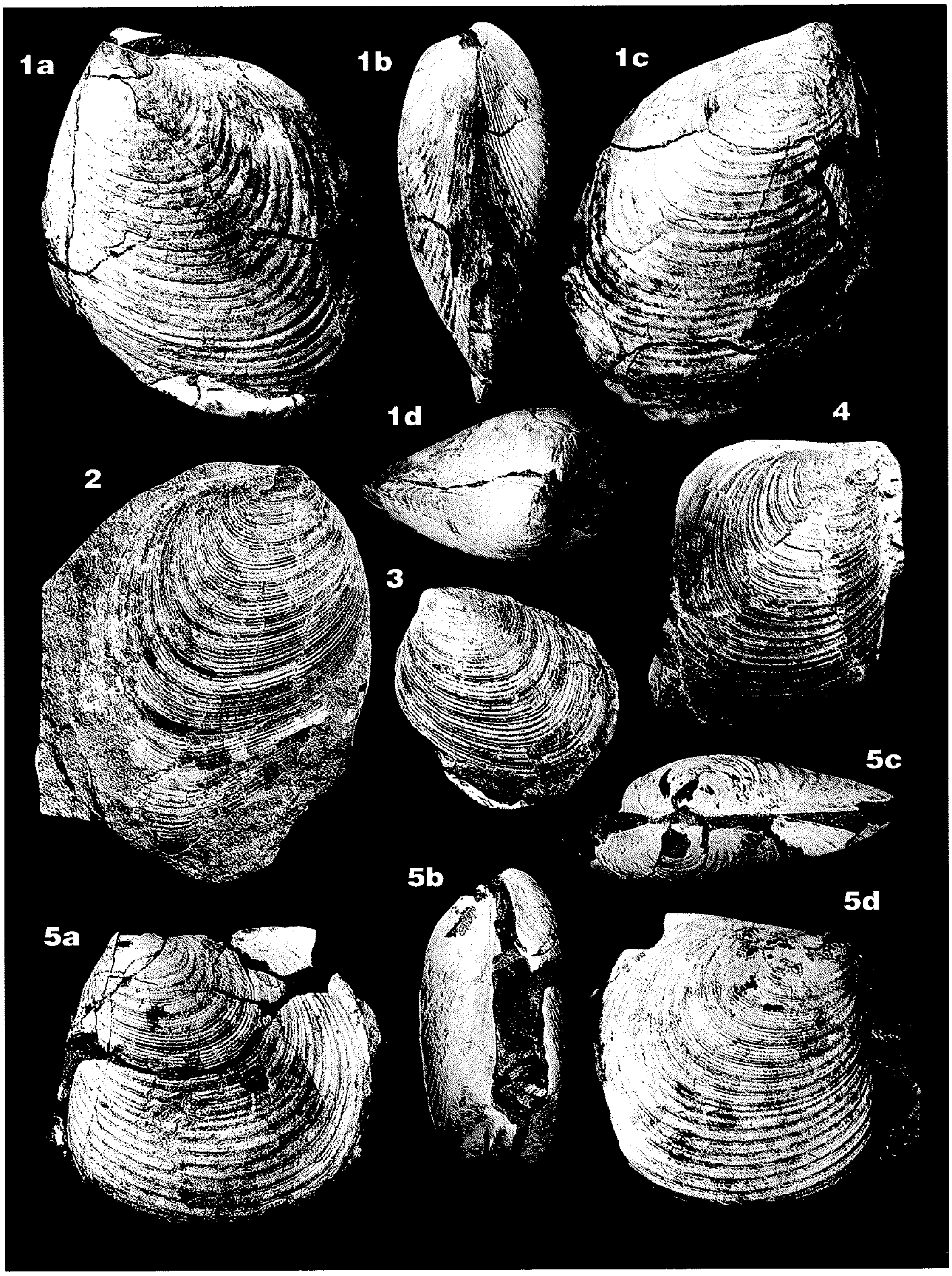
1a
1b
1c
1d
2
3
4
5c
5b
5d
5a

PLATE 15

1-5 – *Mytiloides incertus* (JIMBO, 1894)

1 – Lectotype, UMUT.MM7535-3; a float of the R. Ponbetsu, precise locality unknown, probably from Ik2013; × 1
2 – Paralectotype, UMUT.MM7535-2; precise locality unknown, probably from Ik2013; × 1
3 – UMUT.MM7535-4; precise locality unknown, probably from Ik2013
4 – GK.H10109; loc. Ik2011c, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1
5 – GK.H10087; loc. Ik2013g, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1

6-7 – *Mytiloides mytiloidiformis* (TRÖGER, 1967)

6 – GK.H10130; loc. Ik2014, Ponbetsu area, central Hokkaido; IIIa' member, Upper Yezo Group; × 1
7 – JG.H3505; loc. Ik1727, Ganseki-zawa, Ikushunbetsu area, central Hokkaido; IIIa member, Upper Yezo Group; × 0.95

8-9 – *Mytiloides sublabiatus* (MÜLLER, 1887)
Loc. Ik2799c, Ponbetsu-Gono-sawa, central Hokkaido; IIIb' member, Upper Yezo Group

8 – JG.H3517a; × 0.9; 9 – JG.H3518; × 0.95

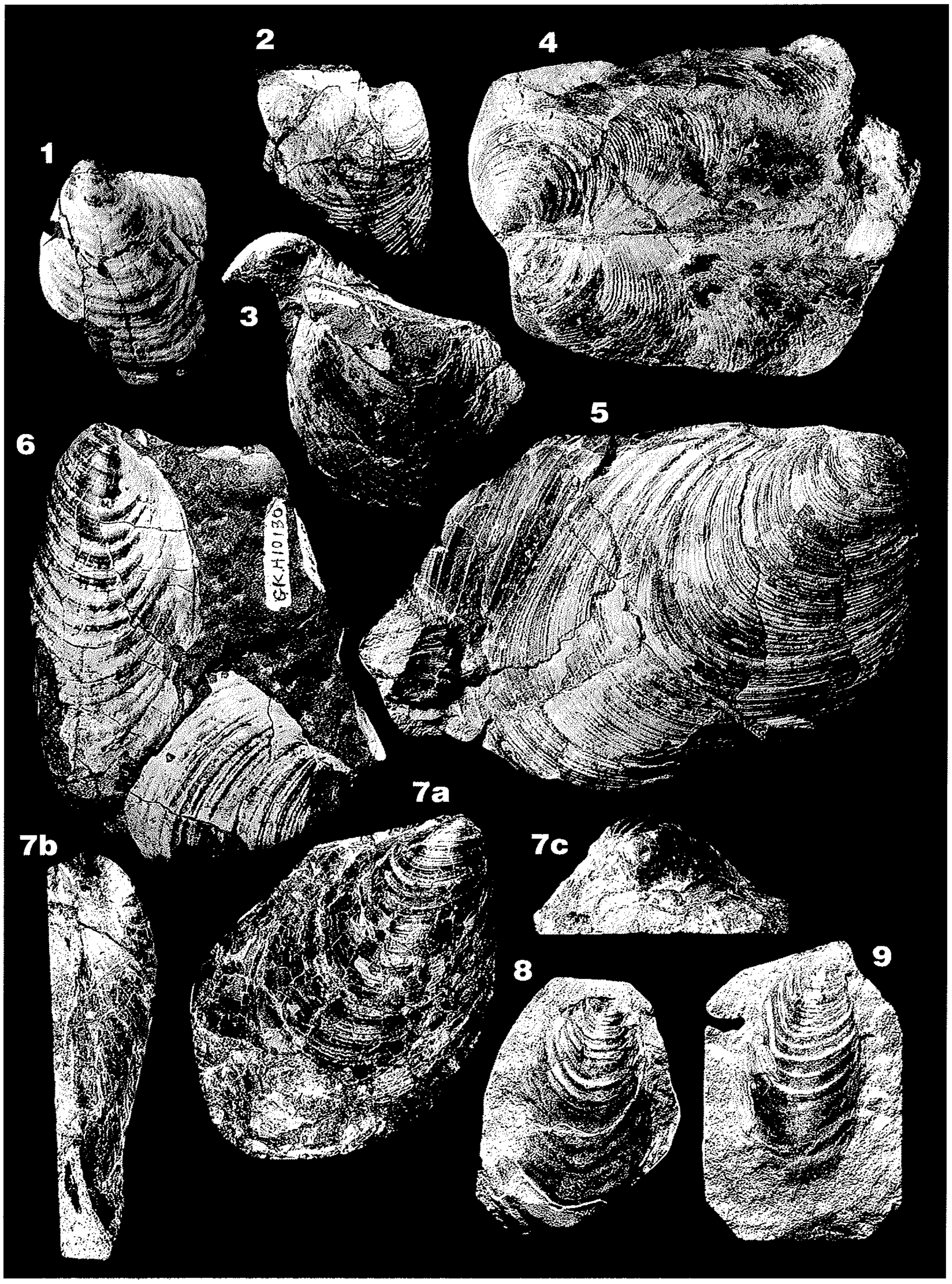
1
2
3
4
5
6
GK.H10130
7a
7b
7c
8
9

PLATE 16

1-2 – *Inoceramus* (*Inoceramus*) *hobetsensis* NAGAO & MATSUMOTO, 1939

1 – JG.H2030; loc. OR234, Onogawa Basin, eastern Kyushu; lower member of the Onogawa Group; × 0.68 [nodulous form, probably identical with *Inoceramus* (*Inoceramus*) *flaccidus* WHITE, 1874]

2 – Lectotype, unregistered specimen from GMH Collection; Kamihobetsu, Hobetsu area, south-central Hokkaido; Middle Yezo Group; × 0.25

3 – *Inoceramus* (*Inoceramus*) *hobetsensis nonsulcatus* NAGAO & MATSUMOTO, 1939; lectotype, IGPS.22809; Takikawano-sawa, Hobetsu area, south-central Hokkaido; Middle Yezo Group; × 1


1
2
3c
3a
3b

PLATE 17

Inoceramus (Inoceramus) iburiensis
NAGAO & MATSUMOTO, 1939

JG.H40-1040; loc. Ob2100, Kamikinanbestu, Obira area, northwestern Hokkaido; Unit Mn-O; Middle Yezo Group; × 0.5 (*see also* Pl. 18)

PLATE 18

Inoceramus (Inoceramus) iburiensis
NAGAO & MATSUMOTO, 1939

The same specimen as in Pl. 17; × 0.5


a
b