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Cover : A terminally resorbed maxillary tooth of iguanodontids (Ornithischia : Ornithopoda). The specimen is from the Kuwajima Formation, the Neocomian section of the Tetori Group, in Shiramine-mura, Ishikawa County, Ishikawa Prefecture, the west coast of Central Honshu, Japan (Shiramine-mura Board of Education, Coll. Cat. No. SBEI 001, 23 mm in dorsoventral length).

987 Redescription of Asano and Nakamura's (1937) cassidulinid species based on their primary types

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Abstract. Asano and Nakamura (1937) described 14 cassidulinid species and subspecies found in Pliocene to Recent marine sediments of Japan. They stored these type specimens in the collection of Tohoku University. However, Asano and his colleague's collection including the cassidulinid types has not been well organized, as reported by Hasegawa (1986). During his investigation of the foraminiferal collection, Hasegawa found the holotype, paratype and hypotype specimens of the species published in 1937. Since these specimens have not been available for later systematic works such as Nomura (1983a, b), herein we redescribe Asano and Nakamura's holotype and hypotype specimens in order to supplement Nomura's work, and revise taxonomically these species according to the modern foraminiferal systematics.

Reexamination reveals that *Cassidulina subglobosa parva* is a synonym of *Cassidulina decorata* Sidebottom. *Globocassidulina parva* as described by Nomura (1983b) is in part synonymous with *Globocassidulina canalisuturata* Eade (1967) from Recent sediments off New Zealand.

Key words : Cassidulinid foraminifera, type specimens, Pleistocene, Recent, Japan

Introduction

The foraminiferal family Cassidulinidae d'Orbigny is widely distributed in inner neritic to deep-sea sediments throughout the Cenozoic Era. Since Yabe and Hanzawa (1925) described a new species of *Cassidulina*, more than 80 species-group taxa (species and subspecies) belonging to eleven genera have been reported in and around the Japanese Islands. Among them, nine species-group taxa were described in the first published monograph of the cassidulinids from Japan by Asano and Nakamura (1937). One of the present authors (R.N.) has examined in detail the external and internal morphology of 76 Japanese cassidulinid species based on topotypic materials of Pliocene to Recent age (Nomura, 1983a, b).

The late Professor K. Asano of Tohoku University and his colleagues originally described more than 300 species-group taxa mainly from Japan, most of which have been reported repeatedly by subsequent workers. The original specimens including his holotypes and paratypes are stored in the foraminiferal collection of the Institute of Geology and Paleontology, Tohoku University in Sendai. However, Asano's collection including the cassidulinid specimens of Asano and Nakamura (1937) has not been well organized until now, because of some problems including an imperfect curatorial system for microfossils.

After the publication of Nomura (1983a, b), one of the present authors (S.H.) found several foraminiferal slides with the type specimens of Asano and Nakamura's *Cassidulina* in Asano's collection during a taxonomic study on Japanese late Cenozoic foraminifera (Hasegawa, 1986). They are associated with registered numbers of the Institute of Geology and Paleontology, Tohoku University, Sendai ("I.G.P.S. Coll. Cat. No." or "IGPS number"), as shown in Table 1. Since such numbers are usually given for describing new taxa, the specimens with the registered number should be primary types. We compared these specimens with the original descriptions by Asano and Nakamura (1937), and determined the type specimens of their taxa.

A single specimen of the following species is isolated from other specimens and mounted in a slide with an IGPS number : *Cassidulina japonica, C. setanaensis, C. sublimbata, C. yabei* and *C. wakasaensis.* The morphologic features of each species correspond to these of the type figures and description given by the original authors. Therefore, we confirmed that it is the holotype, and that the specimens in the other slides are paratypes. Another isolated specimen of *C. japonica* and *C. sublimbata* each

Table 1. Type specimens of cassiduline species described by Asano and Nakamura (1937) in Asano's collection of Tohoku University.

Cassiduline species of Asano and Nakamura (1937)	Original registration (and figures)	Revised registration (and number of specimens)	Types	Remarks
C. japonica Asano and Nakamura	21434 (Pl. 13, figs. 1a-c)	21434A (1)	holotype	Recent, Japan Sea
	(Pl. 13, figs. 2a-c)	21434B (1)	paratype (figured)	Pleistocene, Sado Island
		21434C-E (71)	paratypes	
	(text-figs. 2a, b)			specimen not found
C. yabei A & N	21435 (Pl. 14, figs. 1a, b)	21435A (1)	holotype	
		21435B (1)	paratype (figured)*	ex 21435D
		21435C-D (31)	paratypes	
C. sublimbata A & N	21436 (Pl. 14, fig. 3)	21436A (1)	holotype	Pleistocene, Sado Island
	(Pl. 14, figs. 4a, b)	21436B (1)	paratype (figured)	Pleistocene, SW Hokkaido
		21436C-E (44)	paratypes	
C. setanaensis A & N	21437 (Pl. 13, figs. 7a, b)	21437A (1)	holotype	
		21437B-C (76)	paratypes	
C. kazusaensis A & N	21438 (Pl. 14, figs. 2a, b)	21438A (1)	holotype	
		21438B (1)	paratype (figured)*	ex 21438D
		21438C (1)	paratype (figured)*	ex 21438D
		21438D (35)	paratypes	
		(1)		not registered (removed from holotype slide)
C. sagamiensis A & N	21439 (Pl. 14, figs. 5a, b)	not changed (1)	holotype	
C. orientale Cushman	(Pl. 14, figs. 6a, b)	102540 (1)*	hypotype	
C. subglobosa Brady	(Pl. 13, figs. 3a, b)	102542 (1)*	hypotype	
C. subglobosa parva A & N	21140 (Pl. 13, figs. 5a, b)	not changed (1)	holotype	
C. subglobosa depressa A & N	21441 (Pl. 13, figs. 8a, b)	not changed (1)	holotype	
C. pacifica Cushman	(Pl. 13, figs. 6a-c)	102543 (1)*	hypotype	
		(5)		not registered
C. wakasaensis A & N	21442 (Pl. 14, figs. 7a-c)	21442A (1)	holotype	
		21442B-D (931)	paratypes	
C. alternans Yabe and Hanzawa	63670	not changed (1)	holotype	text-figs. a and b of Yabe and Hanzawa (1925)
C. laevigata d'Orbigny (?)	(Pl. 13, figs. 4a, b)	102541 (1)*	hypotype	
	(text-figs. 12a, b)			specimen not found

* designated in this study

is mounted without number. Judging from its morphologic similarity to the original illustrations and from its described locality, we recognized it as the paratype drawn in the original paper of Asano and Nakamura (1937).

Two specimens of *Cassidulina kazusaensis* are stored in one slide with registered numbers. Since these specimens differ markedly in their test morphology, the holotype specimen is identified carefully based on the original description of Asano and Nakamura (1937).

Cassidulina sagamiensis, C. subglobosa parva and *C. subglobosa depressa* are each represented by a single specimen with a registered number. Therefore, each specimen is the holotype without any original paratypes. The type specimen of *C. alternans* Yabe and Hanzawa (1925), whose original description was quoted in Asano and Nakamura (1937), is also found in the collection. We confirmed it as the holotype on the basis of its registered number and morphologic similarity to the original description and figures.

In addition to these, the following four specimens illustrated in their 1937 paper were also found: *Cassidulina orientale* Cushman, *C. subglobosa* Brady, *C, laevigata*

d'Orbigny (?) and *C. pacifica* Cushman.

Among the forms illustrated by the original authors, the following two have not been recovered in Asano's collection as yet: A paratype specimen of *Cassidulina japonica* from an unknown locality (text-figs. 2a, b), and a specimen of *C. laevigata* d'Orbigny (?) collected from Ishikawa Prefecture (text-figs. 11a, b).

Through the reexamination, we recognized that most taxa have been treated well in Nomura (1983a, b), except for one subspecies, *Cassidulina subglobosa parva* (=*Globocassidulina parva* of Nomura, 1983a, b). This species has been obviously misunderstood by many workers. In this paper, we attempt to redescribe the morphologic features of the original specimens of Asano and Nakamura following the modern systematics of Loeblich and Tappan (1992). Also, we redescribe the other reported taxa in their paper, for which subsequent workers had to rely on the insufficient descriptions of Asano and Nakamura (1937).

All the species described by Asano and Nakamura (1937) are reillustrated with SEM micrographs which are taken with a low vacuum SEM in a coating-free condition,

except for the two unrecovered specimens of *C. japonica* and *C. laevigata* (?). We also give optical micrographs to demonstrate the external appearance of the inner structures of some species.

All of the paratypes and hypotypes of Asano and Nakamura (1937) are newly registered in the collection of Tohoku University. The original registered numbers are revised by adding "A" to the end of the number as IGPS 21434A for all the holotypes accompanied by paratypes. A series of paratypes in a species is registered under the same number as the holotype with a suffix letter (eg., 21434B, 21434C, ⋯). Paratypes are numbered for slides in which one or more specimens are stored. For those species based on a single specimen (i.e., automatic holotype), the registered number is not changed.

Systematic descriptions

Class Foraminiferea, J.J. Lee, 1990
Order Buliminida Fursenko, 1958
Superfamily Cassidulinacea d'Orbigny, 1839
Family Cassidulinidae d'Orbigny, 1839
Subfamily Cassidulininae d'Orbigny, 1839
Genus *Islandiella* Nørvang, 1959

Islandiella japonica (Asano and Nakamura)
[Original designation : *Cassidulina japonica* Asano and Nakamura]

Figures 1-1a—2d

Cassidulina japonica Asano and Nakamura, 1937, p. 144, text-figs. 2a, b ; pl. 13, figs. 1a-c, 2a-c ; Asano, 1939, p. 45, text-fig. 3 ; Asano, 1951, p. 1, figs. 3, 4 ; Matsunaga, 1963, pl. 48, figs. 4a, b ; Ishiwada, 1964, pl. 7, fig. 99.
Cassidulina californica Cushman and Hughes var. *japonica* Asano and Nakamura. Ishiwada, 1950, p. 192, figs. 11a, b.
Islandiella japonica (Asano and Nakamura). Troitskaja, 1970, p. 150, pl. 6, figs. 3, 4 ; Nomura, 1983a, pl. 4, fig. 6, pl. 6, fig. 1 ; pl. 10, figs. 4-10 ; 1983b, p. 2, pl. 1, figs. 1a-c, 2a-c.

Redescription of holotype.—Test large, nearly circular in side view, except for last-formed chamber which is slightly projected, and elongate oval in edge view ; periphery narrowly rounded, slightly lobulate ; chambers broadly elongate, four pairs in last-formed whorl, somewhat inflated ; umbilical region closed, depressed ; sutures distinct, limbate, depressed, gently curved ; aperture narrowly elongate, with cristate tooth whose tip is serrated, and with tongues at the base of apertural face ; wall smooth, matte, and polished. Length 1.24 mm, width 1.09 mm, thickness 0.59 mm.

Types.—Holotype : IGPS 21434A. Figured paratype : IGPS 21434B (Pl. 13, figs. 2a-c of Asano and Nakamura). Other paratypes : IGPS 21434C (19 specimens), IGPS 21434D (30) and IGPS 21434E (22).

Type localities.—Holotype and unfigured paratypes (IGPS 21434A and C) : Urashima-sho (=Urashima Bank) St. 5, Wakasa Bay, southern part of the Japan Sea (198 m in water depth ; Asano, 1939). Figured and unfigured

paratypes (IGPS 21434B, D and E) : Sawane, Sado Island, Niigata Prefecture.

Type level.—Holotype : Recent. Paratypes : Recent, and Sawane Formation (=Shichiba Formation of early Pleistocene age).

Observations.—Five original slides labeled "*Cassidulina japonica*" are found in Asano's collection. Two of them are labeled as collected from the Urashima Bank, and three are from the Sawane Formation. The holotype specimen is isolated from the other 19 specimens (=paratypes) by the original authors and is stored in one of the two slides containing the Urashima Bank specimens. One specimen collected from the Sawane Formation is also isolated from 52 specimens in the remaining two slides of the same locality. The fourth from last chamber of this specimen is partially depressed by some accident as shown in Figures 1-2a and 2d. Because the same feature was illustrated by Asano and Nakamura (1937), this specimen is assignable to the figured paratype of the original authors. Another specimen illustrated by Asano and Nakamura (1937 ; text-figs. 2a and b) has not been found in Asano's collection as yet.

As already pointed out by Nomura (1983b) based on the illustrations of Asano and Nakamura (1937), the holotype has a depressed umbilicus and distinctly inflated chambers, whereas the figured paratype does not show such features. Such differences are also recognized among the unfigured paratypes. The Recent specimens from the Urashima Bank are characterized by tests with a closed (or very small) and depressed umbilicus, depressed sutures, and four to five pairs of inflated chambers in the final whorl. On the other hand, the specimens from the Pleistocene Sawane Formation have a small stellate umbilicus and more limbate sutures flush with the test surface except for the last-formed chambers. They are composed of four pairs of chambers in the nepionic stage, but five to six pairs in the neanic and gerontic stages. The Pleistocene specimens are somewhat similar to *I. californica* (Cushman and Hughes), but are distinguished from the latter in having a less globular test with a narrowly rounded periphery, and a greater number of chambers per whorl.

In this species, Nomura (1983b) recognized two types of aperture on the basis of different style of its primary tongue which is externally connected to a cristate tooth. This feature is clearly shown in the holotype figure but not in the paratype figure. However, our reexamination of the figured paratype reveals that the primary tongue was broken off, possibly by some accident. The primary tongue is distinct in both of the Recent and Pleistocene unfigured paratypes.

In conclusion, the type series of "*C. japonica*" consists of two morphotypes on degree of chamber inflation ; one with inflated chambers includes the holotype from the Recent sediment, the other has less inflated chamber as does the figured paratype of the Pleistocene. The former has been reported from the Pliocene in Niigata Prefecture by Matsunaga (1963), too. Alternately, the latter form occurs in the Recent Toyama Bay (Ishiwada, 1950). All

previous workers have regarded both morphotypes as falling within the range of variation of a single species. To the contrary, it may be possible that they represent two different species. Such a possibility could be confirmed in future through detailed morphometric analyses or variation studies in morphology. In this moment, we tentatively regard them as intraspecific variants.

Islandiella kazusaensis (Asano and Nakamura)
[Original designation : *Cassidulina kazusaensis*
Asano and Nakamura]

Figures 3-1a—3

Cassidulina kazusaensis Asano and Nakamura, 1937, p. 146, text-figs. 7a, b ; pl. 14, figs. 2a, b ; Asano, 1938a, p. 78, pl. 8, figs. 8a, b ; Asano, 1951, p. 2, figs. 7, 8.
Islandiella kazusaensis (Asano and Nakamura). Nomura, 1983a, pl. 11, figs. 10, 11 ; 1983b, p. 6, pl. 1, figs. 5a-c.

Redescription of holotype.—Test large, subglobular in outline, nearly circular in side view, last chamber broken, oval in edge view ; periphery narrowly rounded, not lobulate ; chambers distinct, suboval in side view, not inflated, seven pairs in last-formed whorl, gradually increasing in size as added ; sutures distinct, not depressed, radiate, but slightly curved near periphery, flush with surface ; umbilical region stellate, not depressed ; apertural opening hidden by secondary fillings of sediments ; wall smooth, finely perforate, polished, translucent. Length 0.99 mm, width 0.90 mm, thickness 0.56 mm except for last chamber.

Types.—Holotype : IGPS 21438A. Figured paratypes : IGPS 21438B and C (selected from IGPS 21438D in the present work). Other paratypes : IGPS 21438D (35).

Type locality.—Mitsumata, Fusamoto-mura (=presently Mitsumata, Otaki-machi), Isumi-gun, Chiba Prefecture.

Type level.—Kiwada Formation (early Pleistocene).

Observations.—Two cassidulinid specimens are mounted in the type slide of *Cassidulina kazusaensis* with the IGPS collection number of 21438. One is characterized by a large test with features which are well agreeable with the type description and illustrations given by the original authors, thereby enabling us to easily recognize it as the holotype. On the contrary, the other specimen is characterized by a medium test size, a lobulate periphery, inflated chambers, depressed sutures, and a tripartite aperture indicating a different species. We identified it as *Globocassidulina bisecta* Nomura, 1983a ; thus we removed it from this original slide.

All the paratypes contained in the other slides exhibit similar features to the holotype in their test morphology. Although details of the apertural structure of the holotype is not clear, the paratype specimens show that an elon-

gate slit is developed at the base of the apertural face. It is almost parallel to the plane of coiling and has a fan-shaped cristate tooth and this apertural ridge (B2 type aperture of Nomura, 1983a).

Islandiella setanaensis (Asano and Nakamura)
[Original designation : *Cassidulina setanaensis*
Asano and Nakamura]

Figures 1-3a—d

Cassidulina setanaensis Asano and Nakamura, 1937, p. 146, pl. 13, figs. 7a, b ; Asano, 1951, p. 3, figs. 15, 16 : Ishiwada, 1964, pl. 7, fig. 100.
Cassilamellina setanaensis (Asano and Nakamura). Saidova, 1975, pl. 91, fig. 1, pl. 115, fig. 9.
Cassidulina (?) lomitensis (Galloway and Wissler). McCulloch, 1977, p. 391, pl. 163, figs. 3a-c.
Islandiella setanaensis (Asano and Nakamura). Nomura, 1983a, pl. 3, fig. 6 ; pl. 4, figs. 3, 4 ; pl. 10, fig. 11 ; pl. 11, figs. 1-3 ; 1983b, p. 5, pl. 1, figs. 3a-c.

Redescription of holotype.—Test large, nearly circular in side view, oval in edge view ; periphery rounded, not lobulate ; chambers broad, not inflated, six pairs making up last-formed whorl ; sutures distinct, flush with surface ; umbilical region filled with clear stellate shell material ; aperture an elongate slit at base of apertural face, running parallel to plane of coiling, having a broken cristate tooth and well developed apertural ridge ; wall smooth, polished, very finely perforate. Length 1.45 mm, width 1.25 mm, thickness 0.85 mm.

Types.—Holotype : IGPS 21437A. Paratypes : IGPS 21437B (58 specimens), IGPS 21437C (18).

Type locality.—Maruyama, Higashisetana-mura (=presently Maruyama, Aichi, Kitahiyama-machi), Setana-gun, Hokkaido (St. 152 in Asano, 1937 ; St. b of the Setana district in Asano, 1938c).

Type level.—Setana Formation (early Pleistocene).

Observations.—The holotype is isolated on a separate slide by the original authors. The paratypes (76 specimens in total) were found in two other slides together with several specimens of other species, such as *I. japonica, Lenticulina* spp. and *Guttulina* spp. Those erroneously included specimens were removed to a new slide by us.

Islandiella setanaensis is closely related to *I. japonica,* particularly in their younger stages, but this species is distinguished by its larger number of chambers per whorl ; *I. setanaensis* has 5.5 pairs, whereas *I. japonica* has 4 to 5 pairs of chambers per whorl in younger stages. So far as fully mature specimens are concerned, *C. setanaensis* differs from *C. japonica* in having the test with a broadly rounded and nonlobulate periphery and flush sutures.

Figure 1. 1-2. *Islandiella japonica* (Asano and Nakamura), 1 : holotype (IGPS 21434A), from Wakasa Bay (Recent, 198 m), 2 : paratype (IGPS 21434B), from Sado Island (Sawane Formation, early Pleistocene). 3. *Islandiella setanaensis* (Asano and Nakamura), holotype (IGPS 21437A), from Kitahiyama, Hokkaido (Setana Formation, early Pleistocene). 4. *Islandiella wakasaensis* (Asano and Nakamura), holotype (IGPS 21442A), from Wakasa Bay (Recent, 190 m). a and b= both sides views, c=edge view, d=optical micrograph showing umbilical region. Scale bars are 100 μm.

1a 1b 1c 3a

2a 2b 2c 3d

2d 4c 3b 3c

4a 4b

■ a–c
■ 2d
■ 3d
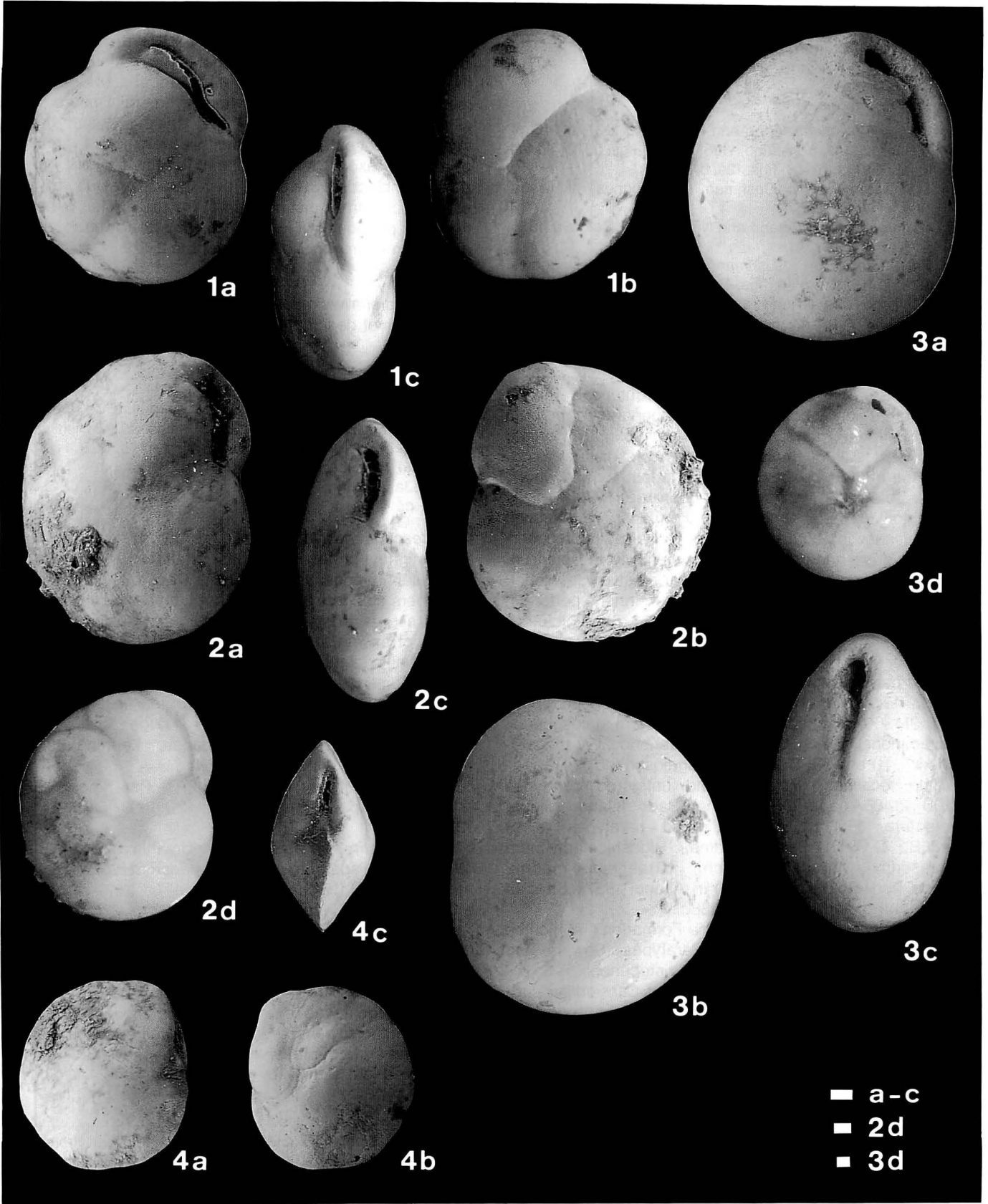
Islandiella sublimbata (Asano and Nakamura)
[Original designation : *Cassidulina sublimbata*
Asano and Nakamura]

Figures 2-1a—2d

Cassidulina sublimbata Asano and Nakamura, 1937, p. 146, pl. 14, figs. 3, 4a, b ; Asano, 1951, p. 5, figs. 23, 24 ; Matsunaga, 1963, pl. 48, figs. 12a, b.

Cassidulina translucens Cushman and Hughes. Ishiwada, 1964, pl. 7, fig. 102.

Cassandra sublimbata (Asano and Nakamura). Saidova, 1975, pl. 92, fig. 2.

Islandiella translucens (Cushman and Hughes). Hasegawa, 1979, p. 150, 151, pl. 4, figs. 4a–c.

Islandiella sublimbata (Asano and Nakamura). Nomura, 1983a, pl. 3, fig. 7 ; pl. 4, fig. 2 ; pl. 5, fig. 7 ; pl. 9, figs. 1-8 ; 1983b, p. 9, pl. 1, figs. 6-c, 7a, b, 8a, b.

Redescription of holotype.—Test large, nearly circular in side view, lenticular in edge view, but nearly flat in umbilical region, showing parallel appearance in both sides ; periphery narrowly carinate, very slightly lobulate only in last pair of chambers ; chambers distinct, elongate, not inflated, six pairs making up last-formed whorl ; sutures distinct, limbate, not depressed, tangentially curved toward periphery ; umbilical region with clear shell material, showing earlier chambers as well as microspheric proloculus ; aperture elongate, parallel to the plane of coiling, accompanied with a cristate tooth, well developed lip, and apertural ridge ; wall smooth, finely perforate, polished. Length 0.83 mm, width 0.74 mm, thickness 0.36 mm.

Types.—Holotype (microspheric form) : IGPS 21436A. Figured paratype (megalospheric form) : IGPS 21436B (Pl. 14, figs. 4a, b of Asano and Nakamura). Other paratypes : IGPS 21436C (microspheric : 1 specimen, megalospheric : 3 specimens), IGPS 21436D (microspheric : 27, megalospheric : 11) and IGPS 21436E (megalospheric : 2).

Type localities.—Holotype and unfigured paratypes (IGPS 21436A and C) : Sawane, Sado Island, Niigata Prefecture. Figured and unfigured paratypes (IGPS 21436B, D and E) : Maruyama, Higashisetana-mura (=presently Maruyama, Aichi, Kitahiyama-machi), Setana-gun, Hokkaido (St. 150 in Asano, 1937 ; St. c of the Setana district in Asano, 1938c).

Type level.—Holotype : Sawane Formation (=Shichiba Formation ; early Pleistocene). Paratypes : Sawane and Setana Formations (both of early Pleistocene).

Observations.—Five original slides of *Cassidulina sublimbata*, two from the Sawane Formation and three from the Setana Formation, were found. Of the two slides from the Sawane Formation, one stores the holotype, and the other includes four paratypes. One slide from the Setana Formation contains the isolated specimen that

was figured by the original authors. Other two slides from the Setana Formation contain 40 paratypes in total. Compared with the paratypes from the Sawane Formation, those from the Setana Formation are characterized by more narrowly elongate chambers, more limbate and slightly undulated sutures. We considered that these morphological differences fall within the range of variation of a single taxon. Megalospheric form has a large transparent umbilicus, where well developed pore tubules are seen to penetrate distinctly into the clear shell material from the proloculus (Figure 2-1d). Such a feature is not distinct in microspheric forms (Figure 2-2d).

Islandiella wakasaensis (Asano and Nakamura)
[Original designation : *Cassidulina wakasaensis*
Asano and Nakamura]

Figures 1-4a—c

Cassidulina wakasaensis Asano and Nakamura, 1937, p. 149, pl. 14, figs. 7a–c ; Asano, 1951, p. 5, figs. 25, 26 ; Ishiwada, 1964, pl. 7, fig. 105 ; Chiji and Konda, 1970, pl. 9, fig. 4.

Islandiella wakasaensis (Asano and Nakamura). Nomura, 1983a, pl. 3, fig. 3 ; pl. 8, figs. 11, 12 ; 1983b, p. 11, pl. 2, figs. 1a–c.

Redescription of holotype.—Test large, nearly circular, very slightly projecting in last chamber in side view, lenticular in edge view ; periphery acute, not carinate ; chambers elongate, indistinct, not inflated except for later ones, six pairs making up last-formed whorl ; sutures indistinct except for later ones, not depressed, undulate, tangentially slightly curved toward periphery ; umbilical region indistinct ; aperture narrow, elongate, nearly parallel to the plane of coiling, with serrated lip and cristate tooth, and with undulated apertural ridge ; wall smooth, polished, very finely perforate, opaque. Length 0.89 mm, width 0.80 mm, thickness 0.47 mm.

Types.—Holotype : IGPS 21442A. Paratypes : IGPS 21442B (282 specimens), IGPS 21442C (277), IGPS 21442D (372).

Type locality.—Urashima-sho (Urashima Bank) St. 8, Wakasa Bay, southern part of the Japan Sea (Water depth 190 m ; Asano, 1939).

Type level.—Recent.

Observations.—The holotype is isolated from the paratype specimens and is mounted in one slide. A large number of paratype specimens are stored in three slides. The wall in most of the paratypes is opaque to semiopaque. Though it was regarded as a specific feature by the original authors, transparency of the wall changes largely due to the state of preservation as well as wall thickness, as pointed out before by one of the authors (Nomura, 1983a).

Figure 2. **1-2.** *Islandiella sublimbata* (Asano and Nakamura), 1 : holotype (IGPS 21436A), microspheric form, from Sado Island (Sawane Formation, early Pleistocene), 2 : paratype (IGPS 21436B), megalospheric form, from Kitahiyama, Hokkaido (Setana Formation, early Pleistocene). **3-4.** *Islandiella yabei* (Asano and Nakamura), 3 : holotype (IGPS 21435A), microspheric form, 4 : paratype (IGPS 21435B), megalospheric form, all from Imakane, Hokkaido (Setana Formation, early Pleistocene). Scale bars are 100 μm. [a-d, see explanation for Figure 1]

1a 1c 1b 1d

2a 2c 2b 2d

3a 3c 3b 3d

4a 4c 4b 4d

a–c
d
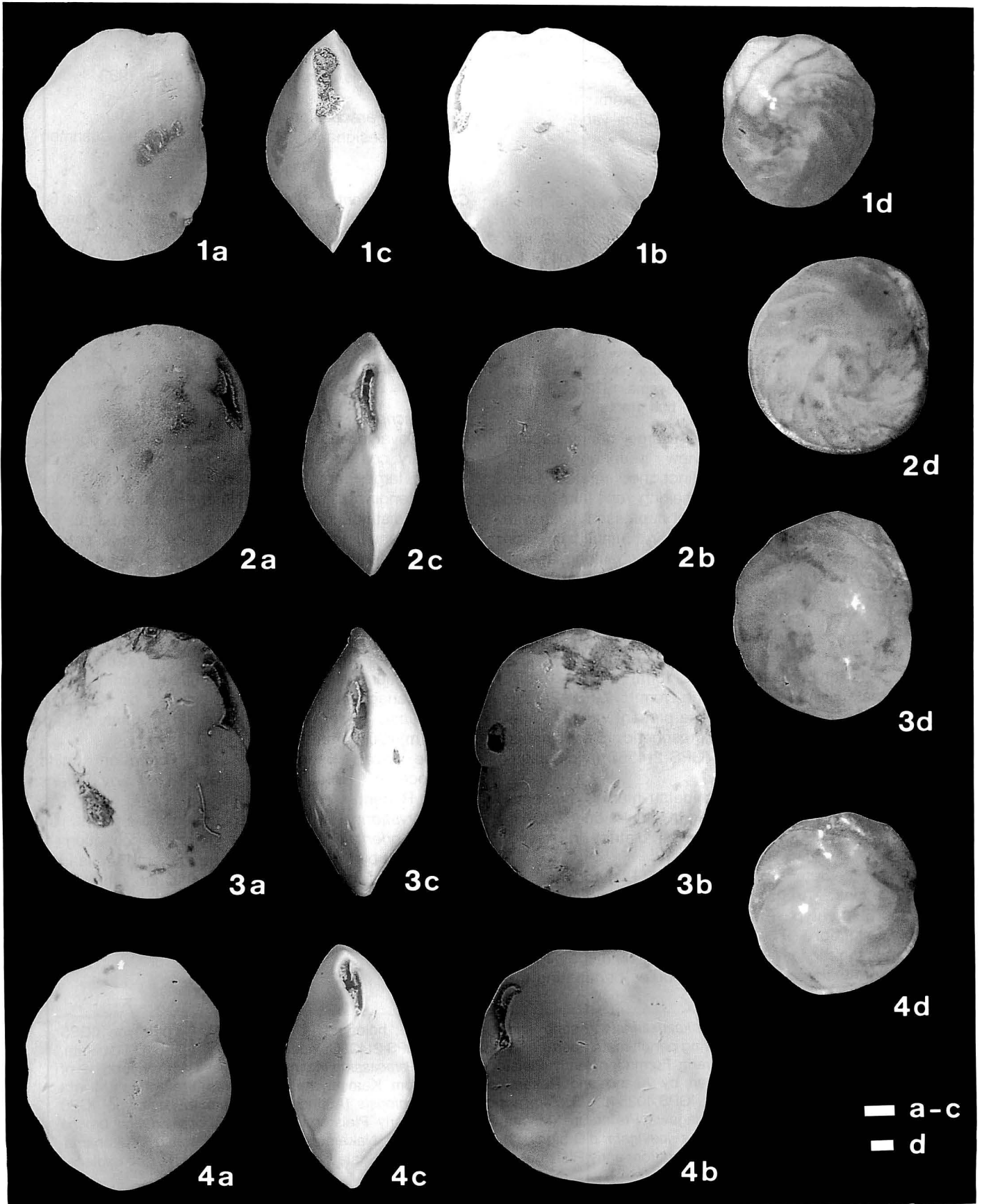
Sutures of the paratypes are nearly straight to undulate, but not so tortuous as those of *I. tortuosa* (Cushman and Hughes).

Islandiella yabei (Asano and Nakamura)
[Original designation : *Cassidulina yabei* Asano and Nakamura]

Figures 2-3a—4d

Cassidulina yabei Asano and Nakamura, 1937, p. 145, pl. 14, figs. 1a, b ; Asano, 1951, p. 5, figs. 27, 28 ; Voloshinova, 1952, p. 89, pl. 1, figs. 10a-c ; Matsunaga, 1963, pl. 49, figs. 1a-2b ; Ishiwada, 1964, p. 42, 43, pl. 7, figs. 103, 104 ; Chiji and Konda, 1970, pl. 9, figs. 3a, b ; Hasegawa, 1979, p. 145, pl. 8, figs. 7a-c.

Islandiella yabei (Asano and Nakamura). Nomura, 1983a, pl. 3, fig. 1 ; pl. 4, fig. 7 ; pl. 9, figs. 9-12, pl. 10, figs. 1-3 ; 1983b, p. 7, pl. 1, figs. 4a-c, 9a, b.

Not *Cassidulina yabei* Asano and Nakamura. Matoba, 1967, p. 253, pl. 28, figs. 8a, b, 9a, b ; Kameyama, 1972, pl. 31, figs. 5a, b ; Inoue, 1989, p. 156, pl. 23, figs. 11a, b.

Redescription of holotype.—Test large, nearly circular in side view, lenticular in edge view ; periphery carinate, slightly lobulate ; chambers distinct, not inflated, large rounded-rhomboid, five pairs making up last-formed whorl ; sutures distinct, limbate, not depressed, flush with surface, gently curved toward periphery ; umbilical region with clear shell material, showing earlier chambers as well as microspheric proloculus ; aperture elongate, extending from the base of final apertural face, parallel to the plane of coiling, with fragile cristate tooth and thick apertural ridge ; wall smooth, finely perforate, transparent. Length 0.92 mm, width 0.78 mm, thickness 0.42 mm.

Types.—Holotype (microspheric form): IGPS 21435A. Figured paratype (megalospheric form): IGPS 21435B (selected from IGPS 21435D in the present work). Other paratypes : IGPS 21435C (microspheric : 5 specimens, megalospheric : 4 specimens), IGPS 21435D (microspheric : 15, megalospheric : 7).

Type locality.—Omagari, Toshibetsu-mura (=presently Pirika, Imakane-machi), Setana-gun, Hokkaido (St. 107 in Asano, 1937 ; St. c of the Hanaishi district in Asano, 1938c).

Type level.—Setana Formation (early Pleistocene).

Observations.—An isolated specimen (holotype) in a slide and 32 paratypes in two other slides were found in Asano's collection. The paratypes have four to five pairs of chambers in the last-formed whorl. The megalospheric form clearly shows many pore tubules penetrating the

thickly calcified transparent umbilicus (Figures 2-4a—d) as observed in *C. sublimbata.*

Genus *Paracassidulina* Nomura, 1983

Paracassidulina nipponensis (Eade)
[Original designation : *Cassidulina orientale* Cushman]

Figures 3-4a—c

Cassidulina orientale Cushman, 1925, p. 37, pl. 7, figs. 6a-c (not of Cushman, 1922, p. 128) [*nom. nud.*] ; Asano and Nakamura, 1937, p. 147, pl. 14, figs. 6a, b ; Asano, 1951, p. 2, figs. 9, 10 ; Matsunaga, 1963, pl. 48, figs. 7a, b ; LeRoy, 1964, p. F40, pl. 11, figs. 15, 16.

Globocassidulina nipponensis Eade, 1969 (part), p. 65, pl. 13, figs. 1a-c, 2a-c, 4 (not fig. 3).

Not *Cassidulinoides orientale* [*sic* !] : (Cushman). Barker, 1960, p. 112, pl. 54, figs. 10a-c.

Paracassidulina nipponensis (Eade). Nomura, 1983a, p. 97, pl. 2, figs. 20a, b ; pl. 25, fig. 8.

Redescription of hypotype.—Test medium, compressed, broadly oval in side view, both sides parallel in edge view ; periphery compressed-rounded, not lobulate ; chambers distinct, large, not inflated, five to six pairs in last-formed whorl, tending in adult specimens to show uncoiling ; sutures distinct, narrowly limbate, nearly straight, flush with surface ; umbilical region narrow, not depressed ; aperture a long, narrow slit at base of last apertural face, with distinct apertural ridge ; wall smooth, very finely perforate, polished, translucent. Length 0.46 mm, width 0.36 mm, thickness 0.14 mm.

Type.—Hypotype : IGPS 102540.

Type localities.—Hypotype : Kamimiyata, Minami-shitaura-mura, Miura-gun (=presently Kamimiyata, Miura City), Kanagawa Prefecture. Holotype of *Cassidulina nipponensis* Eade : "Nero" station 1264, south of Japan (3,806 m) (Cushman, 1925).

Type level.—Hypotype : Miyata Formation (middle Pleistocene). Holotype of *Cassidulina nipponensis* Eade : Recent.

Observations.—A single specimen labeled as *Cassidulina orientale* is stored in Asano's collection. As pointed out by Nomura (1983a), the present form is identical to *Cassidulina orientale* Cushman, 1925. This species name is judged to be a junior primary homonym of *C. orientalis* Cushman, 1922 by Eade (1969) who proposed the new name *C. nipponensis* for the former.

Figure 3. 1-3. *Islandiella kazusaensis* (Asano and Nakamura), 1 : holotype (IGPS 21438A), 2 : paratype (IGPS 21438B), tangential view showing penultimate aperture, 3 : paratype (IGPS 21438C), apertural view. All from Mitsumata, Otaki, Chiba Prefecture (Kiwada Formation, early Pleistocene). 4. *Paracassidulina nipponensis* (Eade), hypotype of *Cassidulina orientale* Cushman by Asano and Nakamura (1937), from Kamimiyata, Kanagawa Prefecture (Miyata Formation, early Pleistocene), IGPS 102540. 5. *Paracassidulina sagamiensis* (Asano and Nakamura), holotype (IGPS 21439), from Kamimiyata, Kanagawa Prefecture (Miyata Formation, early Pleistocene). 6. *Globocassidulina brocha* (Poag), hypotype of *Cassidulina laevigata* d'Orbigny (?) by Asano and Nakamura (1937), from Yatsu, Yokohama, Kanagawa Prefecture (Ofuna Formation, early Pleistocene), IGPS 102541. Scale bars are 100 μm. [a-d, see explanation for Figure 1]

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

1a–c, 2
1d
3
4, 5
6
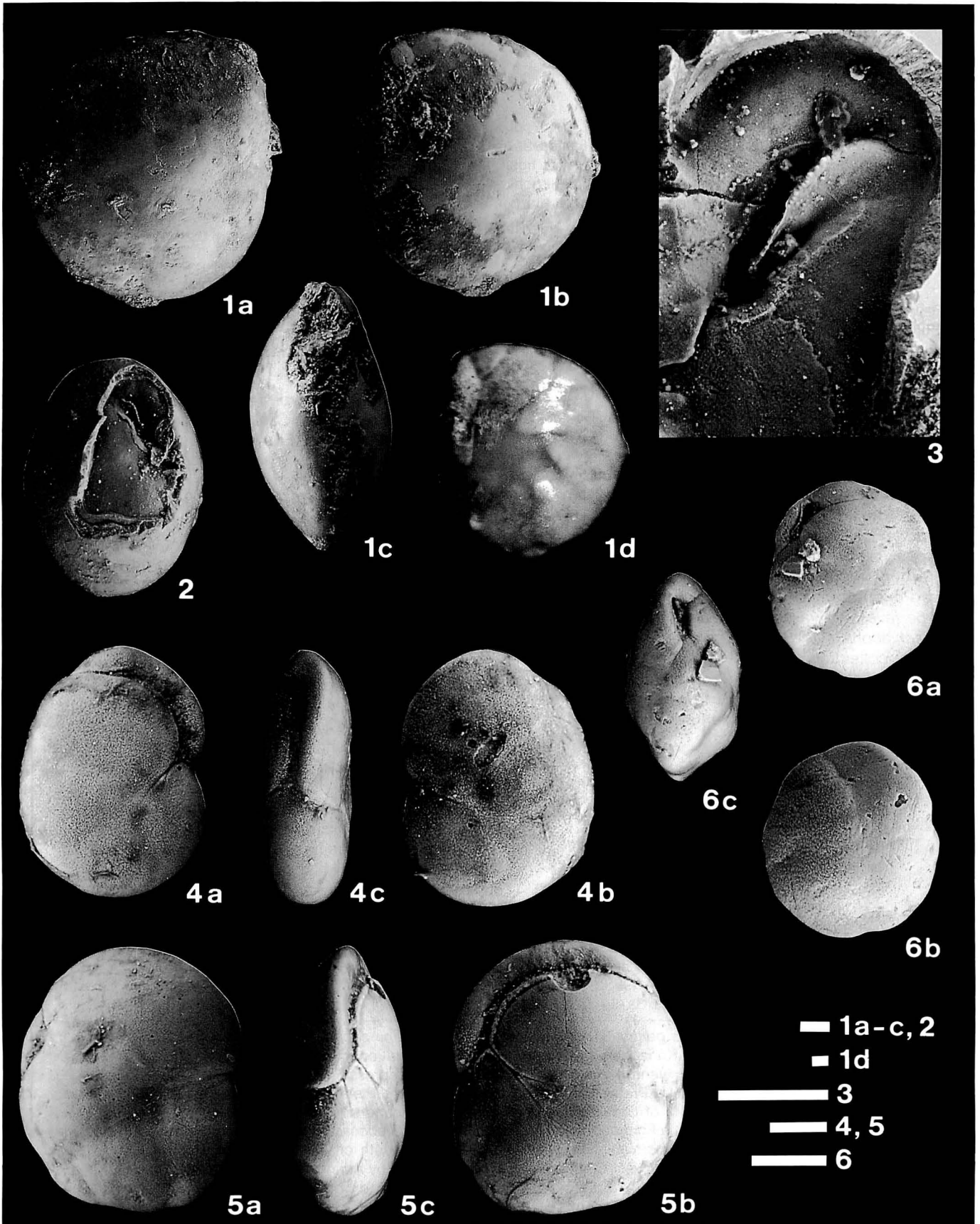
Paracassidulina sagamiensis (Asano and Nakamura)
　[Original designation : *Cassidulina sagamiensis*
　　　　　Asano and Nakamura]

Figures 3-5a—c

Cassidulina sagamiensis Asano and Nakamura, 1937, p. 147, pl.
　14, figs. 5a-c ; Asano, 1938b, p. 71, 84, 88, pl. 8, figs. 9a-
　c ; Asano, 1951, p. 3, figs. 13, 14 ; Higuchi, 1954, pl. 3, figs.
　24a, b ; Matsunaga, 1963, pl. 48, figs. 8a, b ; Kikuchi,
　1964, pl. 7, fig. 16 ; Matoba, 1967, p. 263, pl. 28, figs. 13a, b,
　14a, b.
Paracassidulina sagamiensis (Asano and Nakamura). Nomura,
　1983a, pl. 5, fig. 6 ; pl. 24, figs. 10-12 ; pl. 25, figs. 1, 2 ;
　1983b, p. 67, pl. 6, figs. 1a-3.

Redescription of holotype.—Test medium, somewhat
compressed, subcircular in side view, elongate oval in
edge view ; periphery narrowly rounded, slightly lobulate ;
chambers distinct, large, slightly inflated, four pairs in
last-formed whorl ; sutures distinct, narrowly limbate,
gently curved, slightly depressed ; umbilical region nar-
row, slightly depressed ; aperture a long-narrow slit with
distinct apertural ridge ; wall smooth, very finely perforate,
opaque ; very short fine grooves running out of anterior
end of aperture. Length 0.51 mm, width 0.42 mm, thick-
ness 0.23 mm.
　Type.—Holotype : IGPS 21439.
　Type locality.—Kamimiyata, Minamishitaura-mura,
Miura-gun (=presently Kamimiyata, Miura City), Kana-
gawa Prefecture.
　Type level.—Miyata Formation (middle Pleistocene).
　Observations.—There is no paratype specimen found in
Asano's collection. Nomura (1983b) pointed out that
Paracassidulina sagamiensis is characterized by a long
narrow slit-shaped aperture, a few apertural grooves on
the proximal portion of the aperture, and a small secon-
dary tongue.

Genus *Globocassidulina* Voloshinova, 1960

Globocassidulina brocha (Poag)
　[Original designation : *Cassidulina laevigata*
　　　　　d'Orbigny (?)]

Figures 3-6a—c

Cassidulina laevigata d'Orbigny (?). Asano and Nakamura,
　1937 (part), p. 150, pl. 13, figs. 4a, b (not text-figs. 11a, b).
Cassidulina brocha Poag, 1966, p. 426, pl. 8, figs. 33-35.
Globocassidulina brocha (Poag). Nomura, 1983a, pl. 18, figs.
　8-12 ; Nomura, 1983b, p. 31, pl. 3, figs. 3a-5.

Not *Cassidulina asanoi* Uchio in Kawai *et al.*, 1950, p. 190, fig.
　13 ; Uchio, 1951, p. 39, 40, pl. 3, figs. 2a, b.

　Redescription of hypotype.—Test medium, nearly circu-
lar in side view, biconvex ; periphery subacute, slightly
lobulate ; chambers elongate, very slightly inflated, four
pairs making up last-formed whorl, uniformly increasing in
size as added ; sutures distinct, narrowly limbate, tan-
gentially curved toward periphery, slightly depressed ;
umbilical region closed, very slightly depressed ; aperture
crookedly elongate ; wall very thin, finely perforate, trans-
lucent. Length 0.29 mm, width 0.25 mm, thickness 0.16
mm.
　Type.—Hypotype : IGPS Coll. Cat. No. 102541.
　Type localities.—Hypotype : Yazu, Kanazawa-machi
(=presently Yatsu, Kanazawa-ku, Yokohama City),
Kanagawa Prefecture. Holotype of *Cassidulina brocha*
Poag : S19, Chickasawhay River, Wayne County, Missis-
sippi, U.S.A.
　Type level.—Hypotype : Ofuna Formation (early Pleis-
tocene). Holotype of *Cassidulina brocha* Poag : Paynes
Hammock Formation (Early Miocene ?).
　Observations.—Only one specimen has been found in
Asano's collection. It is characterized by the biconvex
test with a subacute periphery and closed umbilicus,
which is in agreement with the illustration of Asano and
Nakamura (their plate 13, figs. 4a, b).
　On the other hand, they illustrated another form of this
species in their paper (text-fig. 11 of Asano and Nakamura,
1937), which has not been found in Asano's collection yet.
Uchio (1951) understood the difference in morphology
between two figures of Asano and Nakamura (1937), and
identified the present form with his new species, *Cas-
sidulina asanoi* Uchio (Uchio, 1950, 1951). Later Uchio's
species has been regarded as a synonym of *C. delicata*
Cushman (=*Takayanagia delicata*) by many Japanese
workers (e.g., Ishiwada, 1964 ; Matoba, 1967 ; Nomura,
1983a). Though the original figures of Asano and Na-
kamura (1937 ; pl. 13, figs. 4a, b) are quite similar to Uchio'
s species, the original specimen is obviously distin-
guished from *Cassidulina asanoi* or *C. delicata* in having
less elongate chambers, and the crookedly elongate E2-
Type aperture with a tube-like lip, cristate tooth, and a
secondary tongue.

Globocassidulina decorata (Sidebottom)
　[Original designation : *Cassidulina subglobosa*
　　　　Brady *parva* Asano and Nakamura]

Figures 4-3a—c

Figure 4. **1.** *Globocassidulina gemma* (Todd), hypotype of *Cassidulina subglobosa* Brady by Asano and Nakamura
(1937) from Kajigaya, Yokohama, Kanagawa Prefecture (Nakazato Formation, middle Pleistocene), IGPS 102542. 1a=
apertural view, 1b=side view, 1c=ventral view. **2.** *Globocassidulina depressa* (Asano and Nakamura), holotype (IGPS
21441), from Semata, Ichihara, Chiba Prefecture (Yabu Formation, middle Pleistocene). **3.** *Globocassidulina decorata*
(Sidebottom), holotype (IGPS 21140) of *Cassidulina subglobosa parva* Asano and Nakamura, 1937, from Nojima, Yoko-
hama, Kanagawa Prefecture (Nojima Formation, early Pleistocene). **4.** *Globocassidulina elegans* (Sidebottom), holotype
(IGPS 63670) of *Cassidulina alternans* Yabe and Hanzawa, 1925, from south of Okinawa Island (Recent, 1,580 m). **5.**
Burseolina pacifica (Cushman), hypotype of *Cassidulina pacifica* Cushman by Asano and Nakamura (1937) from Kyoshito,
Takao Prefecture, Taiwan, IGPS 102543. 5a, b=edge and side views, 5c, d=optical micrographs in edge and ventral
views showing sutures. Scale bars are 100 μm.
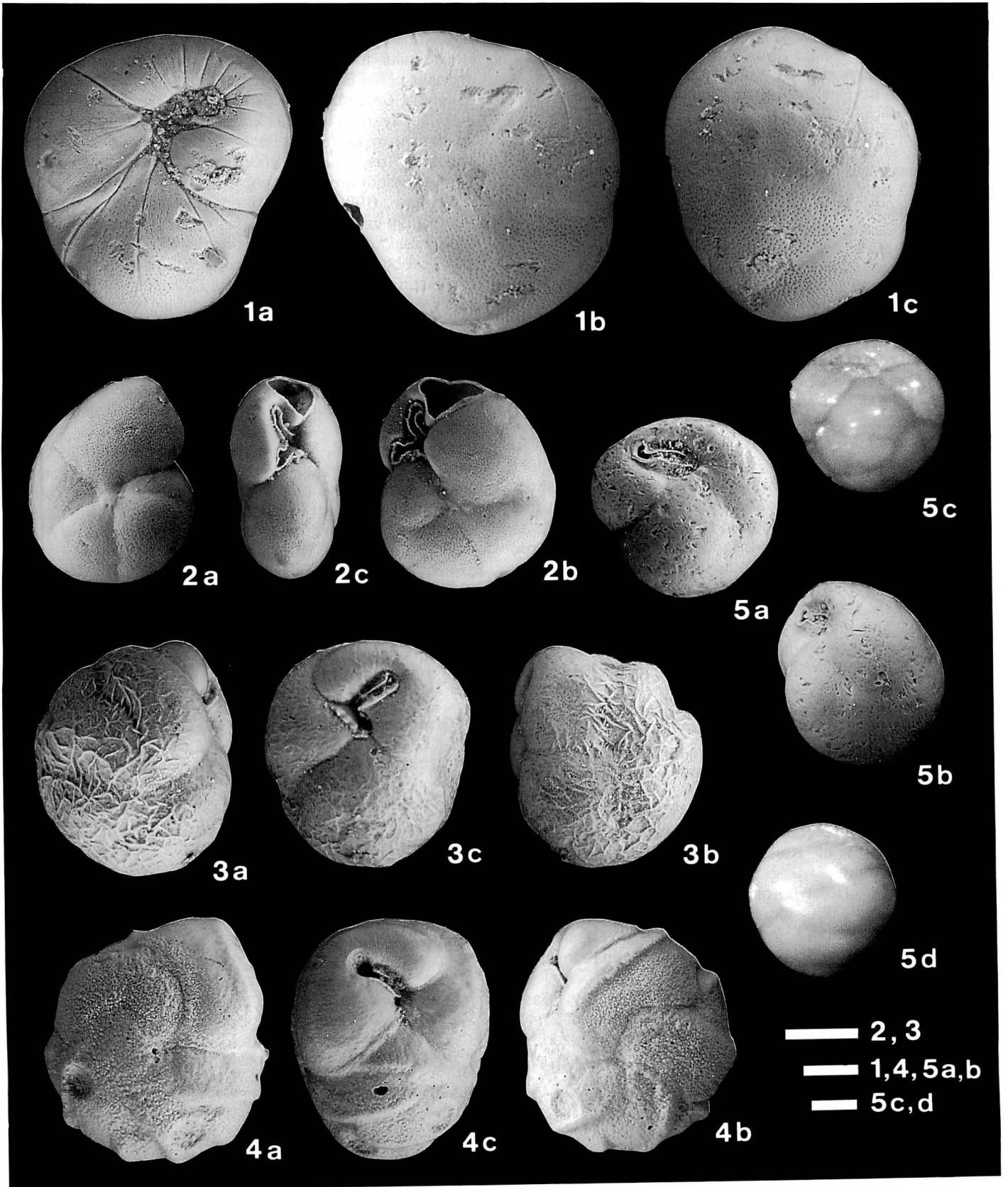
Cassidulina decorata Sidebottom, 1910, p. 107, pl. 4, figs. 2a-c (*fide* Ellis and Messina, 1944 *et seq.*).

Cassidulina subglobosa parva Asano and Nakamura, 1937, p. 148, pl. 13, figs. 5a, b ; Asano, 1951, p. 4, figs. 21, 22.

Cassidulina elegans Sidebottom var. *bosoensis* Kuwano, 1954, p. 34, figs. 7-11.

Cassidulina elegans bosoensis Kuwano. Matoba, 1967, p. 252, pl. 28, fig. 22.

Globocassidulina decorata (Sidebottom). Eade, 1967, p. 435, fig. 5, no. 1 ; Nomura, 1983a, pl. 17, fig. 8 ; 1983b, p. 27, pl. 2, figs. 14, 15a, b, 16.

Not *Cassidulina parva* Asano and Nakamura. Matsunaga, 1963, pl. 48, figs. 10a, b, 11a, b.

Not *Globocassidulina parva* (Asano and Nakamura). Serova, 1978, p. 122, pl. 12, fig. 1 ; Nomura, 1983a, pl. 15, figs. 6-10 ; 1983b, p. 41, pl. 3, figs. 13a, b.

Diagnosis of C. subglobosa parva *Asano and Nakamura*. —"The present form differs from the typical one in the somewhat limbate sutures ; it is quite identical with Brady's *subglobosa* in the shape of aperture." (Asano and Nakamura, 1937).

Redescription of holotype of C. subglobosa parva *Asano and Nakamura*.—Test medium, subglobular ; periphery broadly rounded, lobulate ; chambers distinct on later, but indistinct in early portion, slightly inflated, five pairs in last-formed whorl gradually increasing in size as added ; sutures somewhat indistinct in early portion, narrowly limbate, slightly undulate, depressed ; aperture tripartite with a short basal slit, accompanied by cristate tooth, poorly developed triangular apertural flap on anterior side, and thickened apertural ridge ; wall decorated with a network of irregular costae, except for final chamber wall. Length 0.34 mm, width 0.28 mm, thickness 0.31 mm.

Type.—Holotype of *C. subglobosa parva* : IGPS 21140.

Type localities.—Holotype of *C. subglobosa parva* : Nojima, Kanazawa-machi (=Nojima, Kanazawa-ku, Yokohama City), Kanagawa Prefecture. Holotype of *Cassidulina decorata* Sidebottom ; Off southern Fiji (Lat. 19°04′N, Long. 179°43′E ; Water depth 1,920 m) (*fide* Eade, 1967). Holotype of *Cassidulina elegans* var. *bosoensis* Kuwano : North of Kaisho, Oikawa-mura, Isumi-gun, Chiba Prefecture.

Type level.—Holotype of *C. subglobosa parva* : Nojima Formation (early Pleistocene). Holotype of *Cassidulina decorata* Sidebottom : Recent. Holotype of *Cassidulina elegans* var. *bosoensis* Kuwano : Kiwada Formation (early Pleistocene).

Observations.—A single specimen labeled as *Cassidulina subglobosa parva* with the IGPS number of 21140 was found in Asano's collection, thus it is recognized as the holotype of this taxon.

The present specimen clearly shows reticulate ornamentation on the test surface and the tripartise slit of the aperture. Because such features were not described, and because this taxon was treated as a subspecies with limbate sutures of *Cassidulina subglobosa* by the original authors (Asano and Nakamura, 1937 ; Asano, 1951), the systematics of this taxon has been misunderstood by later

workers.

Kuwano (1954) erected a new taxon, *bosoensis*, for a form similar to the present specimen from Pleistocene deposits of the Boso and Miura Peninsulas, as a reticulate variety of *Cassidulina elegans* Sidebottom. To the contrary, Takayanagi and Hasegawa (1987) observed the type specimens in Asano's collection, and regarded *C. elegans bosoensis* as a junior synonym of *C. subglobosa parva* Asano without any comment.

Nomura (1983b) described *Cassidulina elegans* Sidebottom var. *bosoensis* Kuwano as a junior synonym of *Globocassidulina decorata* (=originally *Cassidulina decorata* Sidebottom, 1910) on the basis of the similar character of the surface networking. Since *Cassidulina subglobosa parva* Asano and Nakamura is a subjective synonym of Kuwano's *bosoensis*, it is also a junior subjective synonym of Sidebottom's species. On the other hand, the form referred to *Cassidulina* (or *Globocassidulina*) *subglobosa parva* by several workers including Nomura (1983a, b) is quite different from Asano and Nakamura's *C. subglobosa parva*. In a redescription based on many topotypic material, Nomura (1985b) stressed that his *G. parva* is characterized by U-shaped depressed sutures, smooth test surface and a tripartite aperture. Such features are observed in *Globocassidulina canalisuturata*, which has been described from Recent sediments off New Zealand by Eade (1967). One of the writers (R.N.) examined the paratypes deposited in the New Zealand Geological Survey (NZGS Reg. No. TF 1559) and confirmed that it has an L-shaped aperture and narrow, depressed sutures like those of Nomura's *G. parva.* Consequently, *G. parva* redescribed by Nomura (1983a, b) should be referred to *G. canalisuturata* Eade.

Globocassidulina depressa (Asano and Nakamura)
[Original designation : *Cassidulina subglobosa* Brady *depressa* Asano and Nakamura]

Figures 4-2a—c

Cassidulina subglobosa depressa Asano and Nakamura, 1937, p. 148, pl. 13, figs. 8a-c ; Asano, 1951, p. 4, figs. 19, 20 ; Kuwano, 1962, pl. 16, fig. 4 ; Ishiwada, 1964, pl. 7, fig. 98 ; Kikuchi, 1964, pl. 7, fig. 11.

Cassidulina subglobosa var. *subcalifornica* Drooger, 1953, p. 140, pl. 22, figs. 8a-c, 9.

Globocassidulina depressa (Asano and Nakamura). Uchio, 1960, p. 68, pl. 9, figs. 18, 19 ; Parker, 1964, p. 624, pl. 99, figs. 28a, b ; Matoba, 1967, p. 252, pl. 28, figs. 19a-c ; Kameyama, 1972, pl. 31, fig. 4 ; Serova, 1978, p. 121, 122, pl. 10, fig. 6 ; Nomura, 1983a, pl. 15, figs. 11, 12 ; pl. 16, figs. 1-4 ; 1983b, p. 35, pl. 3, figs. 6a-c.

Smyrnella subcalifornica subcalifornica (Drooger). Saidova, 1975, p. 334, 335, pl. 88, fig. 8, pl. 115, fig. 1.

Cassidulina (?) cf. *subcalifornica* Drooger. McCulloch, 1977, p. 394, pl. 165, figs. 1a-c, 2a-c, 4a-c.

Not *Globocassidulina depressa* (Asano and Nakamura). Hasegawa, 1979, p. 149, pl. 8, figs. 8a, b.

Redescription of holotype.—Test medium, compressed, subcircular in side view, last chamber slightly protruded ;

periphery compressed-rounded ; chambers distinct, oval, slightly inflated, four pairs in last-formed whorl, gradually increasing in size as added ; sutures distinct, slightly depressed, moderately curved toward periphery ; umbilical region closed, slightly depressed ; aperture tripartite, consisting of basal and areal branches, situated at base of apertural face, associated with cristate tooth, thick lip and secondary tongue, but without apertural ridge ; wall thin, very finely perforate, polished, translucent. Length 0.32 mm, width 0.27 mm, thickness 0.15 mm.

Type.—Holotype : IGPS 21441.

Type locality.—Semata-shinden, Ichito-mura, Ichihara-gun (=presently Semata, Ichihara City), Chiba Prefecture.

Type level.—Yabu Formation (middle Pleistocene).

Observations.—Only one specimen was found in Asano's collection. It shows a much depressed test and the distinctly tripartite aperture with a cristate tooth.

Globocassidulina elegans (Sidebottom)
[Original designation : *Cassidulina alternans* Yabe and Hanzawa]

Figures 4-4a—c

Cassidulina elegans Sidebottom, 1910, p. 106, pl. 4, figs. 1a-c (*fide* Ellis and Messina, 1944 *et seq.*) ; Cushman, Todd and Post, 1954, p. 366, pl. 90, fig. 23.
Cassidulina alternans Yabe and Hanzawa, 1925, p. 53, text-figs. a, b ; Asano and Nakamura, 1937, p. 149.
Globocassidulina elegas (Sidebottom). Eade, 1967, p. 435, fig. 4, nos. 6, 7 ; Takayanagi *et al.*, 1982, figs. X-8 (14, 15).
Islandiella elegans (Sidebottom). Ujiié, 1990, p. 37, pl. 19, figs. 9a-10b.

Redescription of holotype of C. alternans *Yabe and Hanzawa.*—Test medium, subglobular, slightly inequilaterally compressed ; periphery broadly rounded in edge view, strongly serrate in side view owing to ridges on the chambers which move from an anterior position at the chamber periphery to midway across the chamber toward the umbilical region ; chambers distinct, slightly inflated, five pairs in last-formed whorl gradually increasing in size as added ; sutures distinct, limbate, slightly raised ; aperture a long narrow loop-like slit, slightly curved, extending up nearly at right angles to the base of apertural face, surrounded by lip and cristate tooth ; wall smooth, very finely perforate, semiopaque, but translucent only in apertural region. Length 0.48 mm, width 0.43 mm, thickness 0.38 mm.

Type.—Holotype of *C. alternans* : IGPS 63670.

Type localities.—Holotype of *C. alternans* : St. 1116 of the then Imperial Hydrographic Department of Japan (July 17, 1923), South of Okinawa Island (Lat. 25°50.7′N, Long. 127°25.6′E ; Water depth 1,580 m). Holotype of *Cassidulina elegans* Sidebottom : Off southern Fiji (Lat. 19°04′N, Long. 179°43′E ; Water depth 1,920 m) (*fide* Eade, 1967).

Type level.—Holotype of *C. alternans* : Recent. Holotype of *Cassidulina elegans* Sidebottom : Recent.

Observations.—Only one specimen of *C. alternans*

Yabe and Hanzawa is found in Asano's collection. It is mounted in a slide with the registered number of 63670 written on a red-colored label, thus indicating the holotype slide, although no number was given in the papers of either Yabe and Hanzawa (1925) or Asano and Nakamura (1937). Furthermore, the morphologic features of this specimen correspond to these of the type figures and description by Yabe and Hanzawa (1925). We thus confirmed that it is the holotype.

Ujiié (1990) regarded *C. alternans* as a junior synonym of *Cassidulina elegans* Sidebottom, 1910. On the contrary, Cushman, Todd and Post (1954) regarded the two species as different without further comment. The specimen of *C. alternans* is characterized by a subglobular test having a serrate periphery, with ridge-like chambers, limbate sutures, and a slightly curved loop-shaped aperture. Such morphological features of *C. alternans* are identical to the descriptions of *C. elegans*. So far as can be judged from the original descriptions of the two forms, they are quite similar and hard to distinguish. In addition, Yabe and Hanzawa (1925) did not refer to Sidebottom's species of 1910.

Based on apertural features, *C. alternans* should be transferred to *Globocassidulina*. Ujiié (1990) regarded this species as an *Islandiella* on the basis of apertural characters and wall texture. Judging from his figures of the specimens, however, their apertural feature is of the D3 Type of Nomura (1983a) which is recognized in the neanic to early ephebic stages of *Globocassidulina* and *Burseolina*. It is never found in *Islandiella*. In addition, Ujiié's specimens are about 160 and 250 μm, respectively, in maximum length. In contrast, both the specimens of Sidebottom (1910) and Yabe and Hanzawa (1925) exceed 300 μm. Therefore, Ujiié's specimens should be of the younger stages of *Globocassidulina elegans*.

Globocassidulina gemma (Todd)
[Original designation : *Cassidulina subglobosa* (Brady)]

Figures 4-1a—c

Cassidulina subglobosa Brady. Asano and Nakamura, 1937, p. 147, pl. 13, figs. 3a-c ; LeRoy, 1941b, p. 85, pl. 6, figs. 16, 17.
Cassidulina gemma Todd. Cushman, Todd and Post, 1954, p. 366, pl. 90, figs. 26, 27.
Cassidulina subglobosa Brady var. Cushman, Todd and Post, 1954, p. 367, pl. 90, fig. 33.
Globocassidulina gemma (Todd). Belford, 1966, p. 147, pl. 24, figs. 22-25, text-fig. 16, nos. 11, 12 ; Nomura, 1983a, pl. 12, figs. 9, 10 ; pl. 13, figs. 7-12 ; 1983b, p. 22, pl. 2, figs. 10a, b, 11.
Cassidulina (?) cf. *gemma* Todd. McCulloch, 1977, p. 389, pl. 167, figs. 8, 11, 12.

Redescription of hypotype.—Test medium, subglobular, slightly longer than broad, last-formed chamber somewhat projected in the plane of coiling ; periphery broadly rounded, very slightly lobulate ; chambers distinct except for earlier portion, broad and rounded triangular in general

shape, very slightly inflated, four pairs in last-formed whorl; sutures indistinct, but moderately curved; sutural grooves visible at the base of apertural face, but not depressed toward periphery; aperture elongate, loop-shaped, at nearly a right angle to suture of apertural face, and oblique to the plane of coiling, surrounded by developed sulcus and lip; numerous grooves clearly visible around apertural margin, but not developed on anterior portion of apertural face; wall polished, very finely perforate, semiopaque. Length 0.52 mm, width 0.42 mm, thickness 0.47 mm.

Type.—Hypotype : IGPS Coll. Cat. No. 102542.

Type localities.—Hypotype : Oshikiri, Hongo-mura, Kamakura-gun (=presently Kajigaya, Totsuka-ku, Yokohama City), Kanagawa Prefecture. Holotype of *Cassidulina gemma* Todd : Bikini 1172, Sylvania guyot, 1,528 m (Cushman, Todd and Post, 1954).

Type level.—Hypotype : Nakazato Formation (middle Pleistocene). Holotype of *Cassidulina gemma* Todd : Recent.

Observations.—Only one specimen of "*Cassidulina subglobosa*" was found in Asano's collection. The present specimen is characterized by the test having inflated chambers, sutural grooves at the base of the apertural face, and apertural grooves. Based on these features, this form is not assignable to *Globocassidulina subglobosa* (Brady), but to *G. gemma* (Todd). It is also distinguished from *G. oriangulata* Belford and *G. bisecta* Nomura, both with a tripartite aperture, in having a loop-shaped aperture at a near-right angles to the base of the final apertural face.

Genus *Burseolina* Seguenza, 1880

Burseolina pacifica (Cushman)
[Original designation : *Cassidulina pacifica* Cushman]

Figures 4-5a—d

Cassidulina calabra (Seguenza). Brady, 1884, p. 431, pl. 113, figs. 8a-c ; Bagg, 1912, p. 42, 43, pl. 12, figs. 1a-c ; Chapman, 1926, p. 42, pl. 9, fig. 12.
Cassidulina pacifica Cushman, 1925, p. 53, pl. 9, figs. 14-16 ; Earland, 1934, p. 137, pl. 6, figs. 23-25 ; Asano and Nakamura, 1937, p. 148, pl. 13, figs. 6a, b ; LeRoy, 1941a, p. 42, pl. 1, figs. 43-45 ; LeRoy, 1964, p. F40, pl. 11, figs. 19, 20.
Cushmanulla pacifica (Cushman). Saidova, 1975, p. 336, pl. 88, figs. 11, 12, pl. 115, fig. 4.
Burseolina pacifica (Cushman). Nomura, 1983a, pl. 6, fig. 2 ; pl. 21, figs. 6-10 ; 1983b, p. 57, pl. 5, figs. 1a, b, 2, 3a, b, 4.

Redescription of hypotype.—Test medium, compact, globular, slightly longer than broad; periphery broadly rounded, not lobulate; chambers distinct, elongate, not inflated, about five pairs making up last-formed whorl, final chamber comprising about one-third of entire test in front view; sutures distinct, limbate, slightly curved, not depressed; aperture large, a bow-shaped narrow slit extending up at an angle of about 70 degrees to suture at base of apertural face, with a distinct apertural flap,

almost parallel to periphery of final apertural face in front view; wall smooth, very finely perforate, opaque. Length 0.33 mm, width 0.29 mm, thickness 0.31 mm.

Type.—Hypotype : IGPS Coll. Cat. No. 102543.

Type localities.—Hypotype : Kyoshito, Takao Prefecture, Taiwan (Formosa). Holotype of *Cassidulina pacifica* Cushman : Challenger St. 185, Torres Strait, South Pacific.

Type level.—Hypotype : Mud volcano (unknown age). Holotype of *Cassidulina pacifica* Cushman : Recent.

Observations.-Six specimens of "*Cassidulina pacifica*" are found in two slides. A specimen is isolated from the others by the original authors themselves, and thus the figured specimen is easily recognized in Asano's collection. It is safely identified as *Burseolina pacifica* by having a compact test with a smooth surface, not inflated chambers, and a burseoline aperture.

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Asano, K., 1938b : Fossil foraminifera from the Boso Peninsula. *Contributions from the Institute of Geology and Paleontology, Tohoku Imperial University*, no. 31, p. 57-96, pls. 6-9. (*in Japanese*)
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Surface water changes in the Ryukyu Trench slope region, western margin of the North Pacific during the last 320,000 years

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Abstract. Two piston cores taken from the Ryukyu Trench slope, western margin of the North Pacific, contain a micropaleontologic record of the last 105,000 years (covering the period from isotope Stage 5 to Stage 1) and 320,000 years (covering the period from Stage 8 to Stage 1), respectively. Planktic foraminiferal assemblages are examined to reconstruct the past surface water conditions. The surface water during interglacial stages 5 and 7 was similar to the postglacial situation, when the studied region was dominated by warmer waters associated with the Kuroshio Current. During glacial stages 2, 3, 4, 6 and 8, the Kuroshio-related warm water was weaker; alternatively the influence of the temperate water which currently occupies the northern part of the Western North Pacific Central Water was stronger. In these glacial stages, the temperate water affected this region more intensely than it does today. However, the polar front characterized by the Oyashio Current has never attained this area during the last 320,000 years. During stages 2, 4 and 6, the surface water was eutrophic; the primary productivity in DCM (deep chlorophyll maximum) layer was probably enhanced during stages 2 and 8.

The sea surface temperature is estimated based on percentage frequency data of planktic foraminifera, using transfer function FP12-E. The estimated paleo-SST are 27-29°C for summer and 18-26°C for winter. As a result, glacial-interglacial fluctuations of the estimated SST are 1-2°C for summer and 4-5°C for winter ; seasonal contrast during interglacials is similar to that of today and slightly greater during glacials. The decline of winter SST during glacial periods is believed to have been caused not only by the southward displacement of the temperate water mass, but also by the upward transporting of the cooler water from the underlying water column.

Key words : Planktic foraminifera, surface water, glacial-interglacial, paleo-SST, upwelling, Western North Pacific Central Water

Introduction

During the past ten years, many piston cores around the Ryukyu Island Arc have been taken for paleoceanographic study. Some of these cores have been examined for benthic foraminifera (Ujiié, 1991) and calcareous nannoplankton (Ahagon et al., 1993). The present study was undertaken by the investigation on planktic foraminifera to reconstruct the aspects of the surface waters in this region during past glacial and interglacials.

Moore et al. (1980) reconstructed the sea surface temperature in the Pacific Ocean of 18,000 years B.P. They proposed a greater southward penetration of the Oyashio Current during the last glacial, but indicated that the southward extension needed closer study and verification. Thompson (1977) pointed out that this subarctic cold current reached the southernmost islands of Japan. On the contrary, Ujiié (1991) assumed a different flow pattern of the Kuroshio Current during the last glacial, in which instead of entering the East China Sea, this warm current ran along the Pacific side of the Ryukyu Island Arc, which is composed of a group of the southernmost islands of Japan.

The purpose of the present paper is to (1) estimate the paleo-sea surface temperatures, (2) discuss the changes of surface water masses, and (3) clarify the influence of the surface currents in the studied region during the last 320,000 years.

Geographic settings

The Ryukyu Island Arc extends approximately from Lat. 24°N to 31°N, and bounds the western margin of the North Pacific. On the ocean side, the southern Ryukyu Island
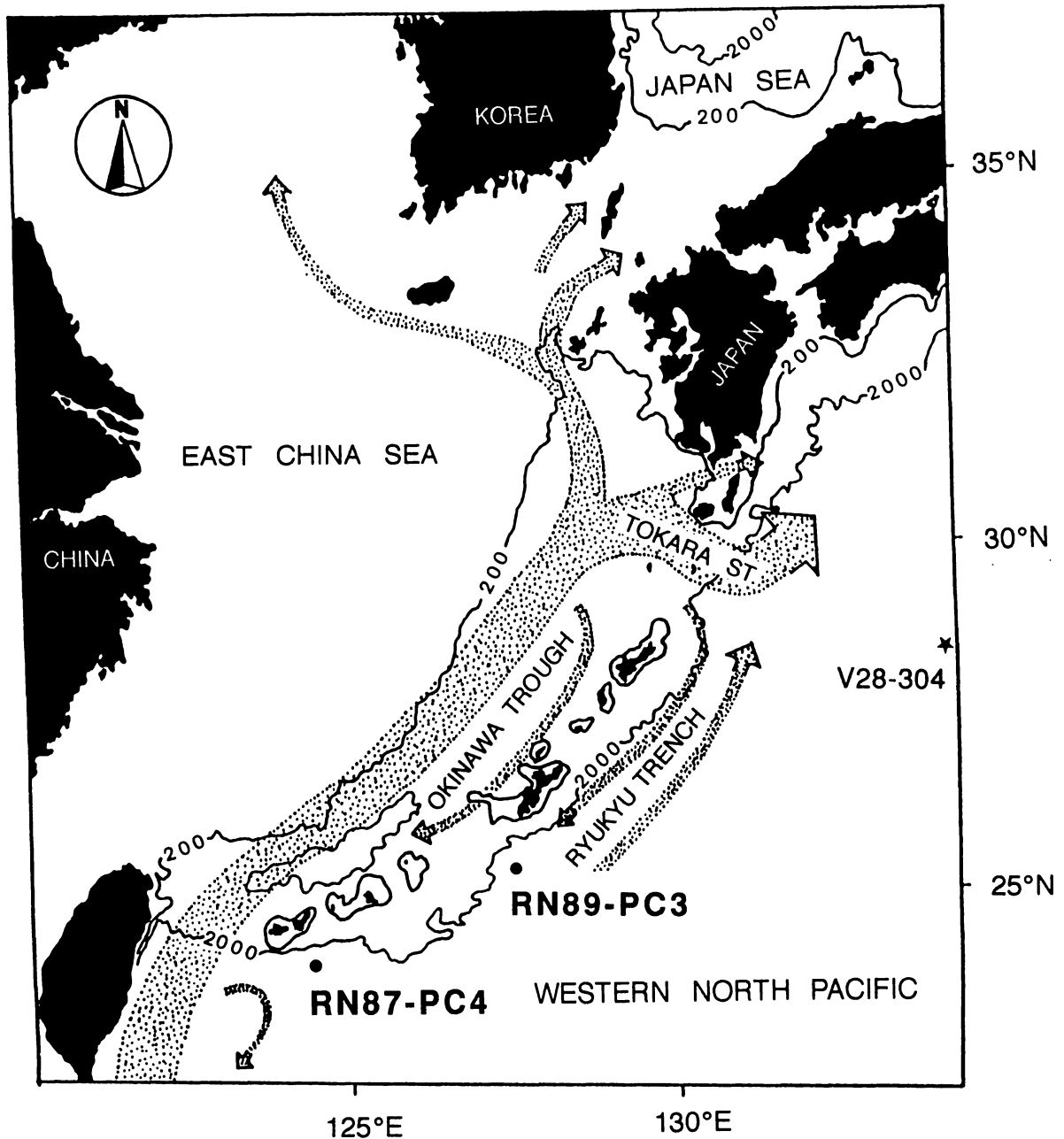
Figure 1. Location map of the cores used (solid circles) and referred to (solid star) in this study. Stippled arrows show the flow of the Kuroshio Current and its branches (after Nitani, 1972).

Table 1. Location, water depth and core length of the piston cores used and referred to in this study.

Core No.	Latitude	Longitude	Water depth (m)	Core length (cm)
RN87-PC4	23°50.2′N	124°24.1′E	2,488	365
RN89-PC3	25°20.7′N	127°28.9′E	2,255	386
V28-304	28°32′N	134°08′E	2,942	

Arc is seperated from the Ryukyu Trench by the Saki-shima Deep-sea Terrace which deepens from 2,000 m to 4,000 m with a very rugged topography.

The two piston cores were taken by the R/V Nagasaki-maru. One, core RN87-PC4, was collected from the central part of the southern Sakishima Deep-sea Terrace, south of Ishigaki Island, and the other, core RN89-PC3, from the outer edge of the terrace, northeast of Miyako Island (Figure 1). Their location, water depth and core length are listed in Table 1.

Hydrographic conditions

The Kuroshio (Figure 1), a warm western boundary current, is the main surface current of the western Pacific. It crosses the southernmost part of the Ryukyu Island Arc, entering the East China Sea, flowing northeastwards along the continental slope, and leaves the East China Sea through the Tokara Strait (Nitani, 1972).

In the western North Pacific (Figure 2), the surface flow of a gyre consisting of North Equatorial, Kuroshio and its extension, and North Pacific currents forms a large water

body, named the Western North Pacific Central Water (Bradshaw, 1959). The water masses here have properties intermediate between the Subarctic water and the Equatorial water. The Western Pacific Central Water was further divided into two water masses on the basis of the dominant assemblage of planktic foraminifera responding to the physical properties of the waters in each region (Thompson, 1981), namely transitional and subtropical (Figure 2). The transitional water mass (usually between 25 and 35°N) develops with a distinctive biological character near the zone of convergence of the Kuroshio and Oyashio currents; farther south of the transitional water mass, a subtropical water mass (usually between 15 and 25°N) develops north of the convergence zone of the North Equatorial Current and the Equatorial Counter Current.

Two piston cores in this study are located at the western margin of the North Pacific, beneath the warm Kuroshio Current (although not the current axis). As a result, the modern surface water in the core region is generally tropical-subtropical. Furthermore, since the anticyclonic waterflow in the North Pacific forms minor
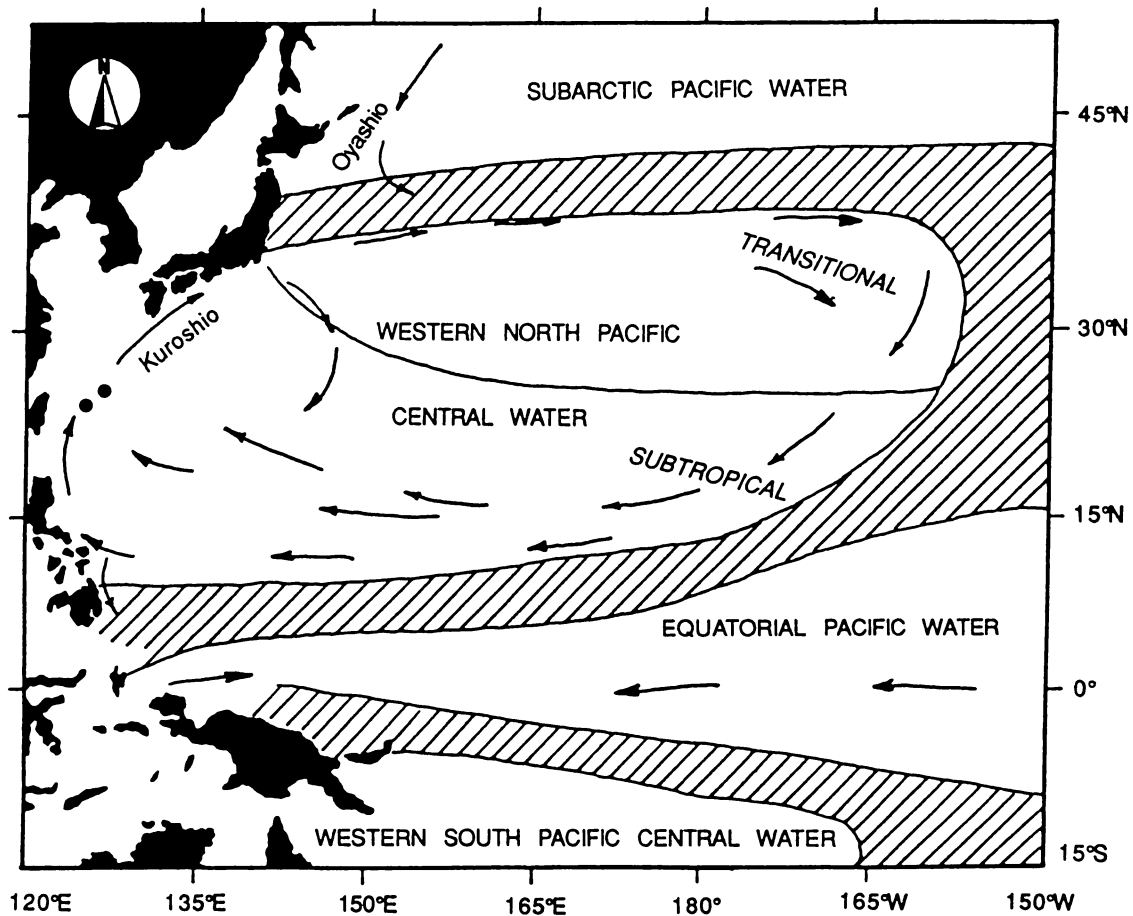

Figure 2. Upper water masses in the Western Pacific (after Bradshaw, 1959). The Western North Pacific Central Water is further divided into "transitional" and "subtropical" (after Thompson, 1981). The two studied cores are indicated by solid circles.

nutrient upwelling along the gyre margin (Thompson, 1981), the core region is also characterized by slight upwelling.

Brief notes on lithology and chronology of the cores

The lithology of the two cores has been described by Ono et al. (1989) and Ono and Takagi (1991). The sediments are composed of hemipelagic silt and clay, and the remains of calcareous organisms not clearly showing the effects of dissolution. A volcanic ash layer which was identified as the Ata Tuff (Ujiié et al., 1991) is contained at a horizon of 321-324 cm in core RN87-PC4 and 89-92 cm

in core RN89-PC3. A slightly bioturbated zone between 145 and 180 cm was recognized in core RN89-PC3.

The chronology of the two cores was based on isotope stratigraphy, tephrochronology and calcareous nannoplanktonic control (Ahagon et al., 1993). The result is adopted here in this paper. Moreover, a planktic foraminifera, pink-pigmented Globigerinoides ruber, last appeared at a horizon of 110-112 cm in core RN89-PC3. The extinction of this species has been assigned at about 120 kyrs. B.P. around the isotope stage 5e/6 boundary (Thompson et al., 1979). The last appearance datum of pink-pigmented G. ruber in this study is consistent with
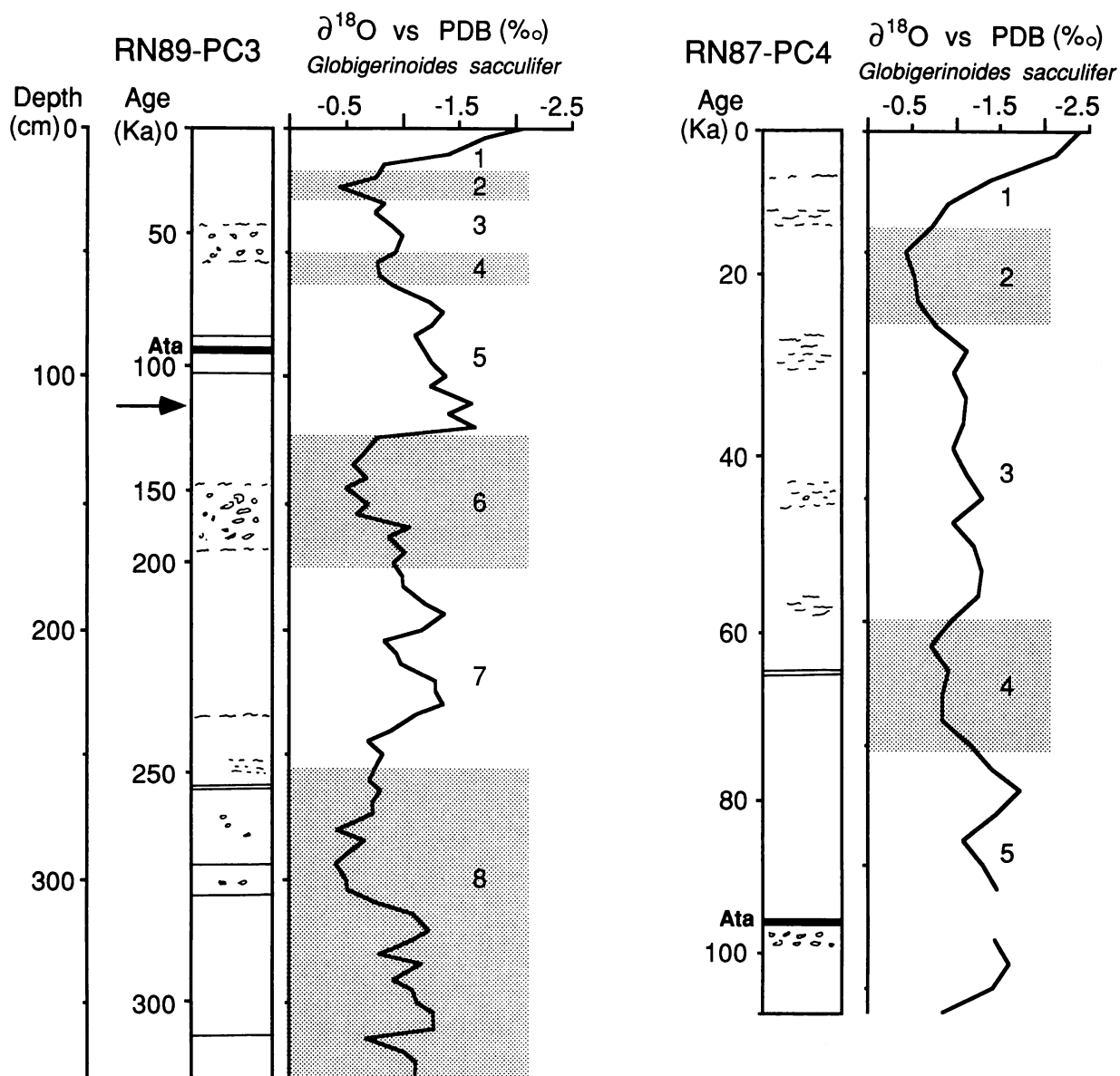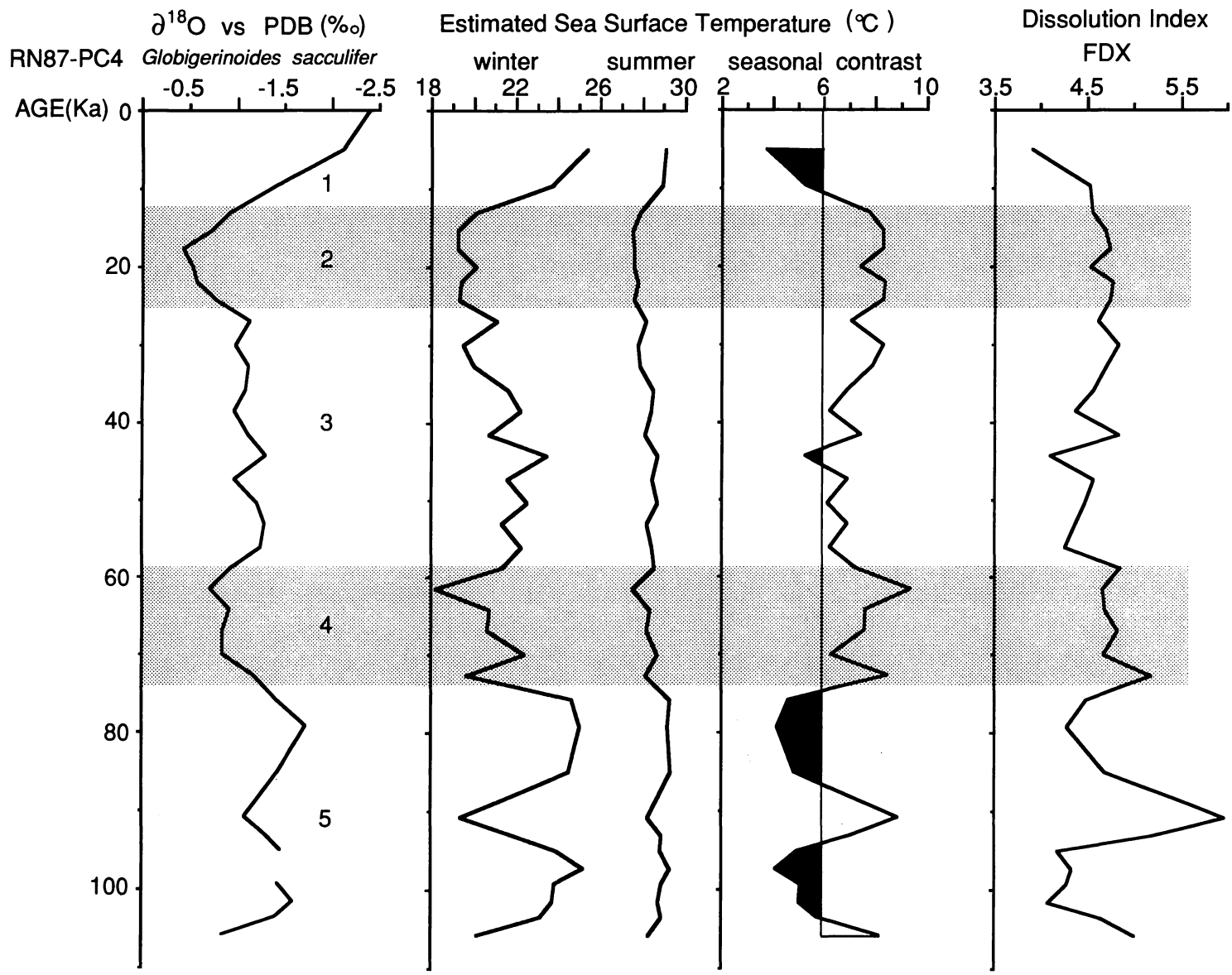

Figure 3. Lithology and chronology of the two studied cores. The arrow shows the last appearance datum of pink-pigmented Globigerinoides ruber which became extinct in the Indo-Pacific region at 120 kyrs.B. P. The LAD here coincides with the previous chronologic results based on isotope stratigraphy, tephrochronology and calcareous nannoplankton control (Ahagon et al., 1993).

∂¹⁸O vs PDB (‰)

RN89-PC3 *Globigerinoides sacculifer*

AGE(Ka)

Estimated Sea Surface Temperature (°C)

winter   summer   seasonal contrast

Dissolution Index
FDX

4-a.

∂^{18}O vs PDB (‰)

RN87-PC4 *Globigerinoides sacculifer*

-0.5 -1.5 -2.5

AGE(Ka) 0

Estimated Sea Surface Temperature (℃)

winter summer seasonal contrast

18 22 26 30 2 6 10

Dissolution Index
FDX

3.5 4.5 5.5

20

40

60

80

100

1

2

3

4

5

4-b.

Xuedong Xu and Motoyoshi Oda
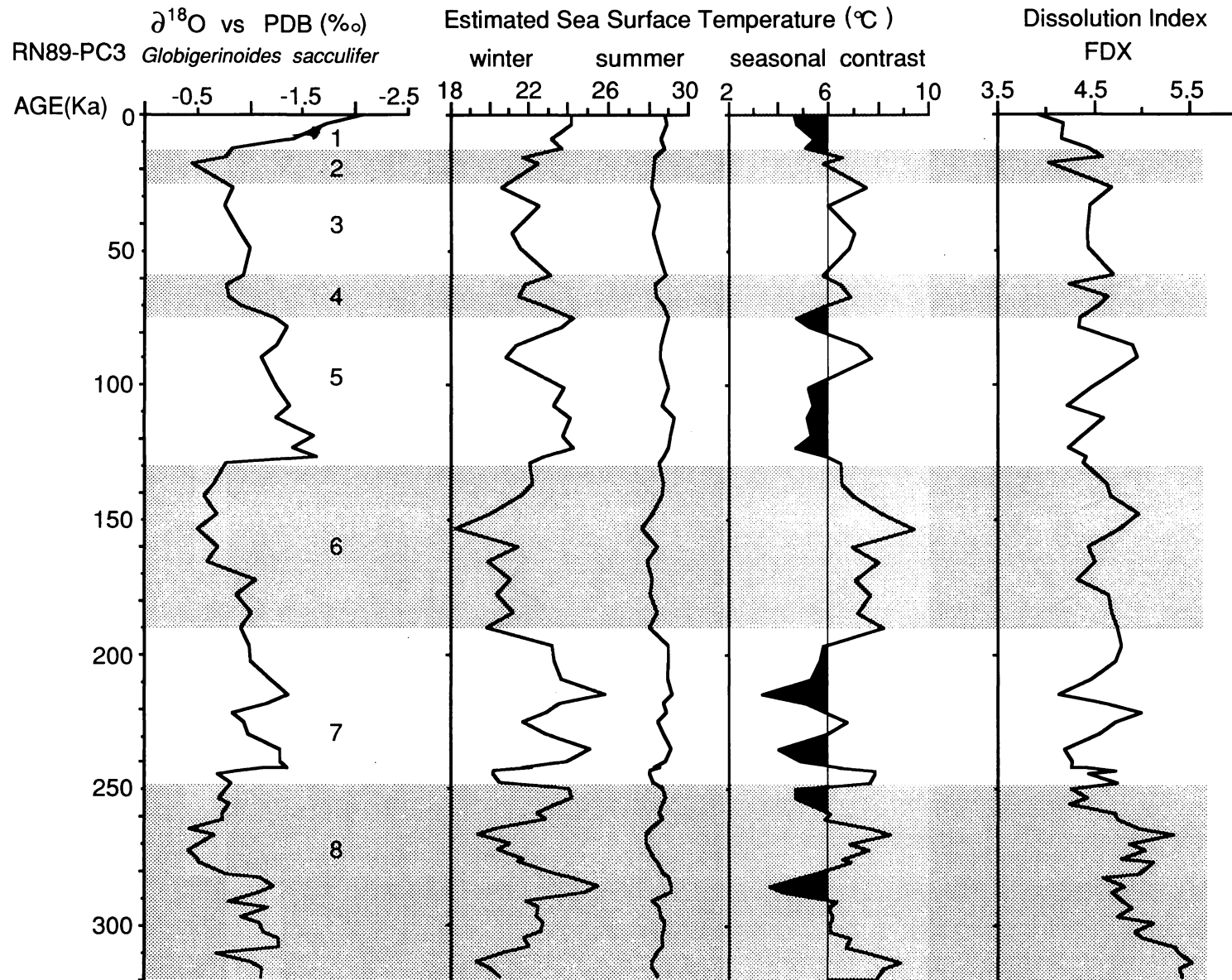
Figure 4. Estimated paleo-sea surface temperature, seasonal contrast and dissolution index (FDX), compared with down core δ^{18}O fluctuations.

Figure 4-a. Estimated paleo-SST, seasonal contrast and FDX changes in core RN89-PC3.

Figure 4-b. Estimated paleo-SST, seasonal contrast and FDX changes in core RN87-PC4.

the previous chronologic study of these cores. As a result, core RN89-PC3 encompasses the last 320,000 years, while core RN87-PC4 represents the last 105,000 years (Figure 3). These ages give an average sedimentation rate of about 1.2 cm/1,000 yrs. in core RN89-PC3, and 3.4 cm/1,000 yrs. in core RN87-PC4, respectively.

Sampling method and taxonomic criterion

Samples of core RN89-PC3 were taken at 5 cm intervals, while those of core RN87-PC4 were taken at 10 cm intervals. After being washed on a 0.063-mm sieve with tap water, the residues on the screen were dried. The residues were then split with a microsplitter until an amount sufficient to yield a workable number of foraminiferal specimens is obtained. The microsplitter aliquot was sieved through a 0.150-mm screen. More than 200 planktic foraminiferal specimens were then picked from the coarser fractions for faunal analysis.

In the taxonomy of planktic foraminifera, criteria given by Saito *et al.* (1981) are basically accepted in the present work. However, it is sometimes difficult to distinguish *Neogloboquadrina eggeri* and *Neogloboquadrina pachyderma*, which are linked by *Neogloboquadrina blowi* and *Neogloboquadrina incompta*. Here, the criterion of Thompson (1977) is adopted to distinguish the four

species. Moreover, different morphologic forms in *Globigerinoides sacculifer* (with/without sac) and *Globorotalia truncatulinoides* (sinistral/dextral) are counted independently for paleo-temperature computation.

Dissolution effect

Berger (1970) demonstrated that dissolution can alter both geographic and temperature information of planktic foraminiferal faunas and may produce unreliable paleoecological estimates downcore where this effect has occurred. On the basis of the broken shells and fragments, as well as the calculated dissolution index, the dissolution effect was evaluated for each sample in this study, although the two cores were collected from a water depth of about 2,500 m, well above the lysocline.

Thompson (1981) indicated that in general deep-sea sediments above the lysocline from the western Pacific show increased fragmentation during interglacials due to intensified dissolution effects. However, such a glacial/interglacial contrast was not discernible in the present two cores. Fragmentation was observed in most samples; several in the top part of the cores were found very well preserved. Nevertheless, their occurrence seldom exhibited obvious decreases or increases.

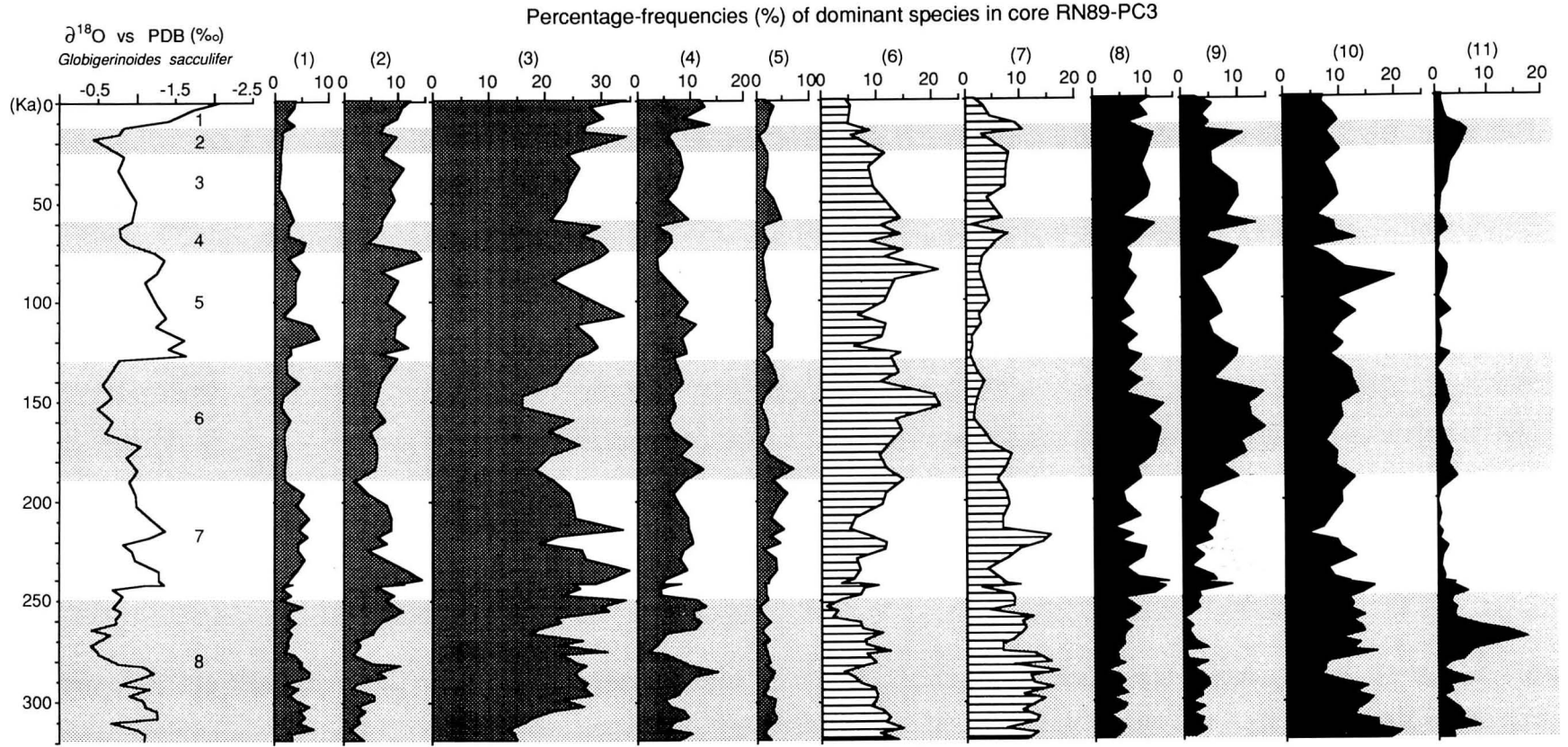The dissolution index (Berger, 1979) is calculated as

Table 2. Modern SST, estimated average SST, seasonal contrast, communality and FDX in the isotope stages included in the studied intervals. The stars indicate stages incompletely covered by core samples.
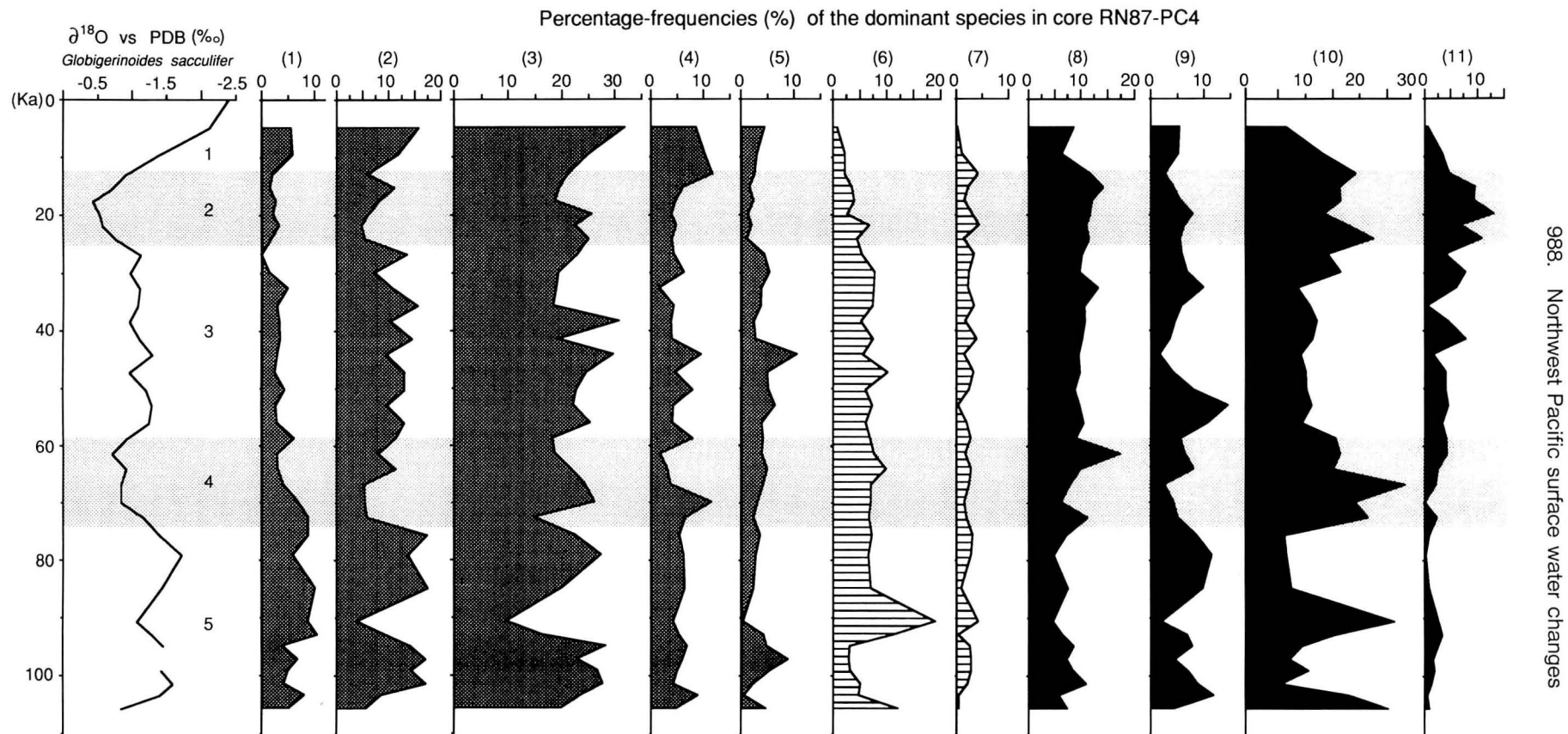
Table 2-a. Data for core RN89-PC3.

RN89-PC3	Modern SST (°C)	Estimated SST (°C)	Seasonal contrast (°C)	Communality	FDX
Core Top	28/21.8	28.78/24.15	4.63	0.98	3.92
Stage 1		28.76/23.82	4.94	0.97	4.09
Stage 2		28.44/22.63	5.81	0.90	4.35
Stage 3		28.42/21.80	6.62	0.90	4.53
Stage 4		28.47/22.05	6.42	0.90	4.47
Stage 5		28.84/23.10	5.74	0.92	4.47
Stage 6		28.24/20.68	7.56	0.86	4.62
Stage 7		28.65/22.68	5.97	0.91	4.53
Stage 8*		28.50/22.07	6.43	0.84	4.92

Table 2-b. Data for core RN87-PC4.

RN87-PC4	Modern SST (°C)	Estimated SST (°C)	Seasonal contrast (°C)	Communality	FDX
	28.2/22.1				
Stage 1		29.01/24.53	4.48	0.93	4.21
Stage 2		27.66/19.58	8.08	0.77	4.68
Stage 3		28.34/21.46	6.88	0.86	4.55
Stage 4		28.21/20.33	7.88	0.84	4.80
Stage 5*		28.90/23.21	5.69	0.87	4.65

$\partial^{18}O$ vs PDB (‰)
Globigerinoides sacculifer

Percentage-frequencies (%) of dominant species in core RN89-PC3

5-a.

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Figure 5. Relative abundances of the 11 dominant planktic foraminiferal species, compared with down-core $\delta^{18}O$ fluctuations. 1=*P. obliquiloculata*, 2=*Gnt. glutinata*, 3=*Gds. ruber*, 4=*Gds. sacculifer*, 5=*Gnl. aequilateralis*, 6=*Grt. inflata*, 7=*Grt. truncatulinoides*, 8=*Gna. bulloides*, 9=*Gna. falconensis*, 10=*Ngd. eggeri*, 11=*Ngd. pachyderma* (dextral).
Fig. 5-a. Down-core frequencies in percent of the 11 dominant species in core RN89-PC3.
Fig. 5-b. Down-core frequencies in percent of the 11 dominant species in core RN87-PC4.

follows : $FDX = \Sigma(R_i P_i)/\Sigma P_i$, where R_i is the ranking of a species i according to its resistance to dissolution ; and P_i is the percentage of species i in the sample. Usually, intense dissolution is reflected by high FDX values. The calculated index (Figure 4) slightly fluctuates throughout the two cores. However, neither a similar nor a reversed trend appears to be present between the dissolution and the climatic oscillations.

One sample taken from 290-292 cm (estimated at about 90 ka) from core RN87-PC4 seems to be severely affected by dissolution, because a marked increase is seen in the FDX value as well as in fragmentation. For this reason, the faunal composition of this sample is not considered in paleoenvironmental interpretations.

Estimated Paleo-SST

The transfer function technique originated by Imbrie and Kipp (1971) has been widely employed to estimate paleo-ecologic parameters from microfossil datasets. The planktic foraminiferal transfer function FP-12E, developed by Thompson (1981) for the western North Pacific, is adopted in this study to estimate the paleo-sea surface temperature (SST).

The paleo-SST curves of the two studied cores are shown in Figure 4. Estimated summer and winter SST values are all greater than 23°C and 14°C, respectively, falling within the range of SST which FP-12E can accurately evaluate (Thompson, 1981). Moreover, the communality of each sample, which is the summation of the squares of the individual factor loadings, is also calculated. A communality of 1.00 signifies that all of the sample variance has been computed. The average communalities of the samples in the two cores are 0.85 and 0.88, respectively. The square roots of the average communalities indicate transfer function FP-12E can account for 92.3% and 94% of the total variance in the observed faunal information. Even the value of the lowest communality among the core samples exceeds 0.7, which can account for more than 84% of the total faunal information. Now that the six faunal assemblages in FP-12E, identified by Q-mode factor analysis, accounted for 93% of the total surface calibration set variance, the communalities of the core samples here are very high. Therefore, FP-12E can be expected to provide proper estimates of SST in the core region, with standard errors of 1.5°C in summer and 2.5°C in winter.

As shown in Figure 4, the summer SST values fluctuate from 27°C to 29°C, while those of winter SST range from 18°C to 26°C. The amplitude of variation of summer SST is about 1-2°C and that of winter SST is 4-5°C, reaching a maximum of 7.6°C, between the glacials and the interglacials. Curves of the paleo-winter SST and the climatic fluctuations (represented by $\delta^{18}O$ oscillations) are almost parallel.

Seasonal contrast (the summer-winter difference in temperature) and the $\delta^{18}O$ are also comparable (Figure 4). The seasonal contrast is greater during glacial stages than during interglacial stages (Table 2) : it averages 4.5-

6°C, which is identical to the modern value during interglacials, and 6-8°C during glacials.

Thompson (1981) mentioned that the largest temperature change occurred in the temperate (transitional) region between 30 and 40°N, where down-core estimates varied as much as 5°C between glacials and interglacials ; the subtropical area, on the other hand showed no temperature shift throughout the past 150,000 years. Although the two cores studied here are under tropical-subtropical water at present, the magnitude of glacial-interglacial SST contrast grades up to those in the transitional region. In addition, it is of interest to note that the surface water in Stage 6 was as cold as or colder than the last glacial (stages 2, 3 and 4) period, while that in Stage 7 was as warm as or warmer than the last interglacial (Stage 5) period. Moreover, the winter SST revealed by the two cores indicates that during stages 2 and 4, the surface water in the southern part of the studied region was colder than that in the northern.

Planktic foraminiferal assemblages through the cores

More than 200 specimens of planktic foraminifera per sample were picked from fractions coarser than 0.150 mm. A total of 34 species, attributed to 13 genera, were recognized. Predominant species with maximum relative frequencies greater than 10% are : *Pulleniatina obliquiloculata*, *Globigerinoides ruber*, *Globigerinoides sacculifer*, *Globigerinella aequilateralis*, *Globigerinita glutinata*, *Globigerina bulloides*, *Globigerina falconensis*, *Neogloboquadrina eggeri*, *Neogloboquadrina pachyderma* (dextral), *Globorotalia inflata* and *Globorotalia truncatulinoides*. These species constitute more than 80% of the faunal assemblages in every one of the core samples.

Down-core frequency changes of the predominant species, compared with the oxygen isotope curves, are shown in Figure 5. The relative abundance of *P. obliquiloculata*, *G. glutinata* and *G. ruber* decreased in glacials and increased in interglacials. On the contrary, the relative abundance of *G. bulloides* and *N. eggeri* increased in glacials and decreased in interglacials. *G. inflata* and *G. truncatulinoides* maintained their low abundance only during few warm periods and increased during most of the studied interval, whereas *N. pachyderma* (d) increased remarkably in isotope stages 2 and 8. Thus, in general, most of them show a similar or reverse trend to the climatic changes.

Brief notes on the predominant species and their occurrence in core top sample

Among the predominant species, *P. obliquiloculata*, *G. sacculifer*, *G. ruber*, *G. aequilateralis* and *G. glutinata* are tropical-subtropical species (Bé, 1977), Particularly, *P. obliquiloculata* belongs to tropical waters, in which its highest abundance occurs between 10°N and 10°S, a belt which coincides generally with equatorial current systems. The relatively high occurrence of this species in
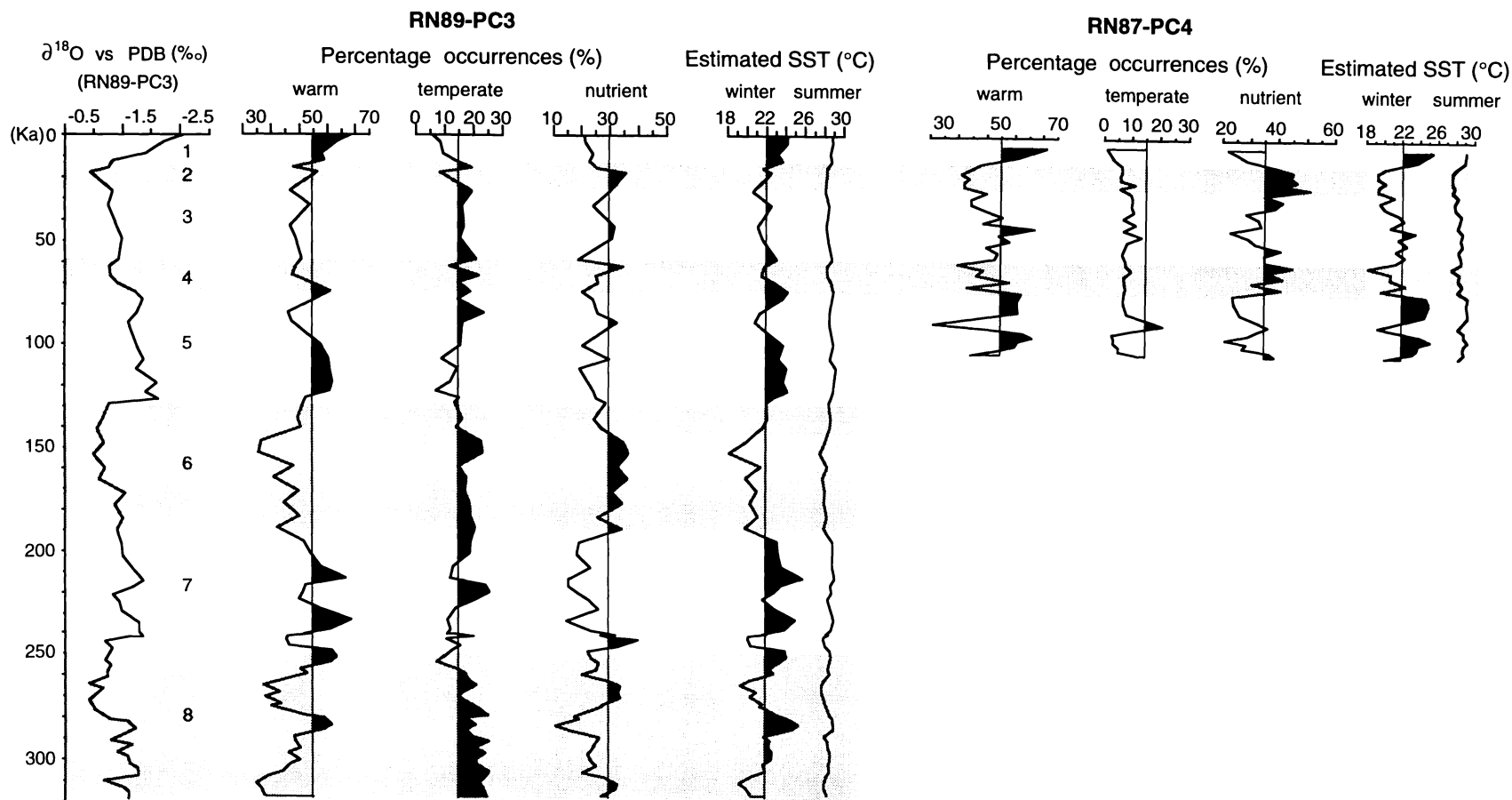
RN89-PC3

RN87-PC4

$\partial^{18}O$ vs PDB (‰)
(RN89-PC3)

Percentage occurrences (%)

Estimated SST (°C)

Percentage occurrences (%)

Estimated SST (°C)

-0.5 -1.5 -2.5

warm   temperate   nutrient

winter summer

warm   temperate   nutrient

winter summer

(Ka)0

30 50 70   0 10 20 30   10   30   50   18 22 26 30

30   50   70   0 10 20 30 20   40   60 18 22 26 30

50

100

150

200

250

300

1
2
3
4
5
6
7
8

Figure 6. Down-core frequency changes of the three categories, compared with estimated paleo-SST. "Warm" represents the warm-water species *P. obliquiloculata, Gnt. glutinata, Gds. ruber, Gds. sacculifer* and *Gnl. aequilateralis* ; "Temperate" represents the temperate-water species *Grt. inflata* and *Grt. truncatulinoides* ; "Nutrient" represents the nutrient-favoring species (eutrophic cool-water fauna) *Gna. bulloides, Gna. falconensis, Ndg. eggeri* and *Ngd. pachyderma* (dextral).

the studied area is believed to be due to the warm Kuroshio Current. These five species together are considered as indicative of warm surface water.

G. inflata and G. truncatulinoides are mid-latitude species. G. inflata is the only indigenous species of the Transition Zone which lies between the subtropical and subpolar zones (Bé, 1977). G. truncatulinoides is most abundant in a narrow band extending across the North Pacific from approximately 40°N to 20°N (Bradshaw, 1959). These two species characterize temperate water in the North Pacific.

G. bulloides is known to characterize upwelling situations regardless of its geographic position (Hemleben et al., 1989). Bé (1977) also reported that G. bulloides occurred not only predominantly in subpolar regions, but also was commonly found in upwelling areas and boundary currents in low-latitude regions. N. eggeri is a tropical-subtropical species in active current systems, along continental margins and upwellings. It is rare in the central oceanic regions far from landmasses. As a result, all the areas where N. eggeri and G. bulloides proliferate are characterized by high nutrient levels. G. falconensis and N. pachyderma (dextral) are species whose distribution patterns are poorly known because many published data lumped them together with G. bulloides and N. eggeri, respectively. G. falconensis, which is closely allied to G. bulloides in morphology, is thought to have similar ecologic requirements, too (Bé, 1977). In core RN89-PC3, the abundance of these two species showed perfectly identical changes, but in core RN87-PC4, they did not match each other. As to N. pachyderma (dextral), it has been indicated that all living representatives of the genus Neogloboquadrina which feed exclusively on phytoplankton (Hemleben et al., 1989) belong to one biogeographic cline (Srinivasan and Kennett, 1976). In both of the cores, N. pachyderma (dextral) went up in percentage only in periods when N. eggeri was abundant. But it is not the case that whenever N. eggeri increased in abundance, N. pachyderma (d) increased; instead it is the case that when N. eggeri was abundant for a time, the percentage of N. pachyderma (d) would increase in part of this period. Regardless of all the discrepancies mentioned above, these species as a whole are assumed to indicate eutrophic surface water conditions.

Summarizing the above, we consider the predominant species to be three indicators representing the tropical-subtropical warm water, the temperate (transitional) water and eutrophic surface water conditions, respectively. P.

obliquiloculata, G. glutinata, G. ruber, G. sacculifer and G. aequilateralis are warm-water species; G. inflata and G. truncatulinoides are temperate-water species; G. bulloides, G. falconensis, N. eggeri and N. pachyderma (dextral) are nutrient-favoring species. Summation of the relative abundance of the constituents in a certain environmental category gives the weight of this environment.

The faunal assemblage in the core top sample contains all the predominant species, and is composed of 60% tropical-subtropical species, less than 10% temperate-water dwellers, and 20% eutrophic-water favoring habitants. The occurrence of the predominant species in the core top sample, which is identical to that in the modern surface sediments taken from the same region corresponds to the current hydrographic condition, in which the core region is mainly influenced by tropical-subtropical water, far from the influence of the temperate water, with a medium nutrient supply.

Relationship between down-core faunal changes and paleo-SST

The correspondence between the core top faunal assemblage and the modern water mass condition suggests that the proportional change of the three categories in a sample can indicate changes in the properties of the surface water. In other words, the proportional change of the three categories in a sequence can be used to indicate the shift of warm or temperate water, and the nutrient supply in this region. The down-core frequency changes of the predominant species as three indicators, compared with the SST curves, are shown in Figure 6.

The percentage occurrence curves of warm-water species are generally parallel to the oxygen isotope curves in both cores. This category maintained its frequency of about 60% (which appeared in the core top sample) in stages 1, 5 and 7. The percentage maxima of the warm-water species occurring at Stage 1 and Stage 7 correspond to the maxima in estimated winter SST. The highest winter SST occurred at both periods in postglacial episode and in Stage 7, which was estimated at about 215,000 yrs. B.P.

In Core RN89-PC3, the eutrophic species and the temperate water species appeared to change in accordance with each other. Both the categories decreased in interglacial stages 1, 5 and 7, and increased in glacial stages 2, 3, 4, 6 and 8. The winter SST minimum occurred in Stage 6 when both the eutrophic and the temperate

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Figure 7. Important species from the studied cores. **1.** *Globigerina bulloides* d'Orbigny (umbilical view), from RN89-PC3, 4-6 cm. **2.** *Globigerina falconensis* Blow (umbilical view), from RN89-PC3, 30-32 cm. **3.** *Globigerinoides ruber* (d'Orbigny) (umbilical view), from RN89-PC3, 10-12 cm. **4.** *Globigerinoides sacculifer* (Brady) with sack (umbilical view), from RN89-PC3, 4-6 cm. **5.** *Globigerinoides sacculifer* (Brady) without sack (umbilical view), from RN89-PC3, 4-6 cm. **6.** *Globigerinella aequilateralis* (Brady) (equatorial view), from RN89-PC3, 50-52 cm. **7.** *Pulleniatina obliquiloculata* (Parker and Jones) (spiral view), from RN89-PC3, 14-16 cm. **8.** *Globorotalia truncatulinoides* (d'Orbigny) sinistral (umbilical view), from RN89-PC3, 104-106 cm. **9.** *Globorotalia truncatulinoides* (d'Orbigny) dextral (umbilical view), from RN89-PC3, 184-186 cm. **10.** *Globigerinita glutinata* (Egger) (umbilical view), from RN89-PC3, 260-262 cm. **11.** *Globorotalia inflata* (d'Orbigny) (umbilical view), from RN89-PC3, 354-356 cm. All scale bars=100μm.
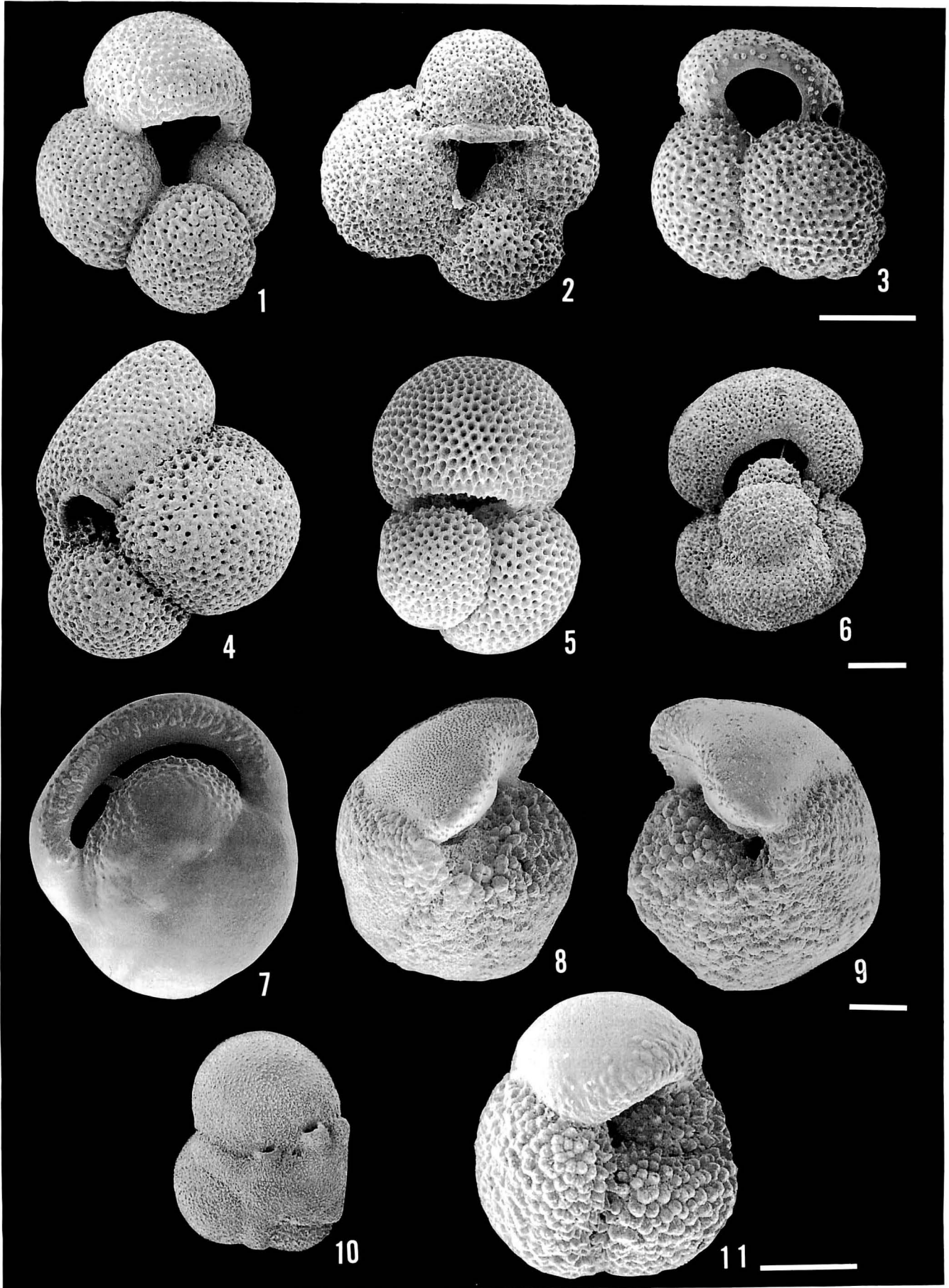
water species were well developed.

In core RN87-PC4, percentages of the eutrophic species are notably greater in stages 2 and 4 than in stages 1, 3 and 5, while those of the temperate species are more abundant in other stages than in Stage 1. The winter SST minima of about 18°C occurred in glacial stages 2 and 4 when the eutrophic species flourished.

Considering the three categories, namely, indicators of the influence of Kuroshio, influence of temperate water, and the level of nutrient supply, we conclude:

1. Nutrient level in surface water was higher during the glacial periods than during the interglacial periods.

2. The influence of temperate water was much stronger in most of the intervals during the last 320,000 years, except the postglacial and some periods in stages 5 and 7.

3. The decline in winter SST during glacials could be correlated with the influence of the temperate water and/or the eutrophic surface water condition.

4. Contrary to general expectations, the glacial winter SST in the southern core was lower than that in the northern one, keeping up with the richer trend of the eutrophic fauna in the southern core.

5. The influence of Kuroshio in both stages 5 and 7 was similar to the present-day situation. Its influence was weaker in the other stages compared with the present.

Discussion

1. During the winter of the glacials, southward advance of the polar front narrowed the zone between subpolar and subtropical, compressing the Western Pacific Central Water. The surface flow of the gyre was intensified, the boundary current became more active and surfce water primary productivity in the marginal region should have been enhanced. Moreover, the southward advance of the polar front forced the transitional zone to shift southward, too. When the heavier and cooler temperate water occupied the upper water column, the stability of stratification could have been destroyed, with vertical mixing causing upwelling of deeper nutrient-enriched water. The surface water would have been, therefore, eutrophicated.

Using abundance data from plankton tows and isotopic composition data from samples taken in the western Atlantic, Fairbanks and co-workers (Fairbanks and Wiebe, 1980; Fairbanks et al., 1982) have demonstrated that species are vertically stratified within the photic zone. The mixed layer waters are relatively oligotrophic, compared to the underlying waters. In our study, the eutrophic fauna increased during glacial periods, but they

did not necessarily match mutually. For example, in core RN89-PC3, G. bulloides and G. falconensis were more prominent in stages 2, 3, 4 and 6, whereas N. eggeri and N. pachyderma (d) were more remarkable in stages 2 and 8. Since G. bulloides is believed to be a mixed layer dweller, the enhanced percentages of this species suggest the mixed layer was eutrophicated during those periods by active vertical mixing. As to the other two species, it has been reported that the N. eggeri peaks in abundance precisely in zones of highest primary productivity and deep chlorophyll maximum (Fairbanks and co-workers); N. pachyderma (d) is most abundant when production in the Deep Chlorophyll Maximum (DCM) layer is at a maximum (Sautter and Thunell, 1991). Thus, the increased percentages of these two species might suggest an enhanced sea surface primary productivity in the DCM layer during stages 2 and 8. Coincidentally, Florisphaera profunda, a nannoplankton species living exclusively in the lower euphotic zone (Okada and Honjo, 1973) and abundantly occurring under great water transparency (Tanaka, 1991), showed minimum relative frequencies in stages 2 and 8 in the same core. Now that a reverse relationship exists between F. profunda abundances and phytoplankton chlorophyll values in the Northwest Pacific (Ahagon et al., 1993), possible primary productivity enhancement in the DCM layer seems to be supported by evidence of nannoplankton as well.

2. The temperate water characterized by G. inflata and G. truncatulinoides influenced this region more powerfully for most of the last 320,000 years. However, these two species appeared to repel one another. G. inflata was more notable during stages 5 to 7, while the abundance of G. truncatulinoides was greater during other periods. G. inflata is a mixed-layer dweller (Fairbanks et al., 1980) and regarded as indicative of a well-mixed cool environment, homothermal water column with intermediate nutrient levels. On the other hand, G. truncatulinoides is believed to be a very deep dwelling species (Tolderlund and Bé, 1971; Hemleben et al., 1989; Lohmann and Schweitzer, 1990), at 600 m or >1,000 m. The flourishing of G. inflata may require slight vertical mixing while that of G. truncatulinoides may require very deep stirring in the water column. Therefore, they may reflect different properties of the central watermass, although both of them are transitional water indicators.

3. During upwelling, the underlying subsurface water which was brought upwards was not only more eutrophic, but also colder. Therefore, the vertical movements of the water in a water column could have depressed the SST, as well as displacing horizontally the water masses. Comparison of the two cores indicates that the temperate water species were more abundant in the northern part of

Figure 8. Selected species of the genus *Neogloboquadrina* from the studied cores. **1a, b, c.** *Neogloboquadrina eggeri* (Rhumbler), from RN87-PC4, 80-82 cm. 1a: umbilical view, 1b: side view, 1c: spiral view. **2a, b, c.** *Neogloboquadrina blowi* Rogl and Bolli, from RN87-PC4, 90-92 cm. 2a: umbilical view, 2b: side view, 2c: spiral view. **3a, b, c.** *Neogloboquadrina incompta* (Cifelli), from RN87-PC4, 50-52 cm. 3a: umbilical view, 3b: side view, 3c: spiral view. **4a, b, c.** *Neogloboquadrina pachyderma* (Ehrenberg) dextral, from RN87-PC4, 60-62 cm. 4a: umbilical view, 4b: side view, 4c: spiral view. All scale bars = 100 μm.
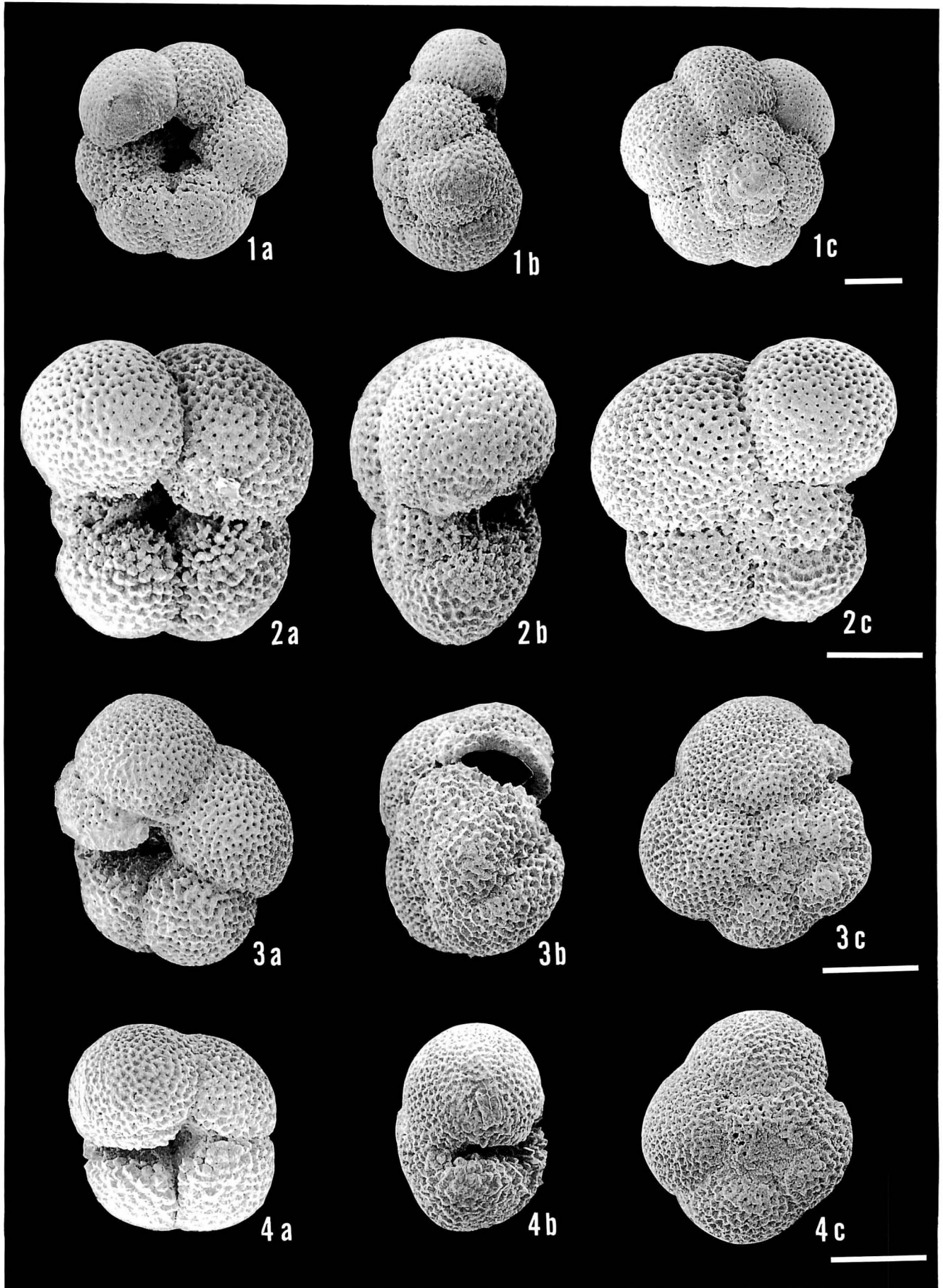
the studied region, while the eutrophic species were more abundant in the southern part. This suggests that the northern part suffered much more temperate water while the southern part witnessed vertical mixing more frequently. On one hand, the slightly higher proportion of temperate water species in the northern core RN89-PC3 might have corresponded to the biogeography, in which the northern core was easily attained by the temperate water. On the other hand, a slightly greater decrease in glacial winter SST in the southern part implies that vertical mixing of cooler water upwards might have contributed more to the surface temperature's declining effect than did a southward shift of the temperate water mass.

4. The strengthening of the temperate water in the core region is the result of the southward advance of the polar front. However, the polar front has never reached the studied region during the last 320,000 yrs., since the unique species *N. pachyderma* (sinistral) which characterizes the Oyashio cold current (Takayanagi and Oda, 1984) never occurred in any core sample. Thompson (1981) mentioned the occurrence of sinistrally coiled *N. pachyderma* in Stage 6 in core V28-304 (Figure 1, Table 1) which is located at Lat. 28°32′N. Hence the southernmost influence of the polar front might have reached somewhere between 30°N and 25°N (where northern core RN89-PC3 is located) at Stage 6.

5. The warm-water species decreased in percentage during the glacial periods. This does not necessarily reflect the decline in influence of the Kuroshio Current itself, for it may have been caused by the intensified temperate water and the more active vertical mixing during glacial periods. However, it is obviously not the case that the main current of the Kuroshio swept across the core region either. It appears that the last glacial flow pattern of the Kuroshio proposed by Ujiié (1991) is not supported by the planktic foraminiferal assemblages. Under that hypothesis, the Kuroshio Current ran along the outer side of the Ryukyu Island Arc instead of entering the East China Sea during the last glacial episode. If this is true, the core region should have been under the main current of the Kuroshio and the proportion of warm-water species should have been much greater.

Conclusions

1. Notable dissolution effects changing in accordance with glacial/interglacial alternations are not shown at the present 2,500 m-deep core site during the last 320,000 years.

2. The paleo-SST changes accord with the paleoclimatic oscillations. Summer SST slightly fluctuated within 1-2°C, while winter SST was 4-5°C lower during glacials than during interglacials. Maximum winter SST of about 26°C occurred in Stage 7, while the minima of about 18°C occurred in stages 4 and 6. The value of seasonal contrast during interglacials was similar to the modern situation, but slightly higher during the glacials.

3. Conditions of the surface water during interglacial stages 5 and 7 were similar to the present. The advance

of the polar front did not reach the studied area during the last 320,000 years. Meanwhile, this region was not dominated by the main current axis of the Kuroshio during the glacials either.

4. The influence of the temperate water was stronger in most of the studied intervals, particularly in glacials, during the last 320,000 years than it is today.

5. Nutrient levels in surface water were higher during all glacial stages than during interglacial stages. Vertical mixing was most prominent in glacial stages 2, 4 and 6. Primary productivity in DCM layer was probably enhanced during stages 2 and 8.

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989 Further observations of *Cunninghamiostrobus yubariensis* Stopes and Fujii from the Upper Yezo Group (Upper Cretaceous), Hokkaido, Japan

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Abstract. Permineralized ovular conifer cones are common in occurrence in the Upper Yezo Group (Late Cretaceous in age) of marine origin, Hokkaido, Japan. This paper describes in detail a taxodiaceous ovular cone which is referable to those described originally by Stopes and Fujii (1910) and later by Ogura (1930) under the name of *Cunninghamiostrobus yubariensis* Stopes and Fujii. Unfortunately previous records did not show the ovular features in detail. However, we could study these in our well preserved specimen. Ovules (or seeds) in this specimen are three in number on each cone-scale, the only similarity between our cone and those of extant *Cunninghamia*. Vasculature in the cone-scale is different in the two. Comparison of the present cone with the other *Cunninghamiostrobus* cones and other allied cones hitherto described is also drawn in this paper.

Key words : Permineralized taxodiaceous cone, *Cunninghamiostrobus*, Upper Yezo Group, Late Cretaceous, Hokkaido (Japan)

Introduction

The Upper Yezo Group of marine origin is extensively exposed to the west of the meridional zone (nearly N–S trend) of Hokkaido (see Ohana and Kimura, 1991, p. 946). This group has abundant calcareous nodules with fossil plants and marine animals such as ammonites and inocerami indicating a Turonian-Coniacian-Santonian age for the main part of the group. Although the fossil plants are fragmentary and their organs mostly isolated in preservation, most of them are permineralized and their histological features are well preserved. Pioneering studies on these were made by Stopes and Fujii (1910) and Ogura (1930, 1932).

Very recently we were fortunate to find a permineralized taxodiaceous ovular cone among the collection made by Hiroshi Takahashi from the upper course of the Obirashibe River, Tappu area (Ohana and Kimura, 1991, p. 946) (roughly 44°04′N, 141°58.5′E). He very kindly gave it to us for our study.

Stopes and Fujii (1910) originally described a permineralized taxodiaceous ovular cone obtained from the Yubari area (Ohana and Kimura, 1993, p. 42) under the name of *Cunninghamiostrobus yubariensis* n. g., n. sp., but in their cone, ovules (or seeds) were not preserved.

Later Ogura (1930) described two similar permineralized ovular cones collected also from the Yubari area under the name of *Cunninghamiostrobus yubariensis*. However in his cones, ovules (or seeds) were detached and not well preserved.

The present cone is very much more like those of *Cunninghamiostrobus yubariensis* than any other ovular cones hitherto described. It has a well preserved cone-axis, cone-scales and ovules (or seeds) with their vasculature, and other histological details. This enabled us to add to the descriptions of *Cunninghamiostrobus yubariensis* and to draw comparisons with those already known and with extant *Cunninghamia* and also with other fossil cones reputed to have *Cunninghamia* affinities.

Acknowledgments

Description

Radial longitudinal section of the cone.—External surface of this cone can not be seen, because it is completely buried in rock matrix. Judging from its radial
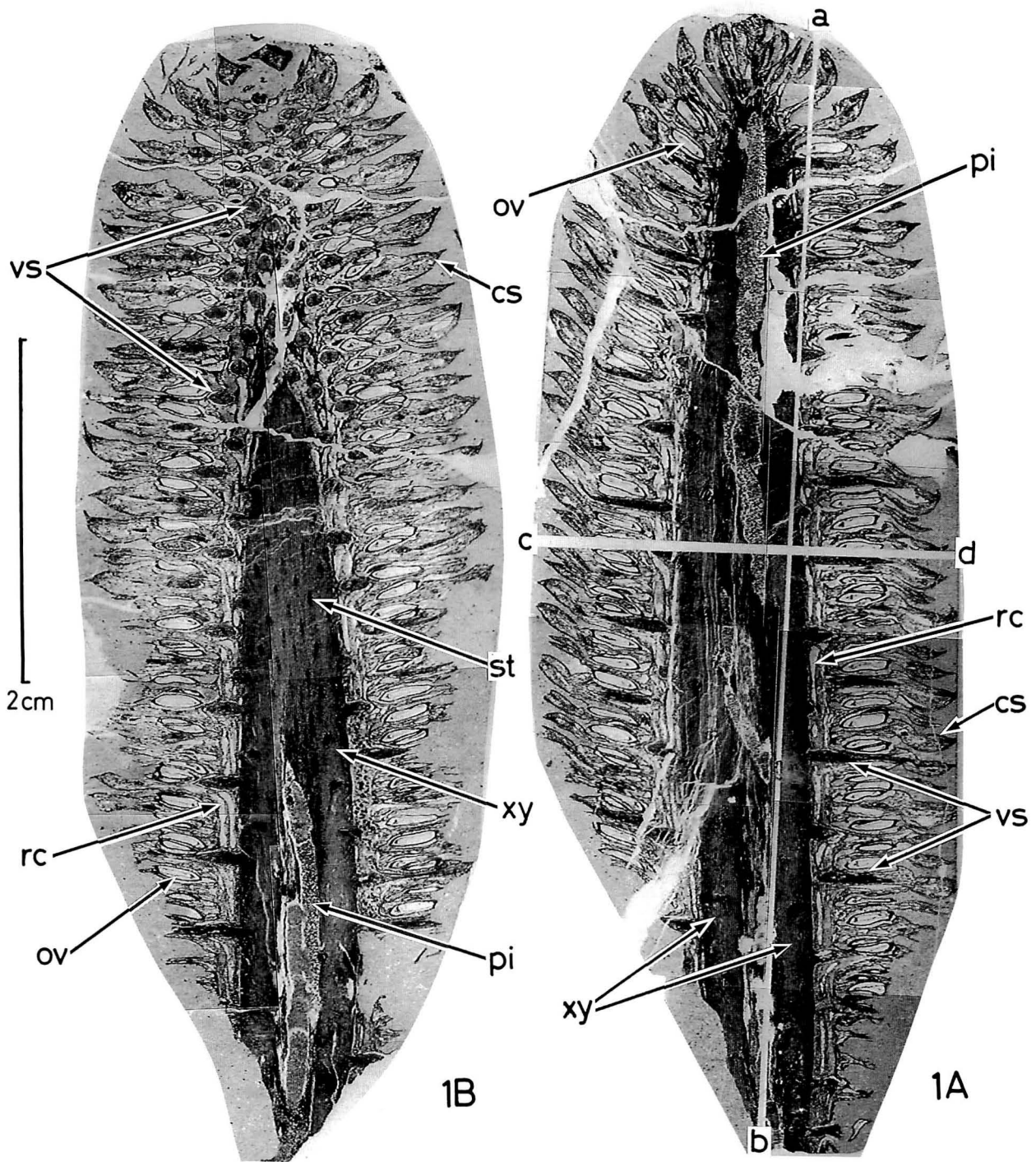
Figure 1. Longitudinal sections of the ovular cone buried in the rock matrix. **1A.** A nearly radial longitudinal section of the cone. Narrow gaps (a-b and c-d) show cutting losses (INH-0014-107). **1B.** A nearly tangential (apical part) and radial longitudinal (proximal part) section cut along the a-b direction in Figure 1A (INH-0014-001). cs : cone scale, ov : ovule (or seed), pi : pith, rc : resin canal, st : scale trace, vs : vascular strand, xy : xylem cylinder. The cross section cut along the c-d direction in Figure 1A is shown in Figure 2B.
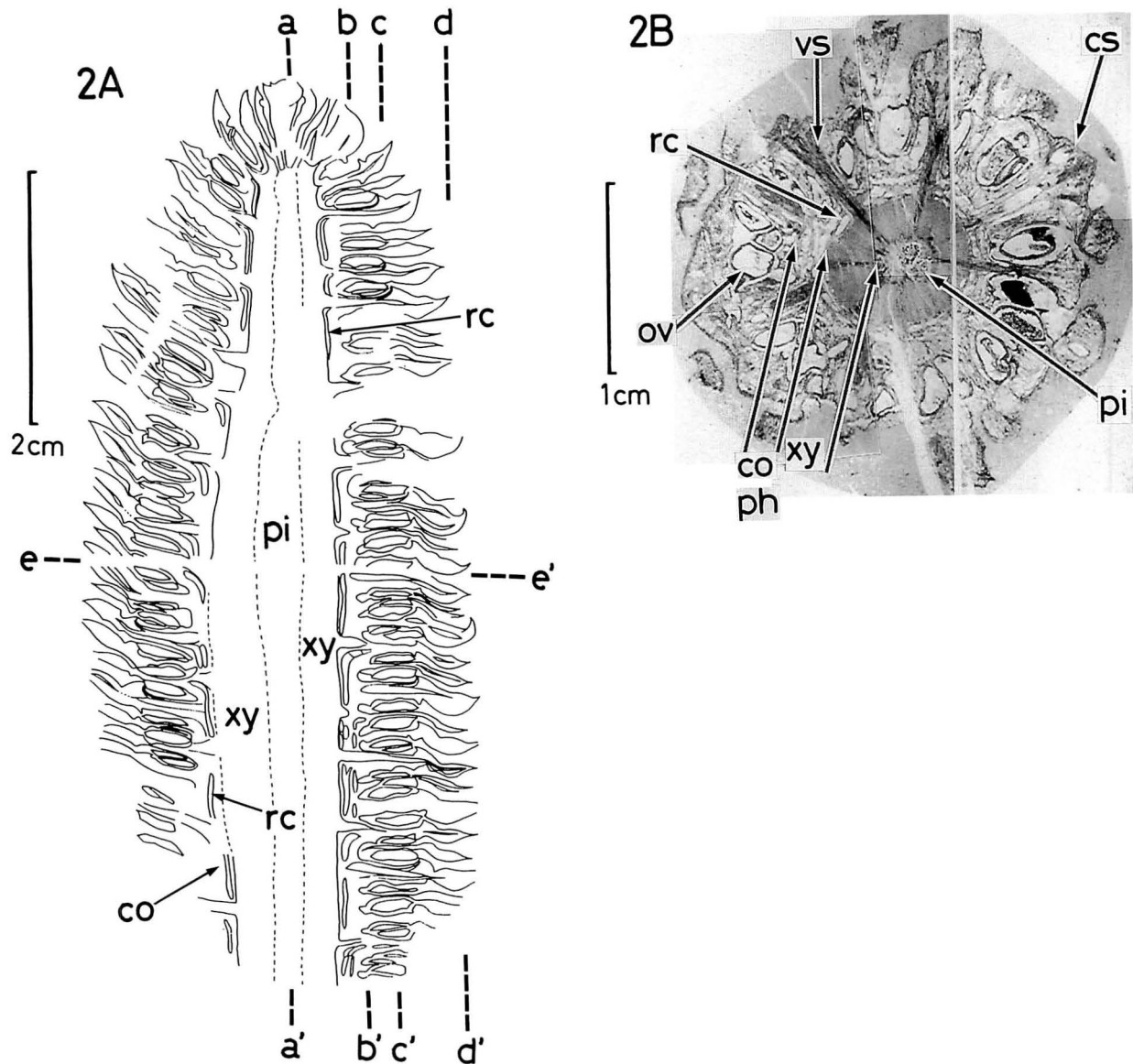
Figure 2. Longitudinal and cross sections of the ovular cone. **2A.** A brief sketch of the cone drawn from Figure 1A. The line a-a′ indicates the radial longitudinal section, the lines b-b′, c-c′ and d-d′ indicate the tangential longitudinal sections, and the line e-e′ (corresponding to the c-d gap in Figure 1A) indicates the position of cross section respectively. **2B.** A cross section cut along the e-e′ direction in Figure 2A, showing pith, xylem phloem cylinders and cortex in outward sequence, and radially and helically disposed scale traces (vascular strand in the cone scale) from the pith to each cone scale (INH-0014-012). cs : cone scale, co : cortex, ov : ovule (seed), ph : phloem cylinder, pi : pith, rc : resin canal, st : scale trace (see Figure 3A), vs : vascular strand, xy : xylem cylinder.

Figure 3. Cross sections of cone axis and longitudinal sections of the xylem cylinder. **3A.** A cross section of the cone axis, an enlarged part of Figure 2B. Two encircling rows of resin canals are recognizable in the cortex. No annual ring is recognized in the xylem cylinder (INH-0014-012). **3B.** A cross section of the boundary area between pith and xylem cylinder, showing the primary xylem tracheids surrounding the pith (INH-0014-012). **3C.** A longitudinal section of the xylem cylinder, an enlarged part of Figure 1A, showing pith cells and primary xylem tracheids, each with annular thickenings (INH-0014-109). **3D.** A longitudinal section, an enlarged part of Figure 1A, showing the primary xylem tracheids with annular, spiral and scalariform thickenings, and the secondary xylem tracheids, each with a single row of the bordered pits on the radial longitudinal section (INH-0014-109). co : cortex, ov : ovule (seed), ph : phloem cylinder, pi : pith, px : primary xylem, rc : resin canal, st : scale trace, sx : secondary xylem, vs : vascular strand (in cone scale), xy : xylem cylinder.
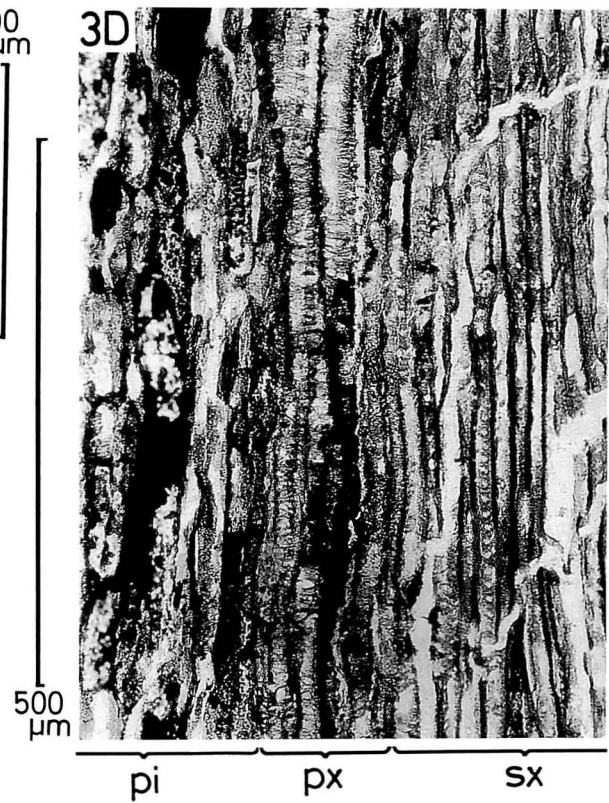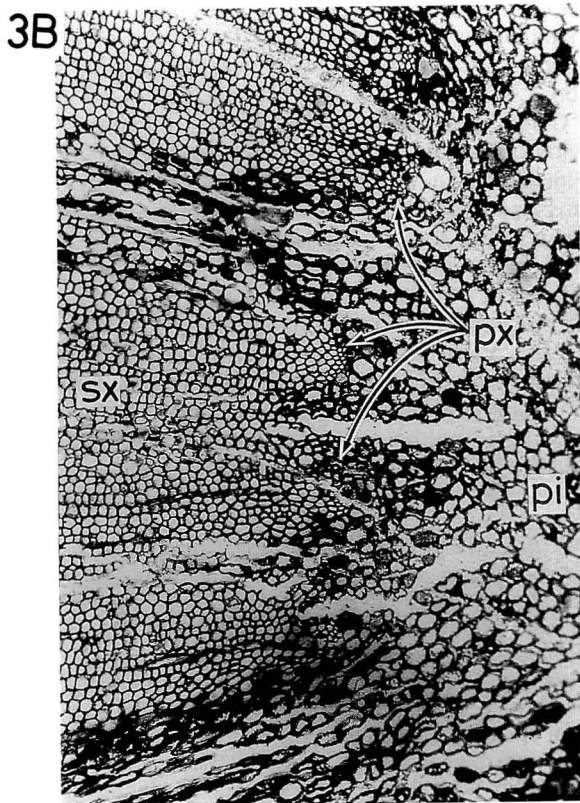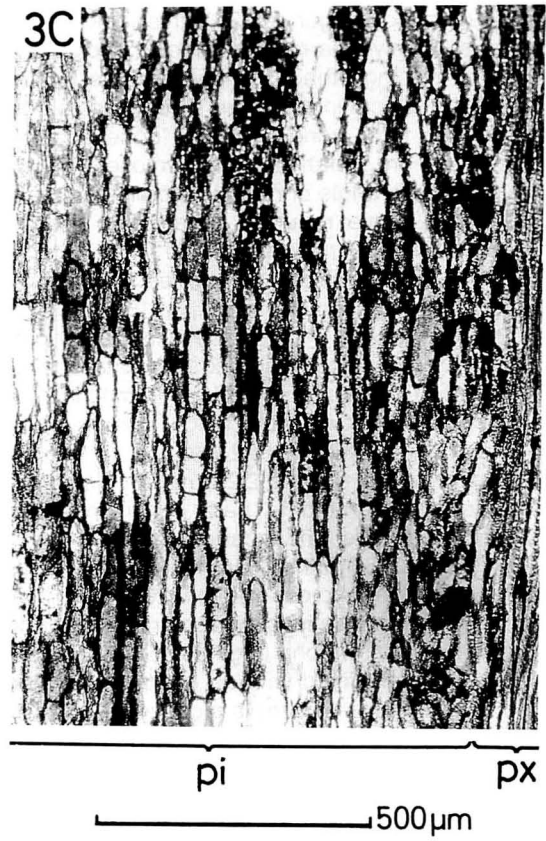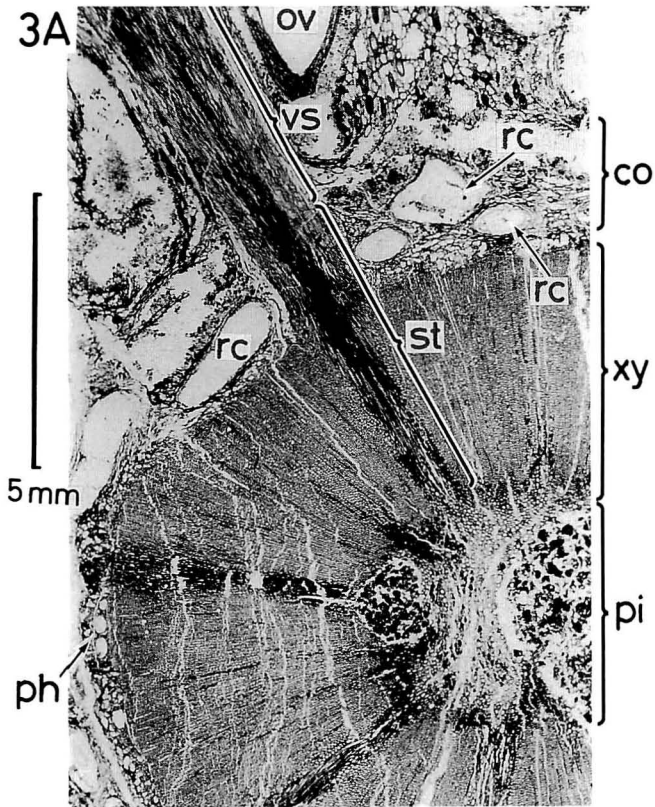
longitudinal section (Figures 1-2A), this looks cylindrical, narrowing suddenly to a rounded apex. Proximal part of this cone is missing: the size may be more than 6.5 cm long and up to 2.5 cm in diameter. Cone-scale complexes (we use the term 'cone-scale' or 'cone-scales' hereafter for short) are quite numerous, closely helical and attached at a wide angle or nearly perpendicular to a thick cone-axis, the angle reduced toward the apex. Their precise phyllotaxy is uncertain.

Each cone-scale bears three ovules (or seeds) on its adaxial surface (Figures 2B, 6C, 7A, 8, 11B, C).

Histological features.—The cone-axis has a pith, surrounded by xylem, phloem, cortex and cone-scales.

Cone-axis.—Cone-axis is thick, 9-11 mm in diameter, narrowing gradually toward the apical portion where it is 5-6 mm in diameter (Figures 1, 2, 3A).

Pith of cone-axis.—Pith is 2.2-3 mm in diameter, often broken and disintegrated in part, consisting mainly of parenchymatous cells and scattered sclerenchymatous cells (Figures 1, 2, 3A); the parenchymatous cells are circular or polygonal in cross section, 20-40 μm in diameter (Figure 3B), and are elongate-rectangular in longitudinal section, 50-120 μm long (Figures 3C, D); the sclerenchymatous cells are filled with an opaque substance.

Xylem and phloem.—Xylem is picnoxylic and is 1.8-2.3 mm wide in cross section, surrounding the outer part of the pith (Figures 2B, 3). The primary xylem is endarch, scattered at periphery of the pith (Figure 3B). Annular, spiral and scalariform thickenings are seen on the walls of primary xylem (protoxylem and metaxylem) tracheids (Figures 3C, D).

The secondary xylem tracheids are nearly square in cross section, 10-20 μm in diameter, larger on inner side and smaller on outer side. No annual ring is observed (Figures 2B, 3A, B). Bordered pits are present on the radial walls of tracheids (Figures 3D, 4A). They are in single or double rows, where they are oppositely arranged.

The medullary rays are single in a row and 2-11 cells high (mostly 3-5 cells high) (Figure 4A). In a cross field, two longitudinally disposed pores are seen (Figure 4A).

Tangentially elongated rectangular cells 4-5 cells thick are recognized between the secondary xylem and phloem cylinders (including cambium?) (Figures 3A, 4A), but most phloem cells are collapsed and it is difficult to recognize the real boundary between phloem and cortex. The total thickness of presumed phloem is about 1 mm.

Cortex and resin canals.—In the cortex, resin canals are well developed in two concentric rows (Figures 3A, 4B, E). They tangentially surround the phloem. They are elliptical and tangentially elongated; inside ones are rather smaller in diameter, 0.4-0.5 mm×0.3 mm, outside ones are 1-1.2 mm×0.4-0.6 mm. The resin canals are lined with tangentially flattened epithelial cells (Figure 4B).

Cone-scales.—In sectional view, the boundary between cone-axis and cone-scales is obscure, because the surface of cone-axis is completely covered with the bases of cone-scales. Also the epidermis and the hypodermis of cone-axis were not visible. It is difficult to recognize cone-scale gaps. They appear to be readily repaired, but a few gaps are seen at the apical portion of the cone-axis (Figure 5E).

In each cone-scale, both ovular (or seed) and bract scales appear to be completely fused together. Our effort in this study to discern the boundary between the two by a fluorescence microscopy failed, because the supposed boundary region in cross and longitudinal sections did not fluoresce.

Cone-scales are typically 10 mm long and 2-3 mm wide at the base of the cone (Figures 1, 2, 4E, 6A, C, 7A, C-E, 8, 11A, C-E); in basal cross section, cone-scales are rhombic in form, 1.5 mm in vertical thickness. The width of cone-scales increases toward the distal part of the cone, reaching a maximum of about 7 mm at the distal two-thirds of its length, then narrowing to the pointed apex; apical region is not peltate. The views of serial cross sections of a cone-scale (Figure 8) vary from rhombic to rhomboidal; in the apical two-thirds of a cone-scale, its laterals are thin wing-like or membranous in cross section.

Cone-scale trace is single and originates from the xylem cylinder accompanying a small amount of pith (Figures 4C, D), where it is circular or vertically elliptical in cross section, about 0.7 mm in diameter (Figure 5C). In this position, the pith is placed rather adaxially (Figure 5C). Each trace enters the cone-scale as a cone-scale vascular strand. In this position the pith region is reduced in size (Figure 5D). On its entering the cone-scale, a small-sized branch strand is separated adaxially from a main strand, endarch primary xylem tracheids are present along the periphery of the pith region and are eccentrically surrounded by the secondary xylem tracheids (Figure 6B). The phloem cells are mostly crushed. The slender adax-

Figure 4. Longitudinal section of the secondary xylem cylinder, cross section of resin canals and longitudinal sections of scale traces and vascular strands in cone scale. **4A.** A radial longitudinal section of the secondary xylem tracheids and ray cells, an enlarged part of Figure 1A. An arrow indicates the cross field (INH-0014-109). **4B.** A cross section, enlarged part of Figure 2B, showing xylem and phloem cylinders and cortex. Phloem cylinder is thin. An arrow indicates a crushed cambial zone between xylem and phloem cylinders. Resin canals are lined by thin epithelial cells (INH-0014-012). **4C.** A longitudinal section of the proximal portion of a scale trace consisting of its pith and xylem cylinder, an enlarged part of Figure 1A (INH-0014-110). **4D.** Further enlarged section from the part indicated by an arrow in Figure 4C (INH-0014-109). **4E.** A longitudinal section, enlarged part of Figure 1A, showing the vascular strands passing through the adaxial side of a cone scale and persisting to its tip. Arrows show the position of vascular strands (INH-0014-107). co: cortex, ov: ovule (seed), ph: phloem cylinder, pi: pith, px: primary xylem, rc: resin canal, xy: xylem cylinder.
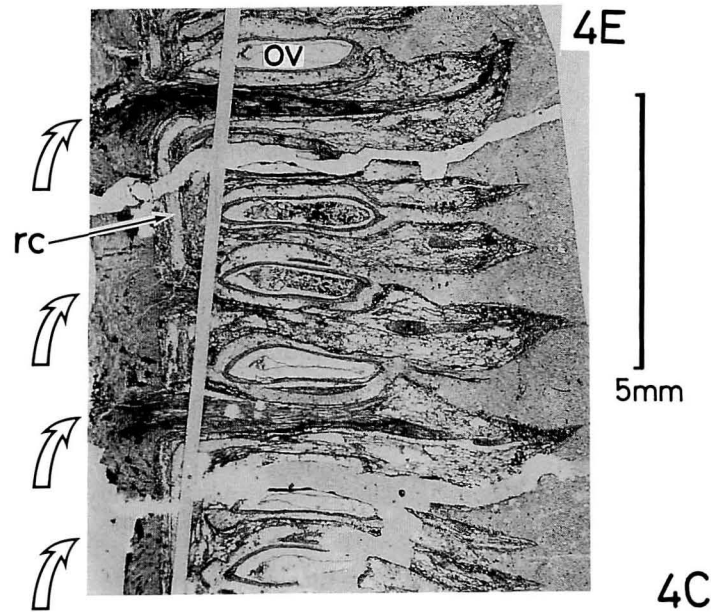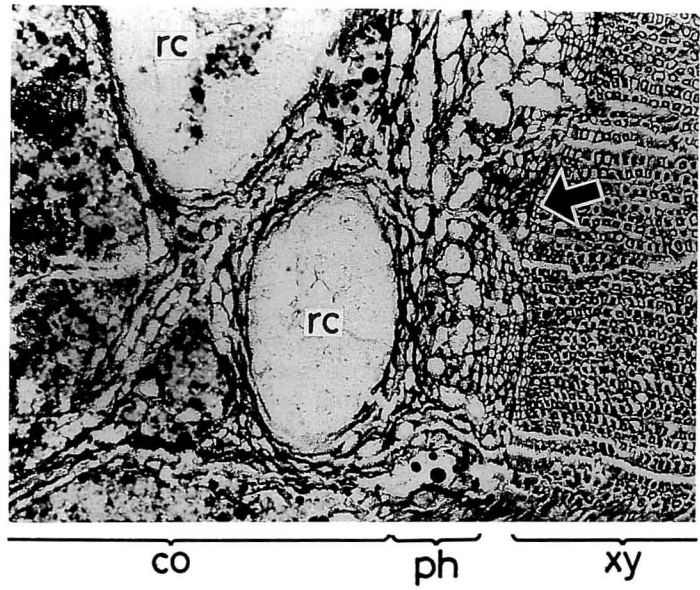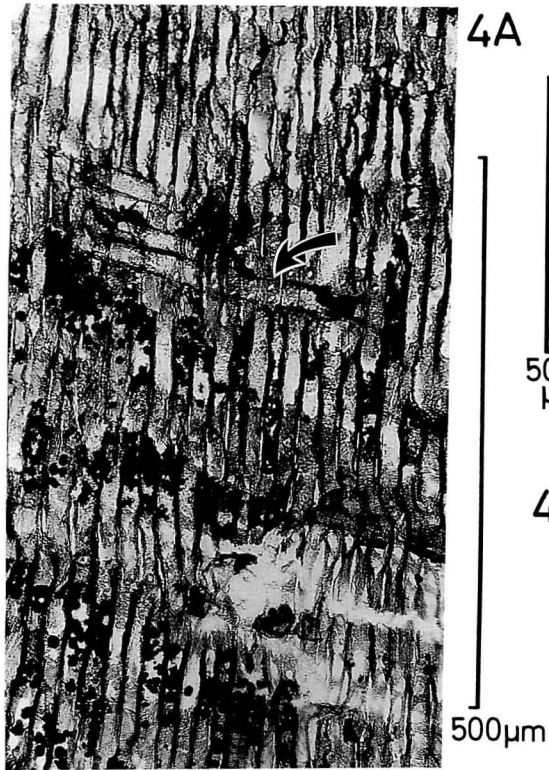
ial strand is separated as a branch, then stands up and becomes a vascular supply to the centrally located ovule (Figures 7B, 8, 9A). The eccentrically thick bundle is then divided into trimerous branches which are extended laterally in the cone-scale (Figures 6D, 7A, B, 8).

Each lateral branch gives rise to a slender and short ovular branch near its proximal end (Figures 7A, B, 8). Both branches stand up for a short distance and become vascular supplies to the laterally disposed ovules (Figures 8, 13A).

Each of the trimerous vascular strands is further divided twice, also in a trimerous manner, on the same internal plane, parallel to that of the cone-scale, and expands flabellately, persisting to the apical part of cone-scale (Figures 8, 10C, D, 11B, 13A).

The cone-scale consists histologically of epidermis, hypodermis, transfusion tissue, ground tissue and resin canals. The epidermis of both surfaces is represented by a single layer of thick-walled polygonal cells, 20-30 μm in diameter in surface view (Figures 12D, E) and rather taller, about 60 μm high in sectional view (Figures 12A-C). Cuticle is not preserved.

Stomata are amphistomatic, restricted to the apical one-fourth of cone-scale on both surfaces. They are rather denser adaxially and absent on the narrow marginal zones of cone-scale. The stoma is sunken and consists of guard cells and 6-8 subsidiary cells (haplocheilic) (Figures 12D, E). Aperture is randomly orientated (Figures 12D, E) and stomatal complex is 70-80 μm in diameter in surface view.

Hypodermis appears to be restricted in distribution on both surfaces of apical one-fourth of the cone-scale. In alternation with the stomatal rows, it consists of a single layer of cells adaxially and two layers abaxially (Figures 12C, F).

Transfusion tissue cells are present in alternation with vascular strands at the apical region of cone-scales. They are rather large in diameter (Figure 12F).

Ground tissue cells are mostly parenchymatous and have the same features as those of the cortex of the cone-axis.

One to three resin canals of large diameter run into the cone-scale successively from the cortex in an abaxial row, but at apical portion of the cone-scale, two disappear and only one with the large diameter is discernible (Figure 8).

Ovules (seeds).—The ovules (seeds) are unexceptional-ly three in number on the adaxial surface of each cone-scale, flattened ovoid in form, typically 4 mm long, 1.6-1.8 mm wide and 0.6-0.8 mm thick. In sectional view three layers of integument (seed coat) possibly corresponding to sarcotesta, sclerotesta and thin endotesta are discernible (Figures 7F, 9B, D), but their details are not well preserved.

The micropyle faces toward the cone-axis (Figures 9A, B). Sometimes several longitudinal ridges are recognized on the surface of the ovules. These ridges are not so-called 'wings', but might have been caused by lateral pressure. The internal details of ovules (or seeds) are not well preserved (Figures 7F, 9).

The mode of attachment and stability of ovules on the cone-scales appear to be unique. To recreate the form of the present cone-scale and ovules, we made a model on the basis of serial cross sections (Figure 8).

In cross section of the cone scale, three lobed swellings are discernible on adaxial surface of the cone-scale (Figure 11D). Each swelling has a socket-like cavity facing the cone-axis. The base of the ovule is inserted in the cavity to keep it stable (Figures 9A, C, 10B, 11A, C). In addition there is a projection tissue of unknown function (placenta?) at the bottom of the cavity (Figures 9A, C, D, 10A, B). There is also a transverse ridge on the abaxial surface of the cone-scale (Figures 8, 11A, E). The location of this ridge corresponds to the row of cavities on the adaxial surface. This kind of ridge is good for keeping ovules stable. The base of each ovule is asymmetrically scooped out (Figures 9D, 10B).

Discussion and comparison.—The present specimen is the only one of a taxodiaceous ovular cone with numerous cone-scales in close helix. Each cone-scale bears three ovules (or seeds) on its adaxial surface. The proximal part and peduncle of this cone are missing, and neither the corresponding vegetative shoot nor pollen cone has been found so far.

Stopes and Fujii (1910) established the organ-genus *Cunninghamiostrobus* and described *C. yubariensis* on the basis of a single, detached and permineralized cone without preserved ovules (or seeds). They did not write about the precise locality from which it came. According to our recent knowledge, it could be true that this cone came from the Upper Yezo Group in the Yubari area. As the original specimen of *Cunninghamiostrobus yubariensis* is obliquely buried mostly in the rock matrix, we can not find out its size, and as all ovules (or seeds) are noted by them to be lost, we do not have the information about

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Figure 5. Cross sections of scale traces in the xylem cylinder and outer cortex. **5A.** A typified tangential longitudinal section of the xylem cylinder, showing the cross sections of fusiform scale traces helically disposed in the xylem cylinder, and the cross sections of circular (cut transversely) or elliptical (cut obliquely) vascular strands on the outside of cortex. Phloem is shaded. **5B.** A longitudinal section of the xylem cylinder cut tangentially, showing the cross sections of fusiform scale traces ; corresponding to the a-b-c-d cutting plane shown in Figure 5A (INH-0014-403). **5C.** A cross section of the scale trace, an enlarged part of the Figure 5B. An arrow indicates the position of the pith (INH-0014-402). **5D.** Right side shows a longitudinal section cut tangentially on/near the outside of the cortex ; corresponding to the cutting plane b-e-f-c shown in Figure 5A. The x-y gap shows a cutting loss (INH-0014-403). **5E.** An apical longitudinal section of the cone cut tangentially, showing a slit consisting of pith cells which is considered to be a leaf gap indicated by an arrow (INH-0014-403). co : cortex, ph : phloem cylinder, pi : pith, st : scale trace, xy : xylem cylinder.
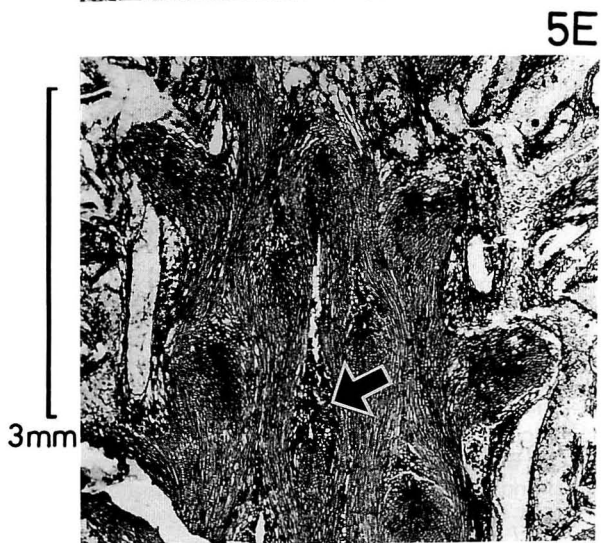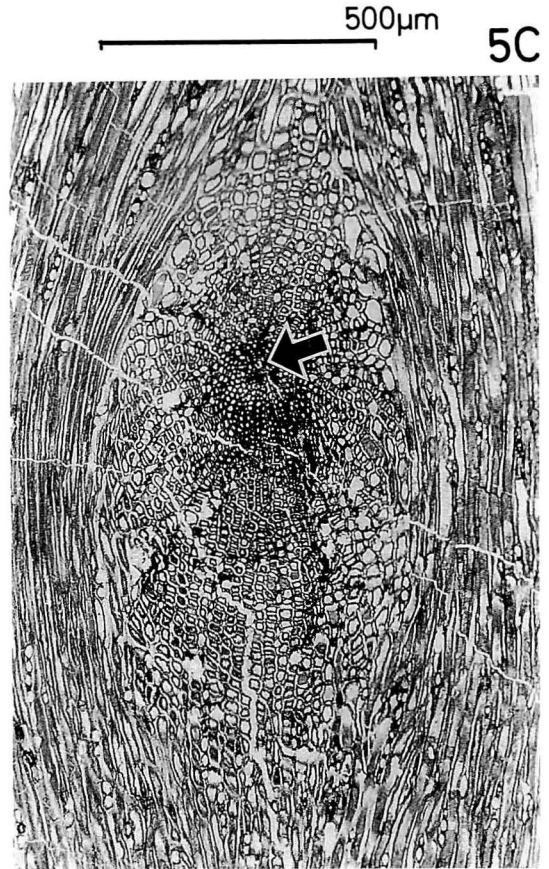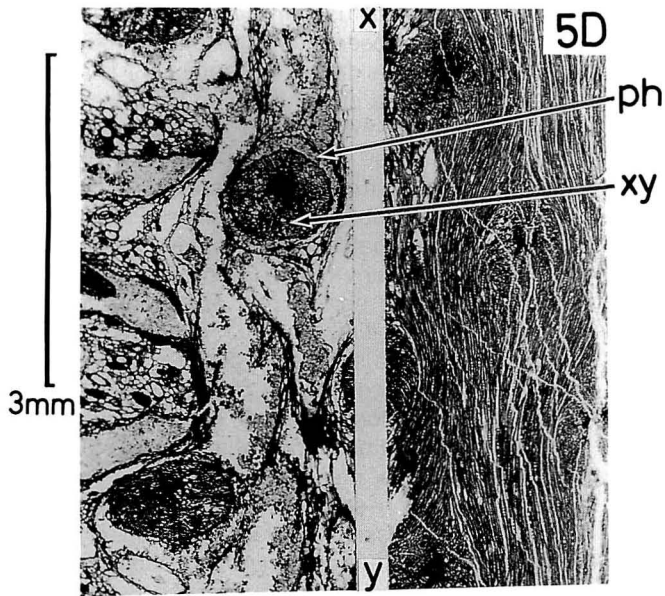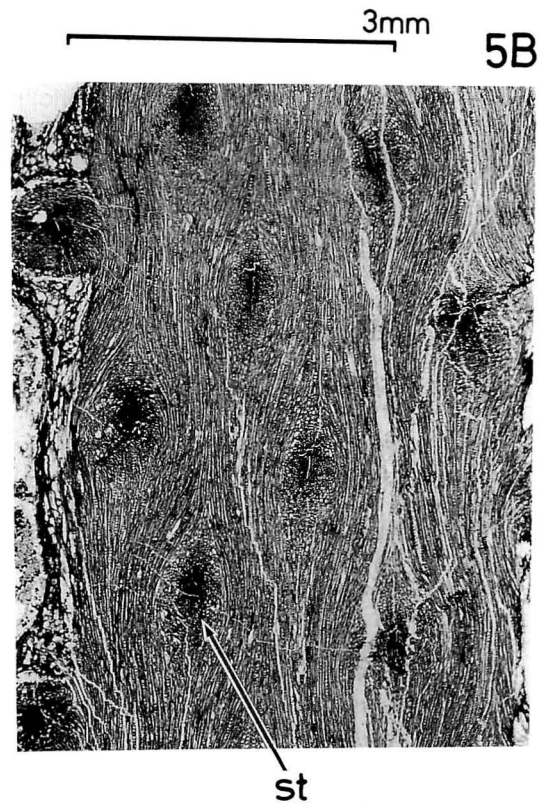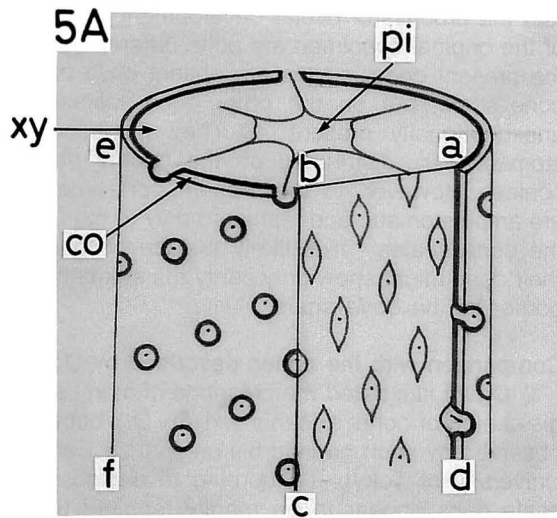
the number of ovules on each cone-scale. According to Stopes and Fujii (1910), however, the histological features of their cone-axis and cone-scales were very close to those of extant *Cunninghamia,* as their generic name suggested.

Later, Ogura (1930) described his ovular cone, referring it unwillingly to *Cunninghamiostrobus yubariensis* on the basis of two permineralized ovular cones obtained from the Upper Yezo Group in the Yubari area.

First of all, we compare our specimen with those described by Stopes and Fujii (1910) and Ogura (1930) and also with that of extant *Cunninghamia.*

Comparison with the cone described by Stopes and Fujii (1910)

1) Their cone is described as 2 cm×3 cm in size which is much smaller than ours. Our specimen is cylindrical, 2.5 cm in diameter and 6.5 cm in length. Possibly they estimated its dimensions on the basis of the obliquely exposed part only. 2) The V-shaped wing-like expansion as shown in their text-fig. 15A has not been found in the cross section of our cone-scales. The wing-like parts in ours are not V-shaped but laterally expanded. 3) In their description and illustrations, the definition of their 'pad' on the adaxial surface of cone-scale is not clear. Similar swelling is also seen on the adaxial surface of centrally thickened part of each cone-scale in our specimen. However there are no ovules on their cone-scales as is the case in ours. Cross section of our cone-scale shows a projection of unknown function in each socket-like cavity of swelling, whereas they illustrated the presence of lateral edges of the 'pad' or 'ligule'-like extension on the adaxial surface of their cone-scale. It is still unclear whether this tissue represents a part of reduced and connated ovular scale or not. In the present cone-scales, this tissue has not been found so far. 4) Resin canals (or resin ducts) are said to be numerous and irregularly distributed except for the main canal. But it is possible that collapsed ground tissue cells might appear like resin canals. They did not mention the presence of epithelial cells lining the resin canal. 5) Ovular branch strands courses were not described by them possibly because of lack of serial sections. 6) The ovules are not attached to the adaxial surface of central 'pad' as they presumed, but to the cavities in the swelling as mentioned before in this paper. 7) They inferred that there were three abortive ovules on an apical cone-scale. It is likely

that the process of ovular development and preservation of the original specimen are quite different from ours. In the present cone, ovules are absent on a pair of apical cone-scale, but on the other cone-scales ovules are unexceptionally present. 8) They mentioned that the stomata were distributed on the central part of cone-scales. However, in the present cone-scales stomata are amphistomatic and restricted only to the apical part of the cone-scales. It is likely that an oblique section of their cone might show only partly the stomatiferous apical portion of the cone-scale.
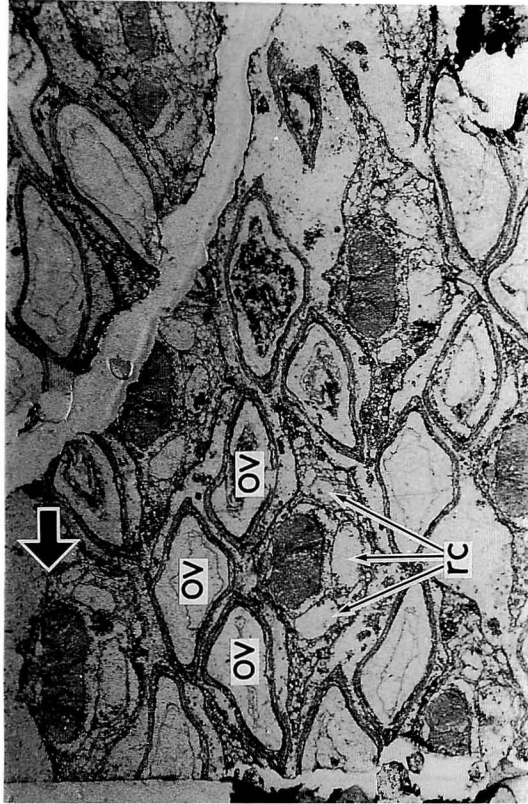
Comparison with the cones described by Ogura (1930)

1) Ogura illustrated the presence of many scale gaps in his sketch of cone-axis (his text-fig. 24), but we could not observe any such gaps in his original section kept at the University of Tokyo. According to our observation, the scale-gaps appear to be readily repaired by the xylem tracheids. 2) A cross section of scale-trace is said to be vertically elongated fusiform with the pith in its center. However, in our observation, the pith is located on the upper side (adaxial side) of the center. 3) In a cross-field of xylem tracheid, a single large and oblique pore is said to be present, whereas in ours there are two vertical pores. In the case of poor preservation, it is highly probable that two crushed pores are seen just as a single one, and such a case is often visible in our cross-fields. 4) He mentioned that an ovular strand was separated at the base of a main thick-strand, then bifurcated and disappeared in the central part of a cone-scale. However, we could not find any such bifurcation of a central ovular strand. The number of ovular strands ought to be three on every cone-scale as mentioned before in this paper. If the section was made fairly obliquely, then it is likely that it did not pass through all the three strands. 5) He mentioned the presence of edges on the adaxial surface of a cone-scale and he regarded them to be margins of the possible ovular scale superposed on the bract scale. But in the present cone-scales, no mark or trace indicating the presence of such ovular scale has been observed.

Comparison with extant *Cunninghamia*

According to Satake (1934), ovular cones of *Cunninghamia lanceolata* Hooker are 3-4 cm in diameter and 4-5 cm long with cone-scales which are fan-shaped, with finely serrate margins, which we could not observe in the
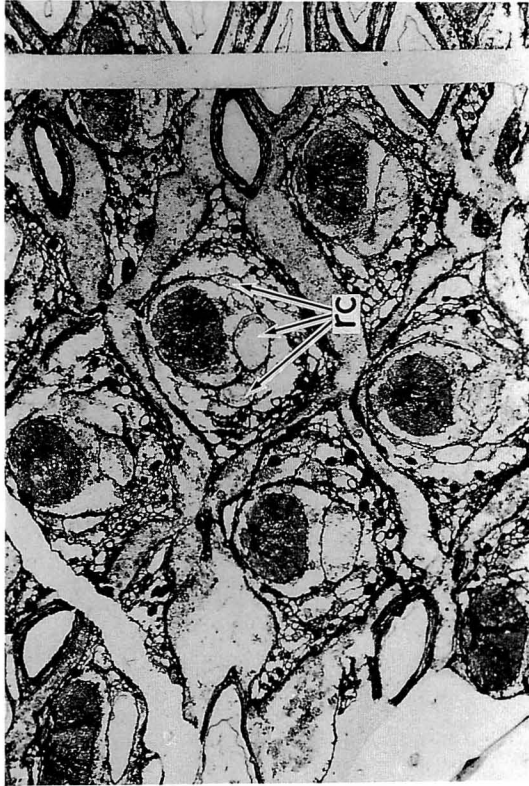

Figure 6. Cross sections of the proximal part of cone scales and vascular strand. **6A.** A cross section of the cone scales cut along the line b-b′ in Figure 2A, showing rhombic cone scales, each with an adaxial thick vascular strand and three abaxial resin canals (INH-0014-210). **6B.** A vascular strand, enlarged part of Figure 6A, showing an adaxial ovular branch just separating from the vascular strand. Vascular strand is surrounded by the phloem cylinder; its thickness is far thinner adaxially and fairly thicker abaxially (INH-0014-210). **6C.** A cross section of the cone scales cut between the lines b-b′ and c-c′ in Figure 2A, showing rhomboidal cone scales each with three ovules (seeds) on the adaxial surface and three resin canals abaxially (INH-0014-301). **6D.** A vascular strand and an outer branch, an enlarged part of Figure 6C (indicated by an arrow). The vascular strand becomes flat and is about to separate into three. This ovular branch is to be received by the central ovule (INH-0014-301). ob : ovular branch, ov : ovule (seed), ph : phloem cylinder, pi : pith, px : primary xylem, rc : resin canal.
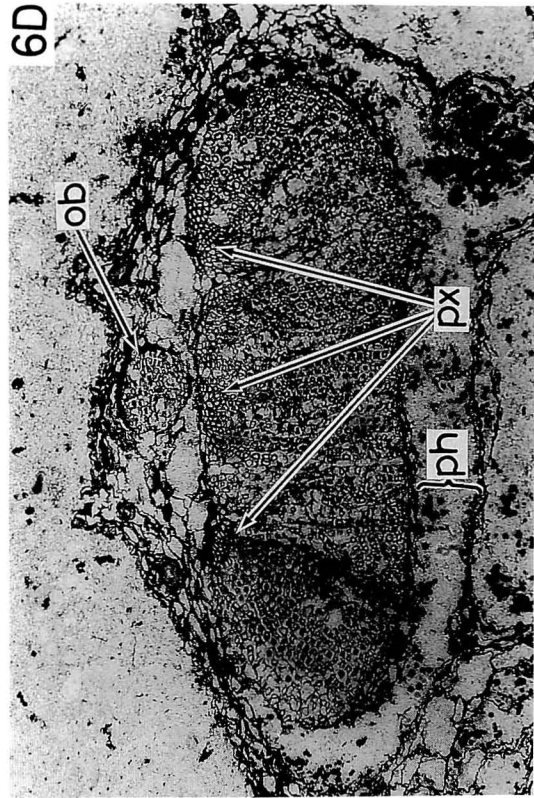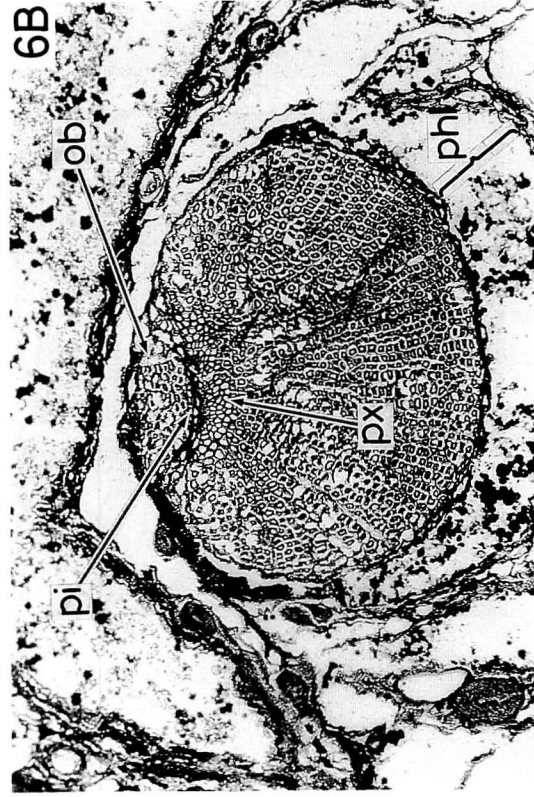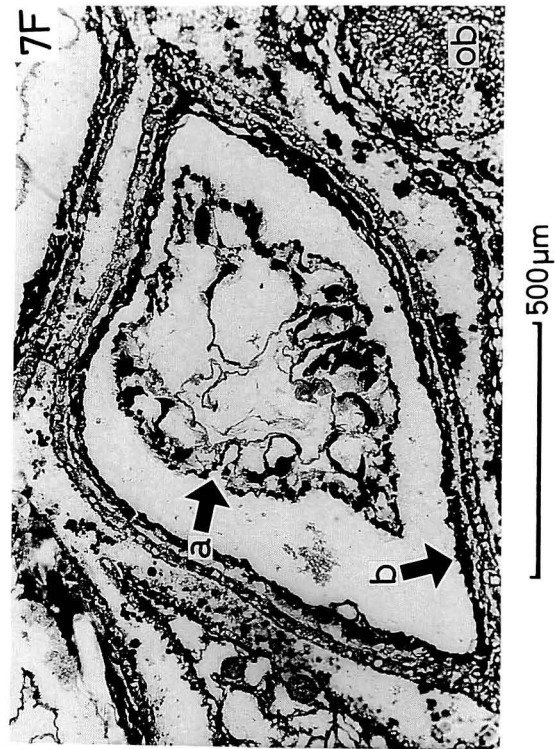
3mm

500μm

8N

8O

vs

8P

rc

8Q

8R

8S

8H

8I

8J

8K

pc   pc

8L

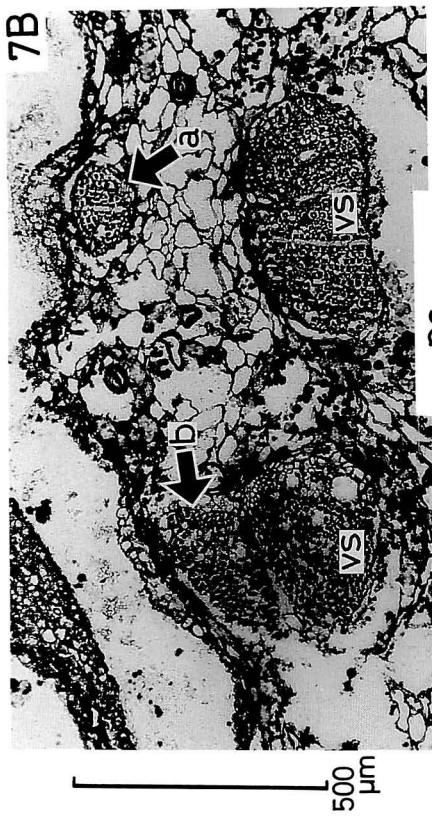pc

8M

8A

rc   rc
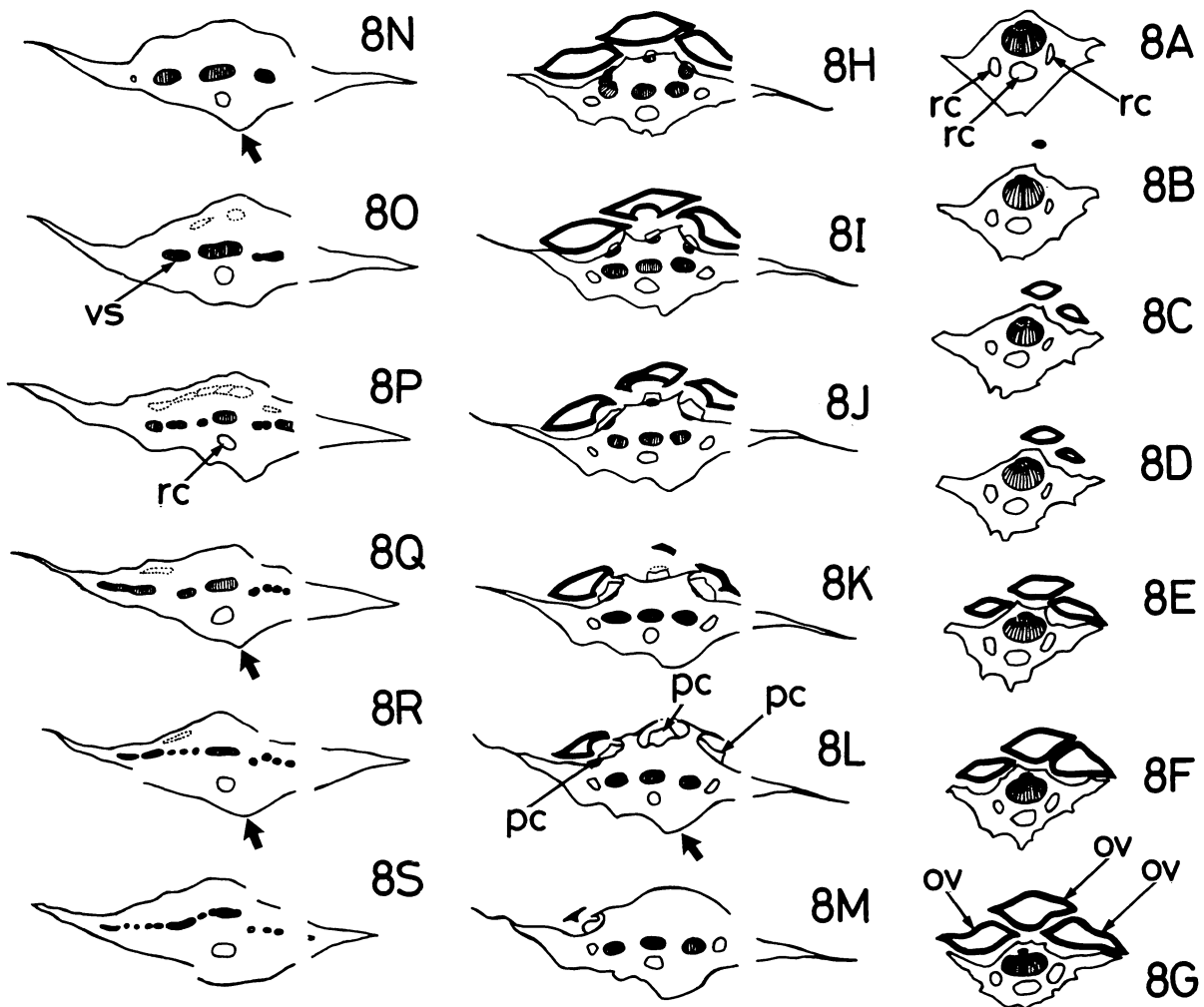
rc

8B

8C

8D

8E

8F

ov   ov   ov

ov

8G

Figure 8. Serial cross sections of a cone scale shown in alphabetic order. Figures 8A, 8G, 8H, 8J, 8R and 8S were drawn from Figures 6A, 6C, 7A, 7C, 7D and 7E respectively. Slides : 8A = INH-0014-210, 8B = -209, 8C = -208, 8D = -206, 8E = -204, 8F = -201, 8G = -301, 8H = -514, 8I = -511, 8J = -510, 8K = -509, 8L = -508, 8M = -507, 8N = -506, 8O = -505, 8P = -504, 8Q = -503, 8R = -502 and 8S = -601. ov : ovule (seed), pc : placenta (?), rc : resin canal, vs : vascular strand. For explanation of arrows, see Figure 11E.

Figure 7. Vascular strands, ovular branches, ovules (seeds) and resin canals. **7A.** A cross section of the cone scales cut along the line c-c' in Figure 2A, showing the branches of vascular strand in trimerous manner. Each lateral strand sends further off an ovular branch reaching to each lateral ovule (INH-0014-513). **7B.** Enlarged part of Figure 7A, showing the two divided strands and an initial ovular branch indicated by arrow a and a lateral ovular branch indicated by arrow b (INH-0014-513). **7C.** A cross section of the cone scale cut between the lines c-c' and d-d' in Figure 2A, showing three projections considered to be placentae in the central part of a cone scale (INH-0014-510). **7D.** A cross section of the cone scale cut along a plane somewhat distant from and outside that of Figure 7C (outside of the ovular attachment), showing the swelled central part and thinner lateral wings. Vascular strands are divided radially in trimerous manner in an adaxial paradermal plane of the cone scale. Resin canals are reduced in number to one at the abaxial center. The distinction of both ovular and bract scales is obscure or indistinguishable (INH-0014-502). **7E.** A cross section of the cone scale cut along somewhat inside the plane from the line d-d' in Figure 2A, showing both branched vascular strands and alternative transfusion tissues in a single adaxial row (INH-0014-502). **7F.** A cross section of an ovule (seed), showing an indefinite nucellus indicated by arrow a and three-layered integument (or seed coat) indicated by arrow b (INH-0014-302). ob : ovular branch, ov : ovule, pc : placenta (?), rc : resin canal, vs : vascular strand.

present cone-scales. In that paper, Satake showed the vasculature of cone-scales in front and in serial sectional views as shown in Figure 13B.

Satake's vasculature of extant *Cunninghamia* cone-scale differs considerably from ours as follows : 1) In the proximal cross section at point no. 1 in his fig. 3, the sectional view of a single vascular strand is quite different from ours, where this strand is circular and its xylem is entirely surrounded by phloem (e.g. Figure 5D). The bundle in the extant species is rather an ellipse with a laterally elongated axis and its xylem and phloem are located at the adaxial and abaxial sides respectively. 2) In the extant specimen the central ovular strand is said to be dichotomously branched near its apex, but in ours, the central ovular bundle originates from the main bundle at the proximal end of the cone-scale and does not branch throughout (Figure 13A). If Satake's account is correct, then we wonder about the position of the branches : Does one of the branches run free or blind ? 3) In Satake's vasculature, each first branch runs obliquely, then bends perpendicularly to the long axis of the cone-scale and gives off the second branches distally, which are parallel with each other and also directed forward (Figure 13B). In the vasculature of our specimen, the strands are branched in a trimerous manner repeatedly and run nearly longitudinally, persisting to the apical part of the cone-scale. 4) In the extant cone-scale, lateral ovules are said to receive the vascular supplies separated from the first branches. However in the present specimen they originate from the lateral branches of the first trimerous ones. 5) At the proximal end of the main scale strand, primary xylems are said to be located adaxially, but in ours primary xylems are scattered around the pith which is located on the upper side of the bundle. 6) It was said that the sectional view of cone-scales was obtriangular in form and lateral membranous extensions were not visible, but in sectional view of the present one, cone-scales are mostly rhombic-rhomboidal and their lateral extensions are well developed. 7) Satake illustrated three lobed swellings at the middle of the cone-scale and three small vestiges located on this side of lobed swelling respectively. He regarded the former as ovular scale and the latter as placentae. In the present cone-scale, the adaxial swelling with three socket-like cavities may correspond to Satake's swelling, but it is unknown whether a projection seen in each cavity corresponds to each placenta or not. In Satake's illustration of extant cone-scale, there are ligule-like free edges in his cross section (his figs. 3-5). It is highly probable that these edges seen in the cross section of cone-scale

represent the free parts of an ovular scale, but such edges are not observed in the serial cross sections of the present cone-scale (e.g. Figure 8). From this comparison it is evident that except for the presence of three ovules on each scale, all the other features are different from the cone described in this paper. Although the present cone does not agree fully with that of the extant *Cunninghamia lanceolata* Hooker, we would like to retain for our specimen the generic name of *Cunninghamiostrobus* established by Stopes and Fujii (1910). We are not aware of a direct systematic lineage between a Late Cretaceous *Cunninghamiostrobus* and the extant *Cunninghamia*.
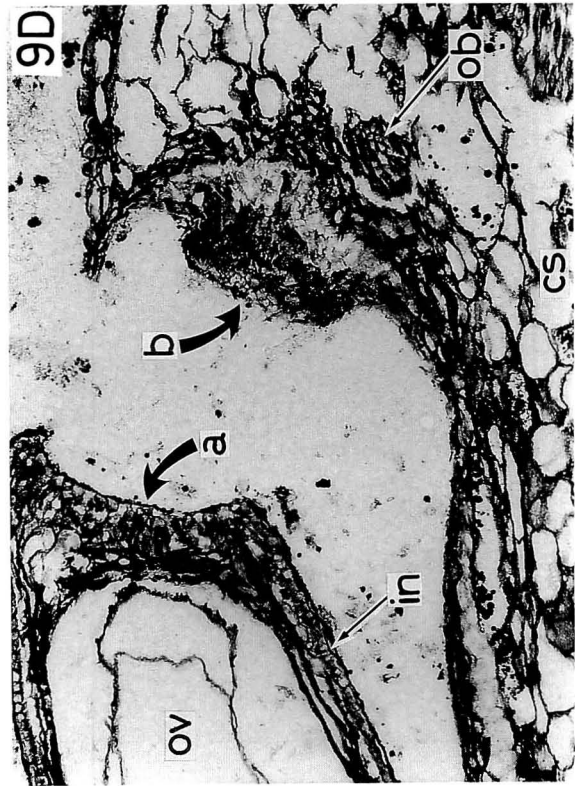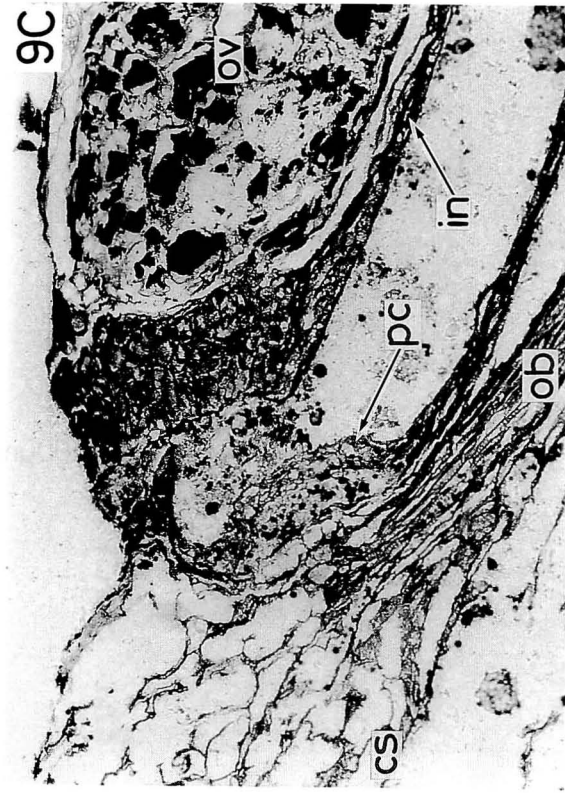
The present cone might be referable to those described by Stopes and Fujii (1910) and Ogura (1930), collected from the same stratigraphical unit, the Upper Yezo Group of Hokkaido, although the ovular features of the latter have not been ascertained so far and some minor differences are recognized between them. We are of the opinion that these minor differences may be attributed to the paucity of histological information in these earlier observations. Therefore we give here an emended diagnosis of *Cunninghamiostrobus yubariensis* together with its systematic position (see below).

Brief comparison with other permineralized *Cunninghamiostrobus* species and other allied fossils hitherto described
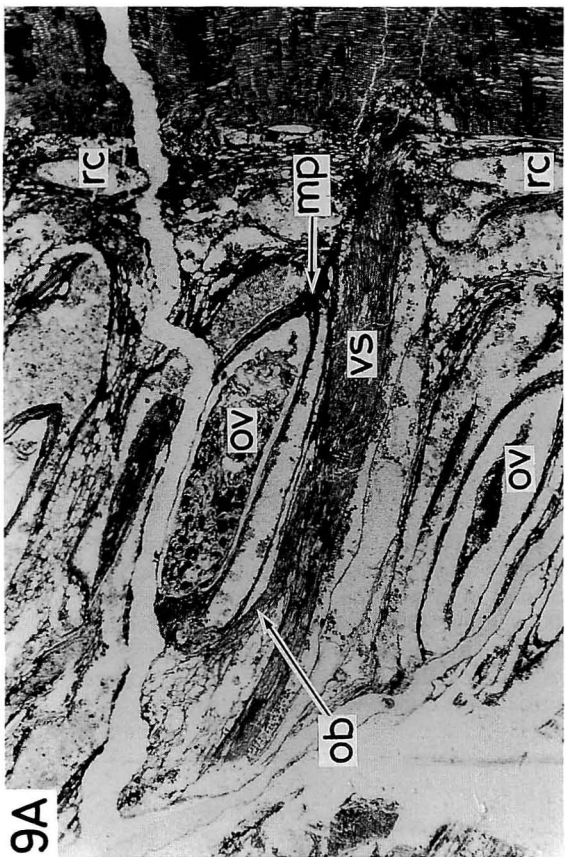
Miller (1975) described *Cunninghamiostrobus hueberi* from the Lower Cretaceous of California and Miller and Crabtree (1989) described *C. goedertii* from the Lower Oligocene of Washington. In both species ovules (seeds) are three in number on each ovular scale and the micropyle faces the cone axis. Besides the above, both *Elatides bommeri* Harris and *Sphenolepis kurriana* (Dunker) Schenk described by Harris (1953) from the Lower Cretaceous of Belgium might be comparable with the present species.

1) *Cunninghamiostrobus hueberi* was based on five ovular cones of which one has its vegetative shoot in organic connection. This species differs from the present species as follows : a) Cones are spherical or subelliptical, b) Presence of an annual ring is suggested in the cross section of vascular cylinder of the cone axis, c) Bordered pits seen on the radial section of tracheids are in two alternate rows, d) Ovular and bract scales are rather clearly recognized in the cone-scale, e) Resin canals are numerous, 8 in number in a bract scale except at the tip of scale where it is single, f) Ovular scale is divided into three at the tip, g) Ovules (seeds) are ellipti-
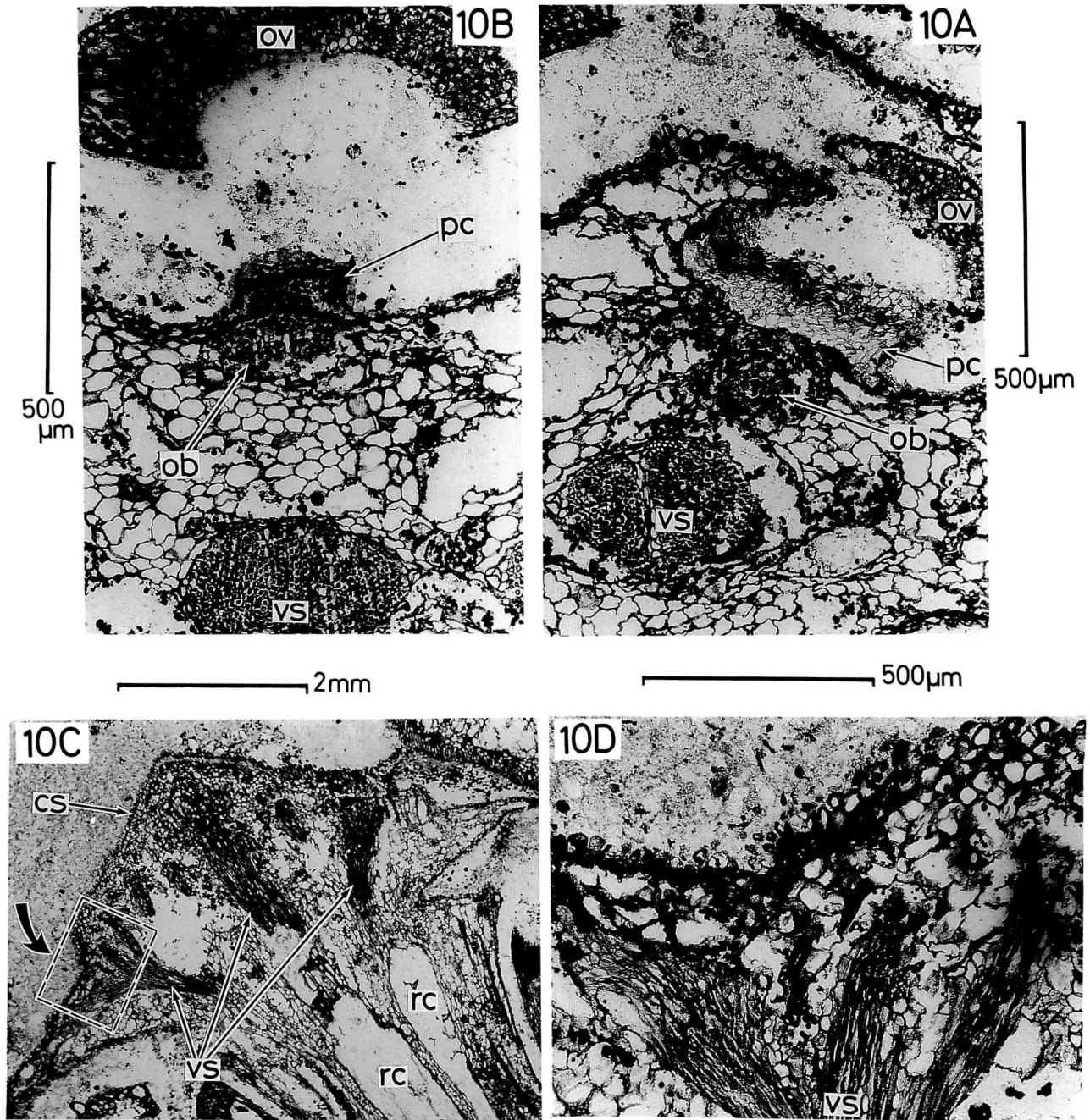
Figure 10. Cross section of ovular branch strands and paradermal section of the apical cone scale. **10A.** A cross section of the cone scale, showing an ovule, ovular branch strand, vascular strand and a supposed placenta (INH-0014-509). **10B.** A cross section of the basal part of a detached ovule (seed), showing a supposed placenta, ovular branch and a vascular strand (INH-0014-509). **10C.** A nearly paradermal section of an apical part of the cone scale, showing branched vascular strands in trimerous manner and resin canals (INH-0014-013). **10D.** Enlarged from the rectangular area in Figure 10C indicated by an arrow. cs : cone scale, ob : ovular branch, ov : ovule (seed), pc : supposed placenta, rc : resin canal, vs : vascular strand.
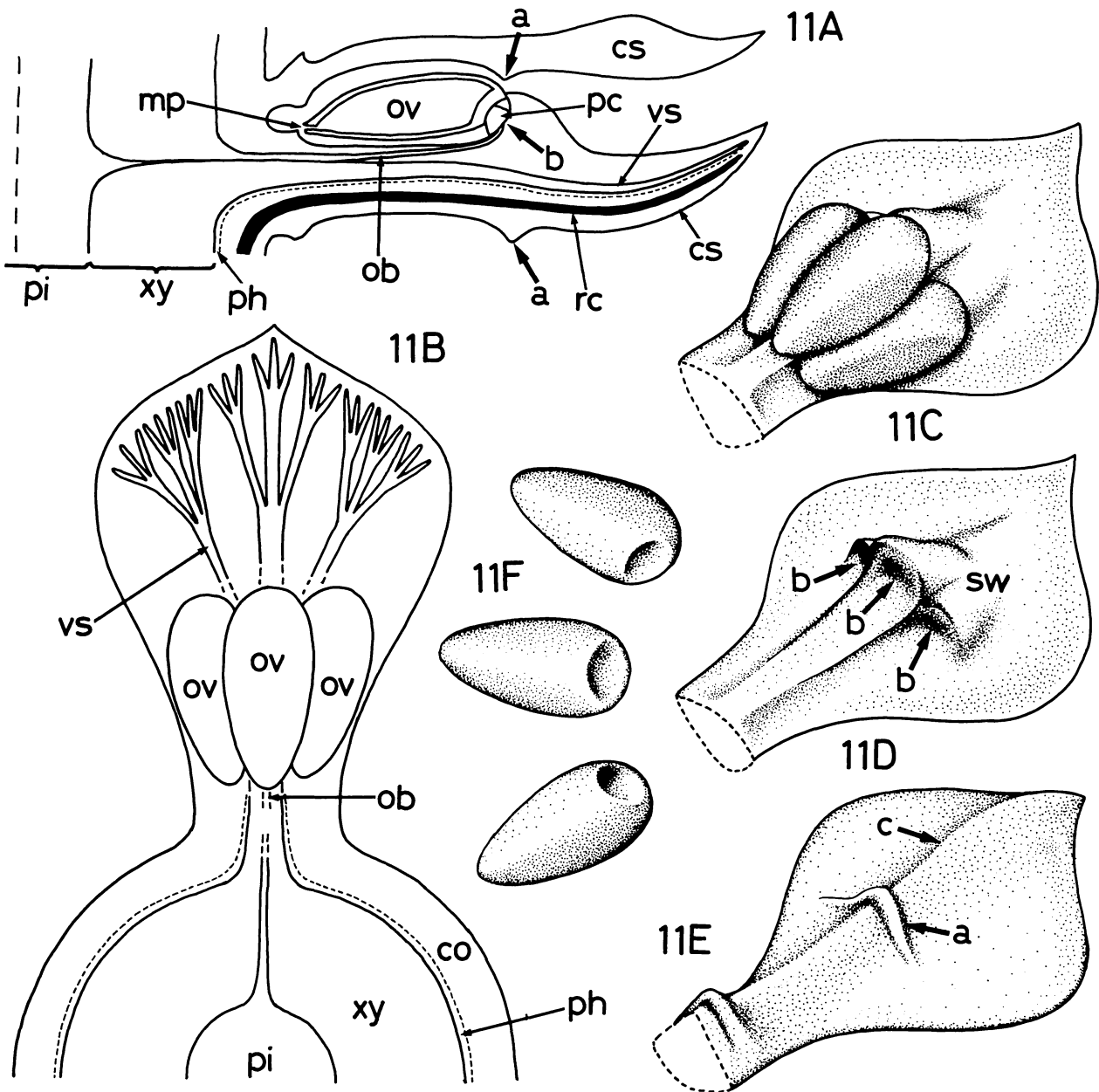
Figure 11. Vascular supplies, mode of attachment of ovules (seeds), form of cone scale and ovule (typified sketches). **11A.** A typical longitudinal section of the cone scale with the cone axis, showing a vascular strand, resin canal, ovular branch strand and an ovule with supposed placenta and micropyle. The abaxial rib indicated by arrow a in Figures 11A and 11E and the socket-like cavities at the inner side of swelling indicated by arrow b in Figures 11A and 11D, are considered to function to fix the ovules (seeds). **11B.** A cross section of the cone axis and a paradermal section of the cone scale, showing the branched vascular strands and ovules attached to the adaxial surface of cone scale. **11C.** An adaxial view of the cone scale and ovules. **11D.** An adaxial view of the cone scale removing the ovules, showing the socket-like cavities (arrows b) on inner side of swelling. **11E.** An abaxial view of the cone scale with a transverse rib, and a longitudinal rib (arrow c) corresponding to the abaxial angles indicated by the arrows, such as in Figures 8L, 8R, 8Q and 8N. **11F.** Ovules (seeds) with asymmetrically scooped base. co : cortex, cs : cone scale, mp : micropyle, ob : ovular branch, ov : ovule (seed), ph : phloem cylinder, pi : pith, rc : resin canal, sw : adaxial swelling, vs : vascular strand, xy : xylem cylinder.
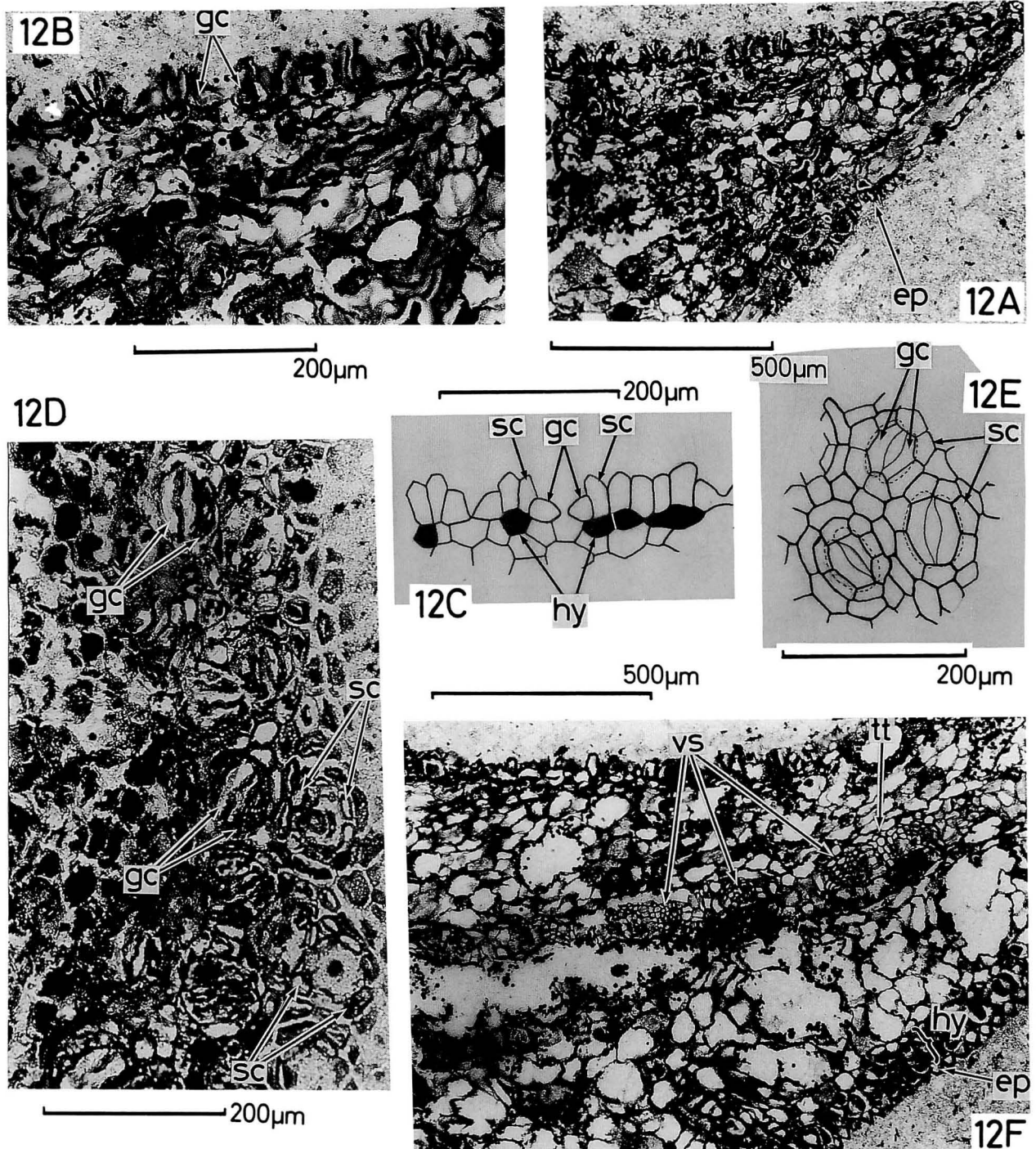
Figure 12. Epidermis, hypodermis and transfusion tissue in the cone scale. **12A.** A longitudinal section of the apical part of a cone scale, showing the epidermis consisting of taller cells. Stomatal complexes are rather closely distributed on adaxial surface of cone scale (INH-0014-109). **12B.** An enlarged part of Figure 12A. Guard cells are sunken and hypodermal cells are a single cell thick and devoid in distribution of stomatal rows. **12C.** A sketch of stomata and hypodermal cells drawn partly from Figure 12B. **12D.** An adaxial paradermal section of the apical part of cone scale, showing stomatal rows. The stomatal apertures are oriented randomly (INH-0014-013). **12E.** A sketch of the stomatal complexes, drawn partly from Figure 12D. Subsidiary cells are typically 7 in number per stoma. **12F.** A cross section of the apical cone scale, showing the branched vascular strands and alternate transfusion tissues, and the adaxial hypodermal layer of a single cell thick and abaxial layers of two or more cells thick (INH-0014-601). ep: epidermis, gc: guard cell, hy: hypodermis, sc: subsidiary cell, tt: transfusion tissue, vs: vascular strand.
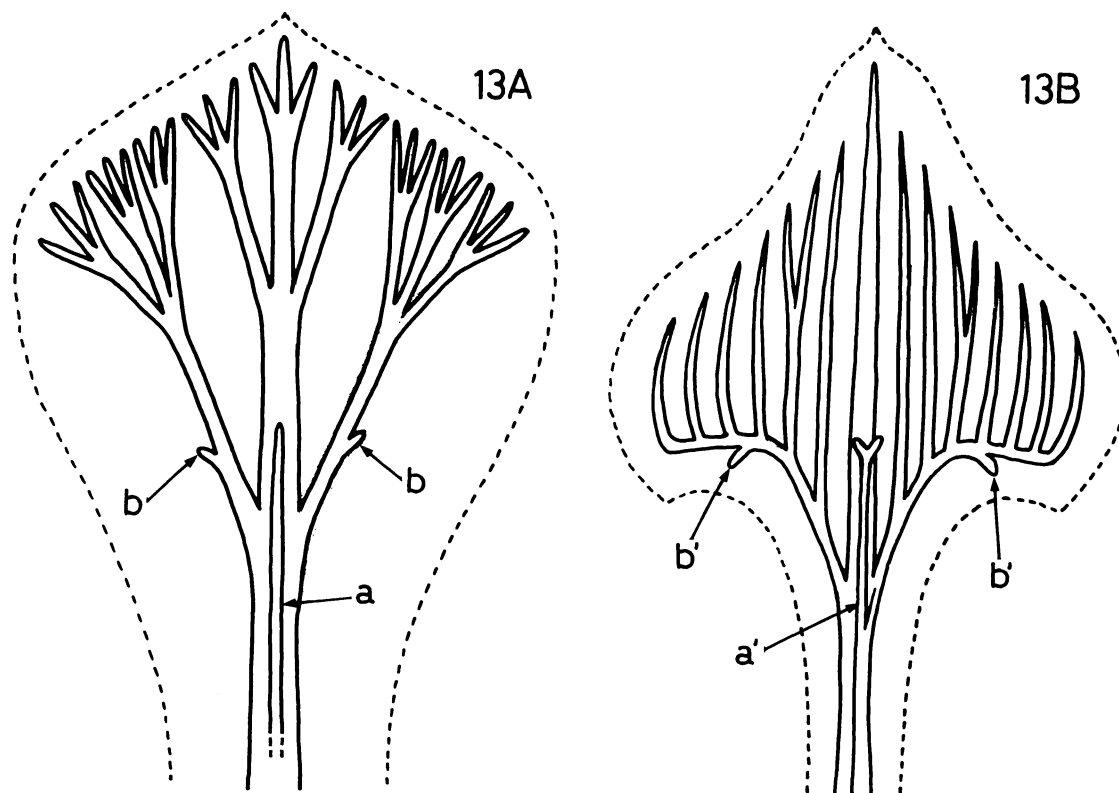
Figure 13. Difference of vasculature in the adaxial paradermal sections of cone scales between *Cunninghamiostrobus yubariensis* (Figure 13A) and extant *Cunninghamia lanceolata* (Figure 13B). **13A.** A central ovular branch strand (arrow a) is separated at/near the boundary region between cone axis and cone scale. A single main vascular strand then divides into three. Each first lateral branch sends off a short ovular branch (arrow b) which is received by the lateral ovule. The main vascular strands are typically divided twice in a trimerous manner. Drawn on the basis of serial cross sections of a cone scale (Figure 8). **13B.** Vasculature of the cone scale of extant *Cunninghamia lanceolata* Hooker (Satake, 1934). Arrow a′ indicates a central ovular branch strand of which the terminal part is dichotomously forked. A single main vascular strand is divided in a trimerous manner. Each first lateral branch sends off a short lateral ovular strand (arrow b′). The second vascular strands are given off from the first vascular strands in parallel to each other and directed forwards; the total number of secondary strands is 13-14.

cal in form with wing-like flanges laterally.

2) *Cunninghamiostrobus goedertii* was based on six ovular cones. This species differs from the present species as follows : a) Cones are spherical or elliptical, b) In cone-scale ovular and bract scales appear to be separated and the former is represented by a small flap, c) Resin canals are numerous, 5-15 in number in each bract scale, d) Seeds are fairly large in size and flattened.

3) *Elatides bommeri* was based on leafy shoots with both ovular and pollen cones preserved as compressions. Its ovular cone differs from that of our specimen as follows : a) Cones are considerably small in size, b) Cone-scale consists of ovular and comparatively large bract scales, each with a spine at the tip, 1 mm long and 0.3 mm wide, c) A single large-sized resin canal is present in a bract scale, d) Ovular scale is represented by a 'ligule' with trifurcate tip, e) Seeds are 3-5 in number in each cone-scale.

4) *Sphenolepis kurriana* was based on leafy shoots

with ovular cones and has often been referred to in the comparison of fossil taxodiaceous conifers. Its ovular cones have been compared by some authors with those of *Cunninghamiostrobus,* but the former cones differ from the latter in having six ovules on each cone-scale.

5) Recently such taxodiaceous ovular cones without peltate scale-tip were described from the Upper Yezo Group as *Parataiwania nihongii* (Nishida *et al.,* 1992) and *Mikasastrobus hokkaidoensis* (Saiki and Kimura, 1993). Both species are distinguished from the present species mainly by the number of ovules on each cone-scale : four in *Parataiwania* and 4-5 in *Mikasastrobus.*

In this paper we mentioned that *Cunninghamiostrobus yubariensis* is far apart from extant *Cunninghamia* especially in the vasculature and the number and arrangement of resin canals in the cone-scale, except for having three ovules on each scale.

It appears that the taxodiaceous conifers were at the culmination of their development in Late Cretaceous time.

To our knowledge they appear to have been much diversified during that period. The extant taxodiaceous conifers are thought to be restricted decendants, although at present we can not explicate fully the direct systematic lineages and the transition from the Late Cretaceous taxodiaceous conifers to the present-day ones.

Systematics

Gymnosperms
Coniferophyta
Coniferales
Taxodiaceae

Organ-genus *Cunninghamiostrobus* Stopes and Fujii, 1910

Emended generic diagnosis.—Cone scales and axis in structure like those of the living genus *Cunninghamia*. Cone taxodiaceous ovular. Cone-scale not peltate, but in close helicals, bearing three ovules (seeds) on each adaxial surface. Micropyle facing the cone axis. Histological features of the cone axis and cone scale rather more similar to those of the extant *Cunninghamia* than to any other extant taxodiaceous genera.

Cunninghamiostrobus yubariensis Stopes and Fujii, 1910. emend.

Figures 1-13A

Specimen.—Lectotype: INH-0014 (peel-slides; 001, 002, 011-014, 102-110, 201-211, 301-303, 401-403, 501-514, 601). All are kept in the Institute of Natural History, Tokyo.

Locality and horizon. — Present specimen: Kami-Kinenbetsu Valley, Tappu, Obira-cho, Rumoi-gun, Hokkaido (roughly 44°04′N and 141°58.5′E). Upper Yezo Group (Turonian) (collected by Hiroshi Takahashi).

Occurrence.—A single ovuliferous cone buried in a calcareous nodule was collected.

Emended diagnosis.—Cone ovular, cylindrical, more than 6.5 cm long and up to 2.5 cm in diameter. Cone axis thick, 9-11 mm in diameter, with many helically arranged cone-scale complexes, at a wide angle or nearly perpendicular. Cone-scale flattened and expanded laterally in its apical half. Ovular and bract scales completely adherent. Cone axis consisting of pith, xylem and phloem cylinders and cortex. Pith consisting mainly of parenchymatous cells. Primary xylem endarch and secondary xylem without annual rings and with bordered pits in one or two row opposite. Ray a single row 2-11 cells high. Resin canals in two concentric cylinders in the cortex and outer ones continuing into the cone-scale. A thick and eccentric vascular strand separating from the xylem cylinder and entering into the cone-scale, the strand giving adaxially a slender ovular branch, connecting with the central ovule. The vascular strand branching twice or thrice in trimerous manner. The first lateral branches giving short ovular branches to the lateral

ovules. Resin canals abaxial, three; lateral two disappearing in apical half of the cone-scale. Transfusion tissue present at the apical part of cone-scale alternating with branched vascular strands. Ovules three on the adaxial surface of a cone-scale. The bases of ovules fixed by the socket-like cavities on an adaxial swelling. An abaxial transverse ridge present also helpful for fixing the ovules. Ovules (seeds) flattened elliptical, about 4 mm long, 1.6-1.8 mm wide and 0.6-0.8 mm thick, without wing-like flange and with asymmetrically scooped base. Integuments (seed coats) consisting of three layers, and the micropyle facing the cone axis. Epidermis covering whole surface of the cone-scale and hypodermis present in the apical part, a single layer adaxially and two layers abaxially, devoid of stomatal rows. Stomata amphistomatic in the apical part, haplocheilic, sunken and randomly orientated. Vegetative shoot and male cone not known.

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Hokkaido 北海道, Kami-Kinenbetsu 上記念別, Obira 小平, Obirashibe 小平蘂, Tappu 達布, Yubari 夕張, Yezo 蝦夷.

990 | *Inoceramus* (*Platyceramus*) *szaszi* sp. nov. (Bivalvia) from the Coniacian (Cretaceous) of Hokkaido

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Abstract. *Inoceramus* (*Platyceramus*) *szaszi* sp. nov. is established on a sample and supplementary specimens from the upper Middle Coniacian of the Ikushunbetsu valley, central Hokkaido. It resembles *I.* (*Pl.*) *mantelli* de Mercey, 1877 and also *I.* (*Pl.*) *troegeri* Noda, 1992, but is distinct from them in its fan-shaped outline, fairly constant obliquity and inconspicuous ornamentation. Statistical analyses of some selected characters also reveal significant morphological differences. On the ground of stratigraphic position and morphological resemblance, *I.* (*Pl.*) *szaszi* is presumed to descend from *I.* (*Pl.*) *troegeri* of the Lower to lower Middle Coniacian, but it is probably an offshoot without giving rise to any descendant.

Key words : *Inoceramus* (*Platyceramus*), Coniacian, biometry, phylogeny

Introduction

The area of the Ikushunbetsu River, including its tributary the Ponbetsu, is celebrated as a classical field of Cretaceous stratigraphy and paleontology.

The specimens for this study were previously included in *Inoceramus* (*Platyceramus*) *yubariensis* Nagao and Matsumoto by Noda (1986). At the suggestion of T. Matsumoto, *I. yubariensis* was restudied by Noda and Toshimitsu (1990) and has proved to be a junior synonym of *I* (*Platyceramus*) *mantelli* de Mercey. In the course of that study, a sample from the locality Ik2709 of the Ponbetsu area has been morphologically discriminated from other samples. This paper gives the result of our study of this sample.

Note on stratigraphy

The specimens examined were obtained from a calcareous nodule in the sandy siltstone exposed in the upper reaches of the Ponbetsu-gono-sawa (sometimes called the Takino-sawa or Takiyoshi-zawa), a tributary of the Ponbetsu River, where the Cretaceous deposits of the upper part of the Yezo Group are partly exposed, as described by Matsumoto (1984) and Matsumoto and Noda (1985). We redescribe, herein, the stratigraphic sequence after Matsumoto (1984) with additional information, showing a route map in Figure 1.

The Coniacian strata are well exposed along the creek. Owing to lateral change, the green sandstone at the base of the Coniacian is thinner and more silty than in the outcrops to the east (Matsumoto, 1984, figs. 2, 3). The main part is fine sandy siltstone with a more sandy part in the middle of the Coniacian. Due to NW-SE wrench faults and an anticline, the sequence is observable repeatedly. Throughout this seqence inoceramids occur commonly and successively and are associated with some ammonites. The Coniacian Stage can be divided into three parts in this section. The lower part, represented by Ik2726a, b, 2716, 2717, 2710a-k, 2785 and 2786, contains *Inoceramus* (*Cremnoceramus*) *rotundatus* Fiege (common), *I.* (*I.*) *uwajimensis* Yehara (few), *Didymotis akamatsui* (Yehara), *Anagaudryceras limatum* (Yabe), *Forresteria* (*Reesideoceras*) *petrocoriensis* (Coquand), *F.* (*R.*) sp. and *F.* (*Harleites*) cf. *harlei* (de Grossouvre) (rare). The middle part, represented by Ik2726c, 2725, 2713, 2710l, m, 2709 and 2748, is characterized by the abundant occurrence of *I.* (*I.*) *uwajimensis*. Associated fossils are *F.* (*Forresteria*) *alluaudi* (Boule, Lemoine and Thevenin), *Barroisiceras* (*Baseoceras*) *inornatum* Matsumoto and *Kossmaticeras theobaldianum* (Stoliczka). *I.* (*Pl.*) *szaszi* sp. nov. was found by S. Uchida from Ik2709. The sandy siltstone at loc. Ik2709, which we allocate to the upper portion of the middle part, yields *I.* (*I.*) *uwajimensis* abundantly and *I.* (*Cordiceramus*) *kawashitai* Noda and *I.* (*Cremnoceramus*) *mihoensis* Matsumoto rarely. The
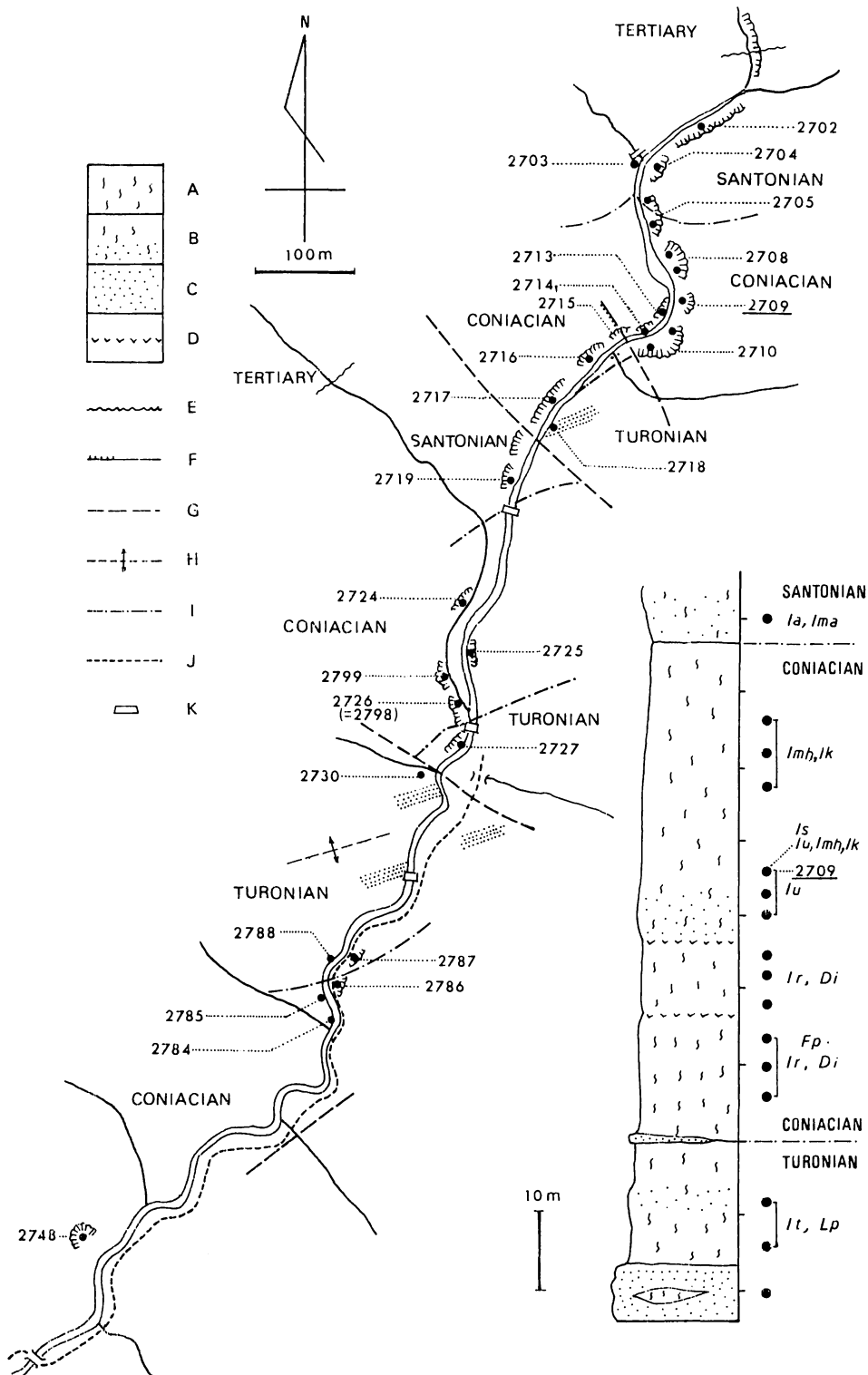
Figure 1. Route map along the Ponbetsu-gono-sawa, with stratigraphic profile. Locality number should have prefix Ik. Legend for profile and map, A : fine-grained sandy siltstone, B : fine-grained silty sandstone, C : thick-bedded sandstone, D : tuff, E : unconformity, F : fault (observed), G : fault (inferred), H : anticline, I : stage boundary, J : path (partly damaged), K : debris barrier. Abbreviation of selected species, *Ia* : *Inoceramus (I.) amakusensis*, *Ima* : *I. (Platyceramus) mantelli*, *Imh* : *I. (Cremnoceramus) mihoensis*, *Ik* : *I. (Cordiceramus) kawashitai*, *Is* : *I. (Pl.) szaszi*, *Iu* : *I. (I.) uwajimensis*, *Ir* : *I. (Cr.) rotundatus*, *It* : *I. (I.) teshioensis* and *I. (I.) tenuistriatus*, *Di* : *Didymotis akamatsui*, *Fp* : *Forresteria (Reesideoceras) petrocoriensis*, *Lp* : *Lymaniceras planulatum*.

upper part, represented by Ik2708, 2705 and 2724, is characterized by *I.* (*Cr.*) *mihoensis*, *I.* (*Co.*) *kawashitai* and *I.* (*Pl.*) *mantelli*.

Another specimen was obtained as a float in a branch of the Kumaoi-zawa, which is a tributary of the upper course of the Ikushunbetsu River, where the Coniacian sediments are exposed, showing gradually higher parts of sequence eastwards along the creek.

Systematic description

Family Inoceramidae Zittel, 1881

Genus *Inoceramus* Sowerby, 1841
Subgenus *Platyceramus* Seitz, 1961

Type species.—*Inoceramus mantelli* de Mercey, 1877 by original designation (Seitz, 1961, p. 54, ex Heinz, 1932, p. 10).

Remarks.—For the diagnosis and affinities of this subgenus, see Seitz (1961, p. 54) and Noda (1983, p. 202 ; 1992, p. 1314).

Inoceramus (**Platyceramus**) **szaszi** Noda and Uchida sp. nov.

Figures 2, 3, 5

Inoceramus (*Platyceramus*) *yubariensis* Nagao and Matsumoto. Noda, 1986 (part), p. 363, listed.

Types.—Holotype : JG. H2901 obtained by Uchida at loc. Ik2709, from the sandy siltstone in the upper Middle
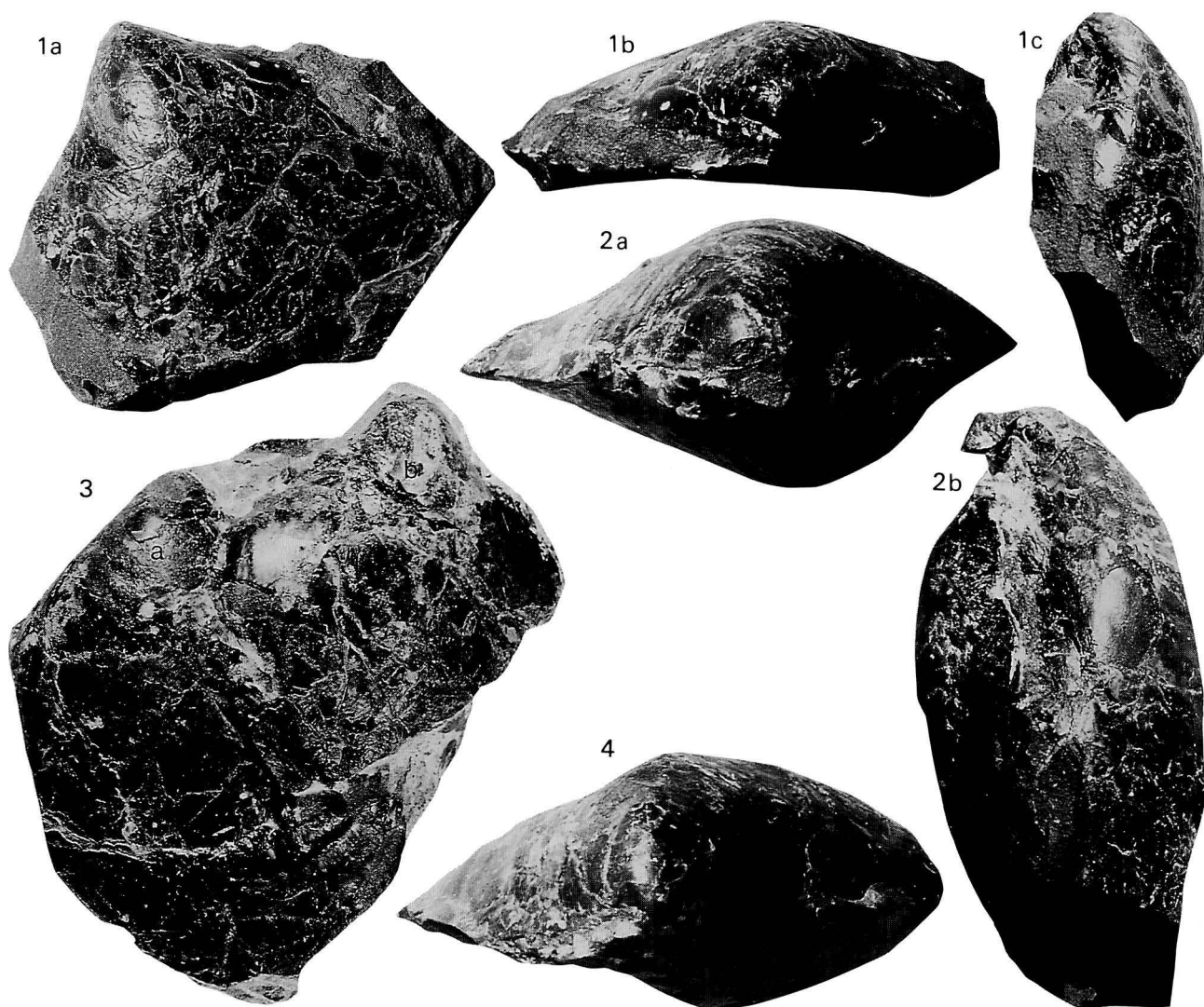

Figure 2. *Inoceramus* (*Platyceramus*) *szaszi* Noda and Uchida sp. nov.   All figures natural size.   **1a–c.** JG. H2909, paratype, from loc. Ik 2709.   **2a, b**. JG. H2794, paratype, same locality.   **3**. JG. H3099a and b, paratypes, from loc. Ik 1623p, a tributary of the Kumaoi-zawa.   **4**. JG. H2903, paratype, from loc. Ik2709.
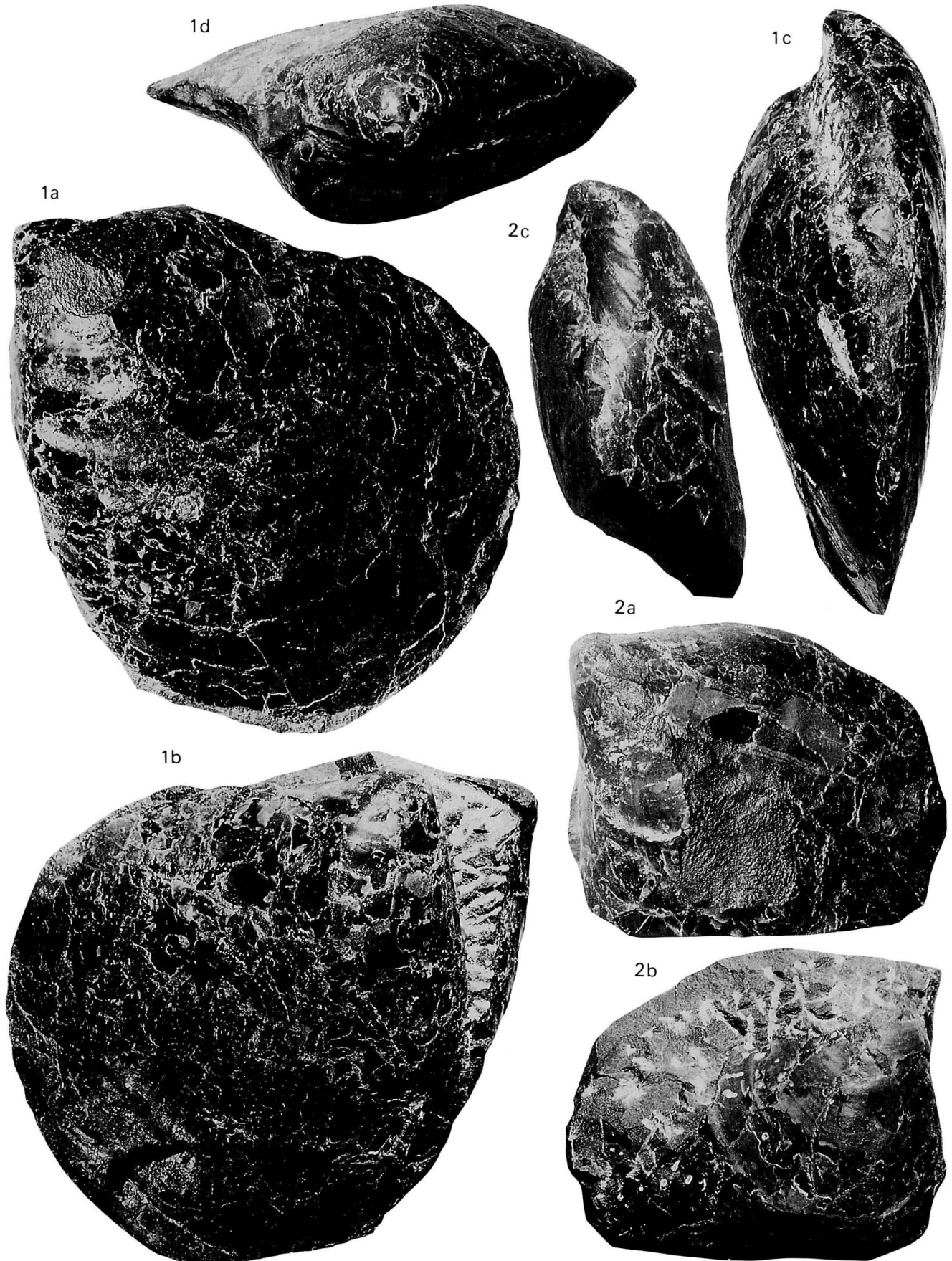
Figure 3. *Inoceramus* (*Platyceramus*) *szaszi* Noda and Uchida sp. nov. All figures natural size. **1a–d**. JG. H2901, holotype, from loc. Ik2709, Ponbetsu-gono-sawa. **2a–c**. JG. H2903, paratype, same locality.

Coniacian in the Ponbetsu-gono-sawa. Paratypes: JG. H2794, 2898, 2903 and 2909, obtained from the same nodule as the holotype. JG. H3099a and 3099b are floats collected at loc. Ik1623 in a branch of the Kumaoi-zawa, originating probably from the Coniacian mudstone exposed along the upper reaches of the creek.

Repository.—JG.: Jonan Geological Association, kept tentatively in Noda's personal laboratory, Oita.

Diagnosis.—Shell medium to large, equivalve, gently and uniformly inflated, fan-shaped in outline and slightly higher than long. Umbo small and terminal. Shell ornamentation weak; concentric undulations developed in later stages of growth, low and irregular in breadth, with superimposed minor rings.

Species name.—This species is dedicated to Dr. Ladislau Szász of the Institute of Geology and Geophysics, Bucaresti [Bucharest], who has contributed much to the paleontology of the Cretaceous Mollusca and biostratigraphy.

Observation.—The holotype (JG. H2901) and paratypes (JG. H2794, JG. H2798 and JG. H2903) are closed valves, but the valves are somewhat displaced along the commissure plane. These specimens are internal moulds for the most part but the prismatic and nacreous shell layers are partially preserved. The shell is slightly higher than long with l/h=0.92 on average, gently and uniformly inflated along the growth axis. The umbo is small, terminal and slightly projected over the hinge line. The anterodorsal part is narrow and steep or nearly perpendicular to the commissure plane, anterior part moderately slopes and gradually flattens out to the posterior part, which passes into the wing-like area without any sharp boundary. The growth axis is nearly straight. The anterodorsal margin is nearly straight, anterior and ventral margins form a semi-circular outline, passing gradually to the broadly arcuate posterior margin, which forms an obtuse angle with the hinge line. The hinge line is slightly longer than half of the shell length on average. The hinge structure is invis-
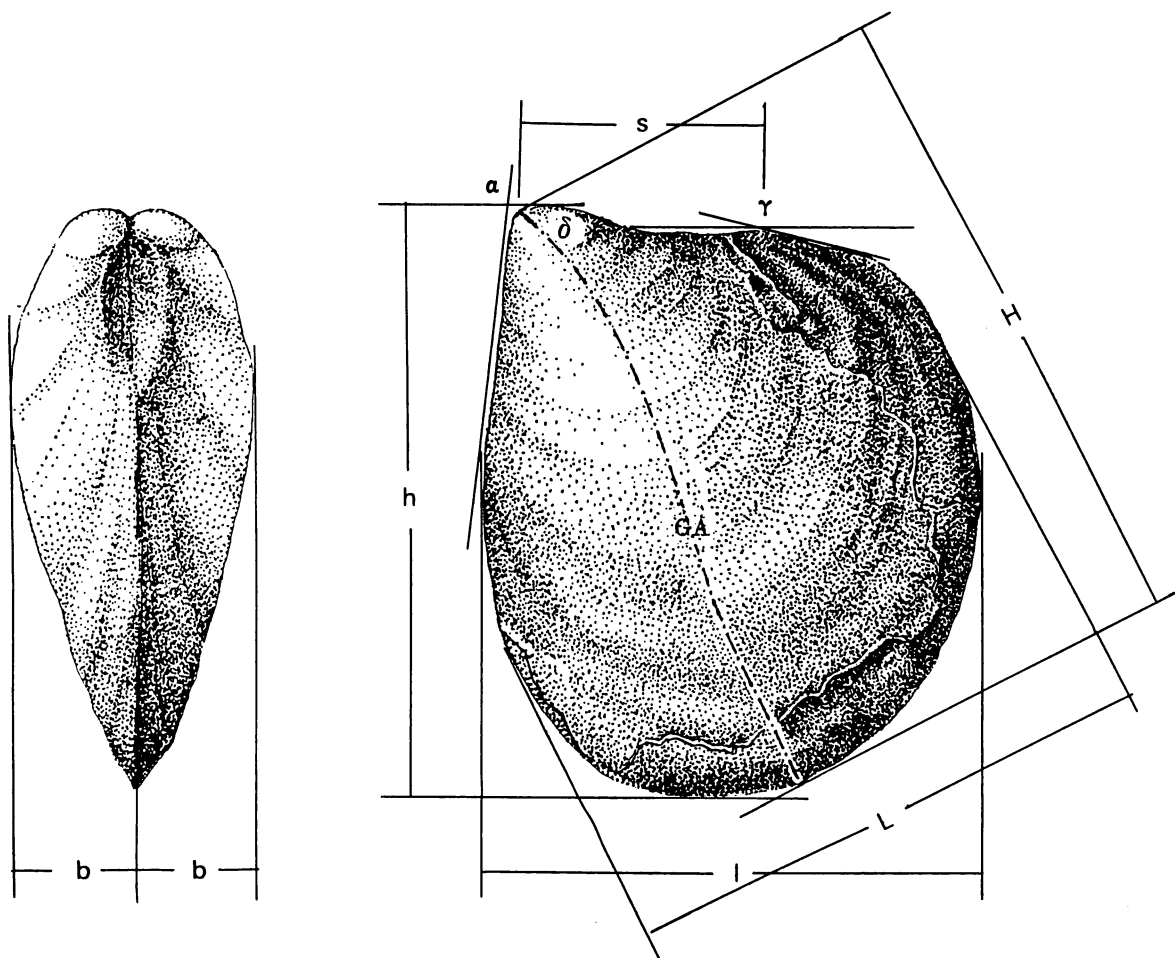

Figure 4. Basic linear measurements and angles. h: shell height, l: shell length, b: shell breadth, H: maximum linear dimension from umbo to ventral extremity, L: maximum linear dimension perpendicular to H, GA: growth axis, s: length of hinge line, α: anterior hinge angle, γ: posterior hinge angle, δ: obliquity, angle between hinge line and H.
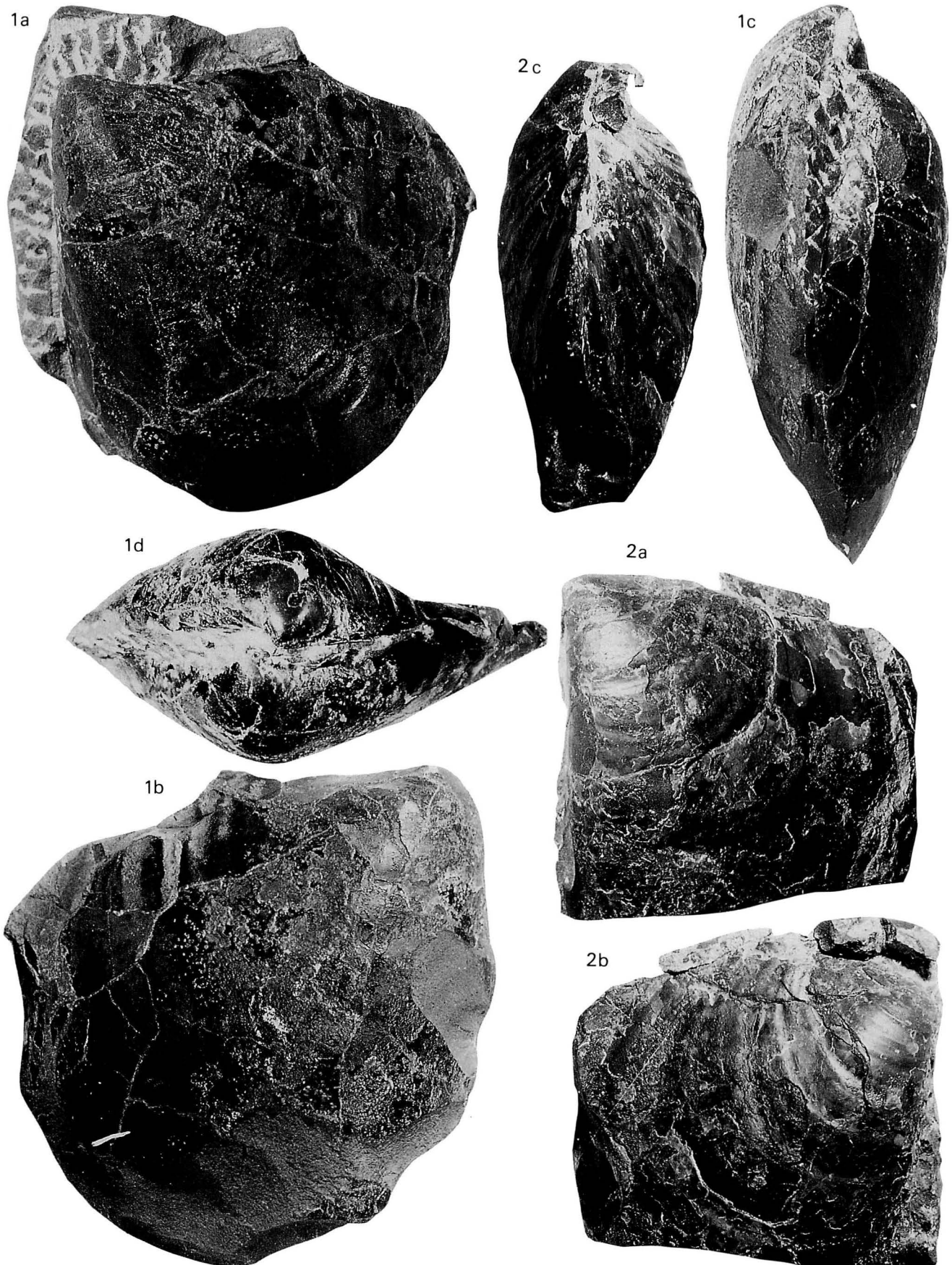
Figure 5. *Inoceramus* (*Platyceramus*) *szaszi* Noda and Uchida sp. nov. All figures natural size. **1a-d.** JG. H2898, paratype, from loc. Ik2709. **2a-c.** JG. H2794, paratype, same locality.

ible.

The ornamentation of the shell consists of major and minor concentric sculptures in combination, which are weak and obscure near the umbo. The concentric undulations are low, round-topped and disposed at irregular intervals; the minor rings develop in umbonal region and also superimposed on the undulations. Fine lirae are discernible near the umbo of the specimens JG. H2903 and 3099a.

Biometry.—The basic linear measurements and angles are shown in Figure 4. The measurements of selected characters and their statistics are shown in Tables 1 and

2, respectively. As shown in Table 2, Pearson's coefficients of variation are, in general, small for all characters examined.

The individual relative growth of shell length (l) vs. shell height (h) and shell breadth (b) vs. shell height (h) of the two well-preserved specimens are demonstrated in Figure 6. The reduced major axes of b vs. h show isometry in the two specimens, whereas those of l vs. h show negative allometry.

The ontogenetic changes of l/h, b/h and obliquity (δ) are shown in Figures 7A, B and C, respectively. As is clear from Figure 7A, l/h decreases gradually with growth

Table 1. Measurements of *Inoceramus* (*Platyceramus*) *szaszi* sp. nov. from Hokkaido. Linear dimensions in mm.

specimen	valve	h	l	b	H	L	s	α
JG. H2794	L	66.0	61.3	17.4	74.5	62.0	—	101°
	R	62.2	57.4	14.9	68.7	59.8	32.0	101°
JG. H2898	L	87.8	82.0	20.6	92.8	83.0	39.1	99°
	R	95.2	89.6	22.0	100.8	87.0	42.6	98°
JG. H2901	L	104.4	92.0	22.0	112.1	97.9	—	98°
	R	91.5	84.2	21.4	102.1	89.3	42.1	96°
JG. H2903	L	64.8	60.6	15.0	71.8	61.5	33.2	99°
JG. H2909	L	51.8	47.0	12.1	53.6	47.0	23.8	103°

specimen	valve	γ	δ	l/h	l/h$_{H=60mm}$	b/h	L/H	s/l
JG. H2794	L	—	67°	0.93	0.98	0.26	0.83	—
	R	—	64°	0.92	0.98	0.24	0.87	0.56
JG. H2898	L	127°	66°	0.93	0.93	0.23	0.89	0.48
	R	127°	65°	0.94	0.97	0.23	0.86	0.48
JG. H2901	L	128°	65°	0.88	0.87	0.21	0.87	—
	R	131°	63°	0.92	0.94	0.23	0.87	0.50
JG. H2903	L	131°	64°	0.94	0.96	0.23	0.86	0.55
JG. H2909	L	132°	64°	0.91	—	0.23	0.88	0.51

l/h$_{H=60mm}$: ratio of l : h at the growth stage of 60 mm in H. L : left valve, R : right valve.

Table 2. Biometric characters of *Inoceramus* (*Platyceramus*) *szaszi* sp. nov. from Hokkaido.

	α	γ	δ	1/h	1/h$_{H=60mm}$	b/h	L/H	s/l
N	8	6	8	8	7	8	8	6
m	99.4	129.3	64.8	0.921	0.947	0.233	0.866	0.513
s	2.20	2.25	1.28	0.0196	0.0390	0.0139	0.0177	0.0344
v	2.21	1.71	1.98	1.99	4.21	5.97	2.04	6.71

N : sample size, *m* : mean value, *s* : standard deviation, *v* : Pearson's coefficient of variation
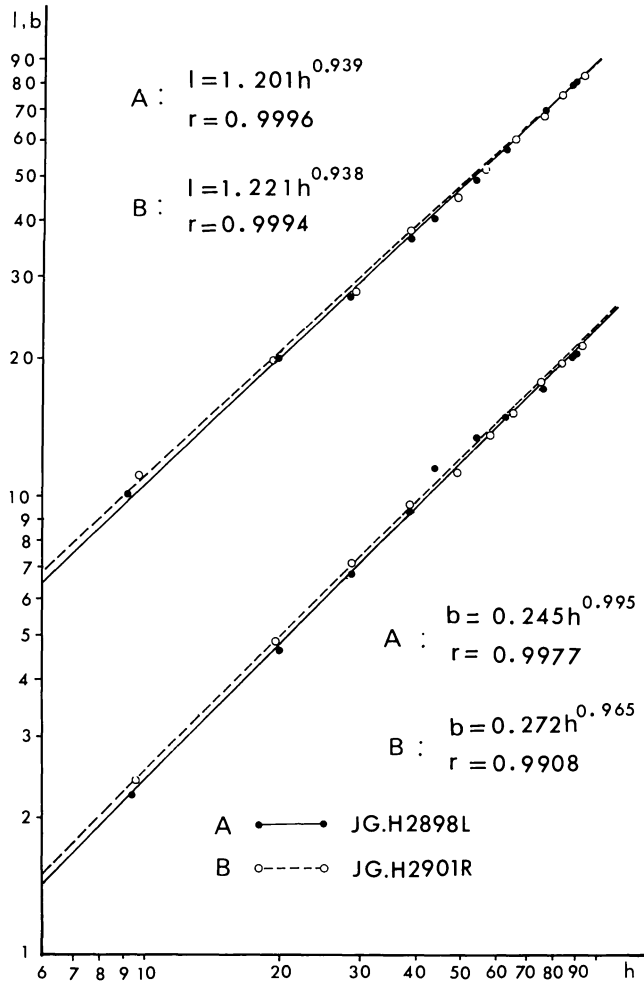
Figure 6. Diagram showing the individual relative growth (l vs. h and b vs. h) for selected specimens of *I. (Pl.) szaszi* Noda and Uchida sp. nov.
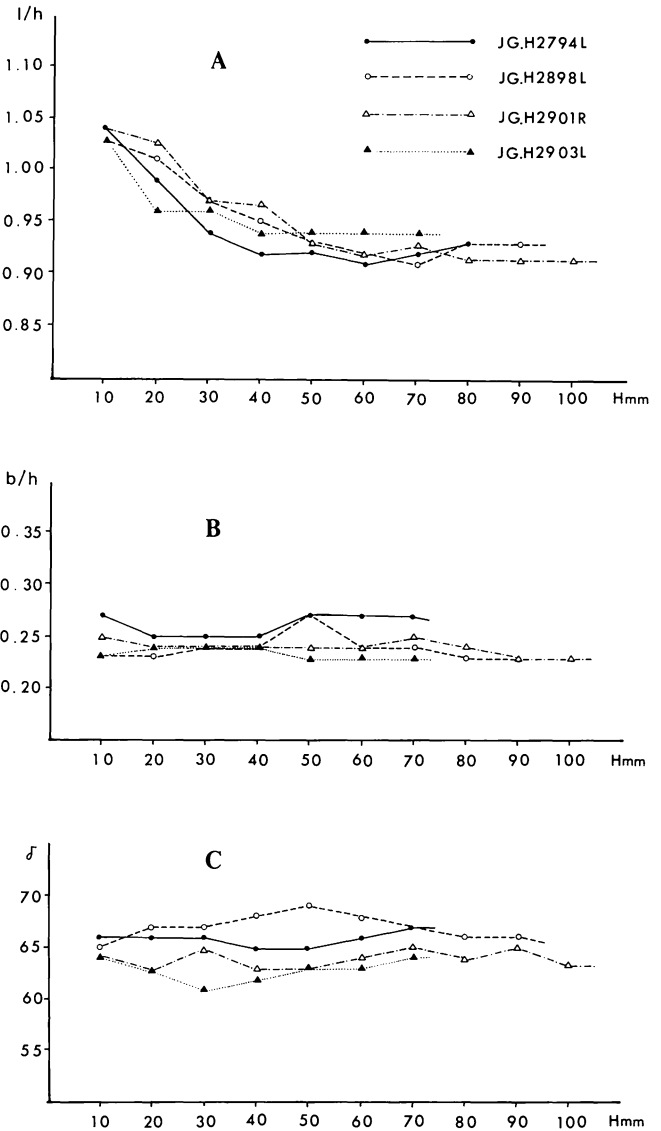

Figure 7. Diagram showing the ontogenetic change of selected characters of *I. (Pl.) szaszi* Noda and Uchida sp. nov. A : ratio l/h, B : ratio b/h, C : obliquity.

up to H=50 mm in each individual, whereas the b/h and obliquity (δ) are nearly constant throughout growth as shown in Figures 7B and C.

The profiles of the two specimens in three directions are illustrated in Figure 8.

Remarks.—The specimens examined are well preserved without secondary deformation, but the valves are somewhat displaced along the commissure plane. The prismatic and nacreous layers are preserved and the surface ornamentation is precisely observed in JG. H2794, 2903 and 3099a. JG. H2901 and 2909 have only the inner layer and JG. H2898 is an internal mould with partially preserved inner shell layer. Several small pits are scattered on the surface of the mould. These are probably the marks of hemispherical pearls produced to cover areas of shell killed by boring barnacles (Seilacher, 1969). Such small pits are commonly observed on the internal moulds of certain inoceramid shells.

Comparison and discussion.—It is noticed that the sample from loc. lk2709 is clearly discriminated mor-

phologically from other samples by means of *t*-tests, other biometric analyses and precise observation. The specimens from loc. lk2709 have a considerably inflated umbonal region, as shown in Figure 8, in comparison with those of *I. (Pl.) mantelli* (see Noda and Toshimitsu, 1990, p. 502, fig. 11), and show a comparatively steep posterodorsal flank. As is clear from Table 3, the results of *t*-tests indicate that the mean values of b/h are also significantly different. The ontogenetic change of l/h and obliquity (δ) is clearly different between the present species and *I. (Pl.) mantelli*. Namely, l/h of the present species decreases gradually up to a growth stage 50 mm in H and then becomes about 0.95 on average, whereas that of *I (Pl.) mantelli* decreases continuously to the full-
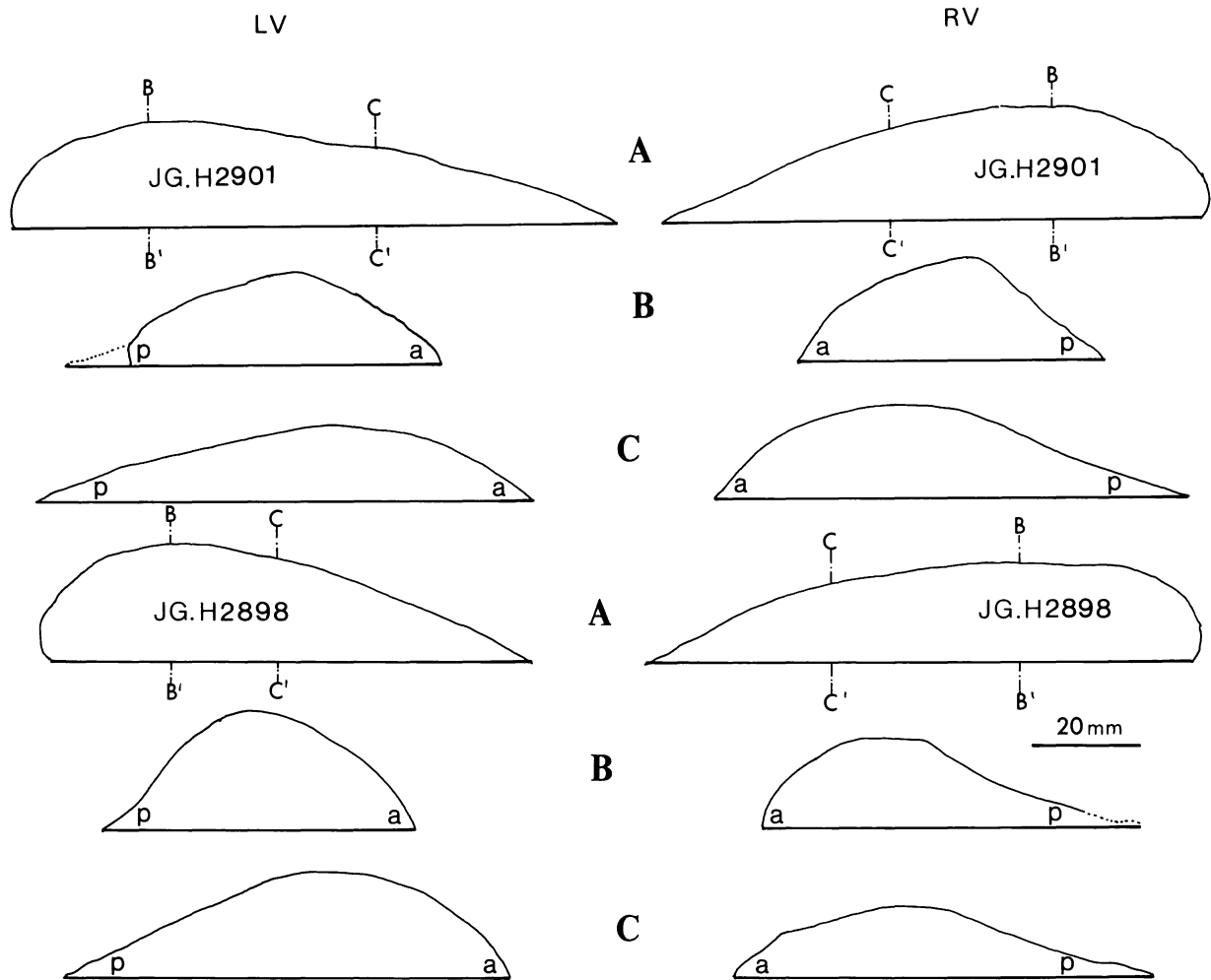
LV

RV

Figure 8. Profiles of two selected specimens of *I. (Pl.) szaszi* Noda and Uchida sp. nov. in three directions. A : vertical section along the growth axis, B : transverse section at the highest point of shell convexity, perpendicular to the growth axis, C : transverse section at the broadest part perpendicular to H.

grown stage. The shell obliquity is about 65° in the present species, whereas that of *I. (Pl.) mantelli* gradually increases with growth (Noda and Toshimitsu, 1990, p. 500, fig. 10C). The individual relative growth of l vs. h and b vs. h are shown in Table 4 and Figure 6 ; the specimens show negative allometry in l vs. h and isometry in b vs. h, whereas the specimens of *I. (Pl.) mantelli* show negative allometry in both characters. From the above comparison the present specimens can be morphologically discriminated from the specimens of *I. (Pl.) mantelli*.

I. (Pl.) troegeri Noda, 1992 from the lower part to lower portion of the middle part of the Coniacian of Hokkaido shows a large extent of variation. The specimens JG. H3010 and 3011b resemble the holotype of the present species in equivalveness, gently inflated shell and weak ornamentation. However, JG. H3010 and 3011b are elongated along the growth axis (L/H=0.76-0.79), and have a larger posterior hinge angle, ranging from 135° to 143° and smaller obliquity (δ=59°-61°) if compared with any speci-

men of the present species (compare Noda, 1992, table 1 and p. 1320, 1321 with Table 1 of this paper). Moreover, as shown in Table 3, the result of t-tests indicates that significant differences exist in the characters of α, γ, δ, l/h and L/H. This fact suggests that the sample from loc. Ik2709 is morphologically different from the sample of *I. (Pl.) troegeri* at the population level. As to the ontogenetic change of selected characters, the specimens of *I. (Pl.) troegeri* show nearly constant values of l/h and obliquity, ranging from 0.89-0.95 and 56°-60°, respectively, and b/h decreases gradually with growth, whereas in those of this species l/h decreases gradually up to 50 mm in H and then becomes constant, ranging between 0.90 and 0.94, and b/h and obliquity are also nearly constant, ranging between 0.23-0.28 and 61°-70°, respectively. Furthermore, with respect to individual relative growth of the holotype and another well-preserved specimen of *I. (Pl.) troegeri*, the relation between l and h is isometric, and the relation between b and h is negatively

Table 3. F-test and Student's t-test for selected characters of *Inoceramus* (*Platyceramus*) *troegeri* Noda, *I.* (*Pl.*) *szaszi* sp. nov. and *I.* (*Pl.*) *mantelli* de Mercey.

		α	γ	δ	l/h	b/h	L/H	s/l
A	N	25	24	25	25	(18)	25	21
	m	93.2	140.1	60.3	0.888	(0.225)	0.782	0.490
	s	4.95	3.66	2.04	0.0569	(0.0193)	0.0286	0.0256
F value significance		5.0625 ●	2.6460 ○	2.5400 ○	2.1289 ○	1.9302 ○	2.6109 ○	1.8057 ○
t value significance		4.925 ●	6.857 ●	5.854 ●	2.610 ●	1.052 ○	7.794 ●	1.801 ○
B	N	8	6	8	(7)	8	8	6
	m	99.4	129.3	64.8	(0.947)	0.233	0.866	0.513
	s	2.20	2.25	1.28	(0.0390)	0.0139	0.0177	0.0344
F value significance		18.4900 ●	17.3056 ●	8.2208 ●	4.5293 ●	6.6705 ●	16.4552 ●	3.6477 ○
t value significance		2.930 ●	2.453 ●	7.429 ●	0.150 ●	2.597 ○	1.139 ●	0.023 ○
C	N	27	24	(16)	(14)	(14)	(14)	24
	m	105.2	124.1	(57.2)	(0.951)	(0.205)	(0.843)	0.511
	s	9.46	9.36	(3.67)	(0.0830)	(0.0359)	(0.0718)	0.0657

A: *I.* (*Pl.*) *troegeri*, B: *I.* (*Pl.*) *szaszi*, C: *I.* (*Pl.*) *mantelli*. The values in parentheses show at the growth stage of 60 mm in H. The t-values underlined were calculated by Welch's method. ● : significant, ○ : not significant, at the level of 5%.

Table 4. Comparison of individual relative growth of *I.* (*Pl.*) *troegeri*, *I.* (*Pl.*) *szaszi* and *I.* (*Pl.*) *mantelli*.

	specimen	$\alpha_{l.h}$	$\beta_{l.h}$	$r_{l.h}$	evaluation	$\alpha_{b.h}$	$\beta_{b.h}$	$r_{b.h}$	evaluation
A	JG. H3011bR	1.001	0.921	0.9997	isometry	0.896	0.403	0.9978	negative allometry
	JG. H3023L	0.990	0.921	0.9999	isometry	0.773	0.523	0.9985	negative allometry
B	JG. H2898L	0.939	1.201	0.9996	negative allometry	0.995	0.245	0.9977	isometry
	JG. H2901R	0.938	1.221	0.9994	negative allometry	0.965	0.272	0.9908	isometry
C	JG. H2917R	0.768	1.950	0.9928	negative allometry	0.837	0.330	0.9927	negative allometry
	JG. H2923R	0.896	1.260	0.9978	negative allometry	0.840	0.420	0.9988	negative allometry

A: *I.* (*Pl.*) *troegeri*, B: *I.* (*Pl.*) *szaszi*, C: *I.* (*Pl.*) *mantelli*. $\alpha_{l.h}$: growth index of l vs. h, $\beta_{l.h}$: Y intercept of l vs. h, $r_{l.h}$: correlation coefficient of l vs. h, $\alpha_{b.h}$: growth index of b vs. h, $\beta_{b.h}$: Y intercept of b vs. h, $r_{b.h}$: correlation coefficient of b vs. h.

allometric, whereas in the present specimens l vs. h is negatively allometric and b vs. h is isometric (see Table 4).

I. (*Pl.*) *collignoni* Sornay (1964, p. 169, pl. 1, figs. 1-3) from the Coniacian of the Tsiribihina Basin of Madagascar resembles the present species in the gently and uniformly inflated shell, moderately sloping posterodorsal area and weak major ornament. The former, however, is clearly different from the latter in its short and concave antero-dorsal margin, large anterior hinge angle ($\alpha = ca$ 130°) and nearly elliptical outline. The variation of *I.* (*Pl.*) *collignoni* is not clear, being represented by a single specimen.

A specimen of *I.* (*Pl.*) *mantelli subrhenanus* Seitz, 1962 from the Lower or Middle Coniacian of the Brezoi Basin, Romania, figured by Szász (1974, pl. 14), closely resembles the specimens from loc. Ik2709 in general outline, shell

convexity and surface ornamentation, but that specimen has a slightly concave anterodorsal margin. Its anterior hinge angle is about 95° in the immature stage and 110° in the adult, and its concentric ribs and rings are narrowly bent at the ventral part, although the variation of this subspecies is unknown, being here a single specimen. His specimen resembles also the specimen JG. H3022 (Noda, 1992, p. 1316, figure 3, holotype), JG. H3010 and 3011b of *I.* (*Pl.*) *troegeri*. Sornay (1986, in a letter to Matsumoto) pointed out that it is doubtful whether Szász's specimen is referable to *I.* (*Pl.*) *mantelli subrhenanus*.

To sum up, the present species represented by a sample from loc. Ik2709 is new, because it is identical with neither *I.* (*Pl.*) *troegeri* nor any other previously named species of *Inoceramus* (*Platyceramus*).

A specimen of *I.* (*Pl.*) n. sp. 2 described by López (1990, p. 293, pl. 13, fig. 3) from the Lower Santonian of the Nord-Castella platform, Spain, closely resembles the present species in its general outline of the umbonal region, shell convexity and weak surface ornamentation. But it is too high in stratigraphic occurrence to be assigned to the present species.

Occurrence.—For the location of Ik2709, see Figure 1. Topographic map, Ikushunbetsu Quad. 1 : 25,000. Long. 141°51'22"E, Lat. 43°17'50"N. A cliff of the forestry road along the Ponbetsu-gono-sawa. Among the assemblage of species (see p. 41, 43) from there *I.* (*I.*) *uwajimensis* occurs abundantly in the Lower to Middle Coniacian of the Japanese scale (see Matsumoto 1984, table 1), and *I.* (*Cr.*) *mihoensis* and *I.* (*Co.*) *kawashitai* are common in the Upper Coniacian. Hence, the stratigraphic position of the type material is ascribed to the upper part of the Middle Coniacian.

Loc. Ik1623. Topographic map, Ashibetsuko Quad. 1 : 25,000. Long. 142°04'22"E, Lat. 43°15'53"N. A float from upper reaches of a branch of the Kumaoi-zawa.

Discussion of phylogeny

Inoceramus (*Platyceramus*) *szaszi* sp. nov. from the upper Middle Coniacian is presumably a descendant of *I.* (*Pl.*) *troegeri* from the Lower to lower Middle Coniacian, because the specimens JG. H3010 and JG. H3011b of *I.* (*Pl.*) *troegeri* seem to foretell the specific characters of *I.* (*Pl.*) *szaszi*. Nevertheless, the specific distinction is clear as mentioned in the foregoing pages. This suggests a sisterhood relationship between *I.* (*Pl.*) *szaszi* and *I.* (*Pl.*) *mantelli*, both of which were derived from a common ancestor, i.e., *I.* (*Pl.*) *troegeri*. Various species of *I.* (*Platyceramus*) from the Santonian and Campanian may be directly or indirectly descended from *I.* (*Pl.*) *mantelli* (Noda, 1983 ; Noda and Toshimitsu, 1990 ; Noda, 1992), whereas no presumable descendant of *I.* (*Pl.*) *szaszi* has hitherto been found from a higher horizon. Hence, *I.* (*Pl.*) *szaszi* may be an offshoot from the root of *I.* (*Platyceramus*).

Conclusions

Based on a sample from the upper Middle Coniacian of the Ikushunbetsu area *I.* (*Pl.*) *szaszi* sp. nov. is proposed. It resembles *I.* (*Pl.*) *troegeri* and *I.* (*Pl.*) *mantelli*. As far as the sample is concerned, the extent of variation is small in every character and is discriminated morphologically from other allied species by means of statistical analyses and precise observation.

I. (*Pl.*) *szaszi* is regarded as a descendant of *I.* (*Pl.*) *troegeri* but is probably an offshoot from the main stock of *Inoceramus* (*Platyceramus*).

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新欧文誌タイトル選考委員会からのニュース

これまでの経緯のあらまし。 日本古生物学会は1995年の学会創立60周年を機に，欧文機関誌「日本古生物学会報告・紀事: Transactions and Proceedings of the Palaeontological Society of Japan」の名称と体裁を改め発刊するために，過去2年以上にわたり評議員会ならびに常務委員会を中心に検討を進めてきました。

　欧文機関誌の名称と体裁の変更が必要である事の主な理由は，現行の機関誌名が古生物学という科学の内容を直接反映したものでなく，単に学会の活動記録と言うような印象を与える点，誌名が長すぎ，海外や専門外の研究者に名称をすぐに記憶してもらえない点，また白紙に黒の単色印刷の表紙は，図書館においても目立たず魅力に欠けるといった様な問題点の指摘からでありました。

　特に名称については，会員全員に魅力的な名称を考えていただくのが，最も望ましいということで，古生物学という科学の内容を良く伝え，しかも国際誌としてふさわしい欧文名称という基本方針で公募を行いました。その結果，1993年11月30日の締め切りまでに25件の応募がありました。これらの応募の中から，常務委員会が中心に絞り込みを行い，最終的には新機関誌名「Nipponites」副題 Quarterly Journal of Palaeontology で，アンモナイト *Nipponites* をあしらったカラーデザインの表紙の国際版として発刊する事を1994年6月熊本での評議員会で決定し，1995年の学会総会で報告了承を得る段階に至っておりました。

　ところが，年会総会に先立つ常務委員会ならびに評議員会でまた会員の間で新機関誌名「Nipponites」は海外や専門外の研究者に理解されないばかりか上記の基本方針に鑑み再考すべきであると言う問題が浮上し，事柄の重要さから，会員にその是非を問う可否投票を行うこととなりました。

　斎藤常正会長から会員あてのニュースレターで報告がなされましたように，可否投票の結果は評議員会案の賛成が投票総数の2/3に達せず本件は否決されました。

　その結果，投票用紙にも記されてありましたように1995年4月号は従来の誌名・デザインを基本に新体裁の国際版として出版するが，タイトルについては，改めて選定手続きを考える事になりました。1995年4月号は新体裁の国際版として既に皆様のお手元に配送されたとおりです。

　評議員会は新欧文誌タイトルの選定に関するいっさいの事項をゼロから再出発し検討する為の作業部会を，取り急ぎ設置することにいたしました。委員の構成は評議員の中から会長が指名した委員長 (小澤智生が指名された) と会員の中から以下に記される点を考慮し，5名の委員を委員

長と会長とで選出し，6月23日に横須賀市自然博物館で開かれた評議員会で正式に委員会の発足が承認されました。

欧文誌タイトル選考委員会委員
　　　(アルファベット順，敬称略)

	Fax No.
遠藤　一佳 (東　大):	
腕足類，系統進化 (分子系統を含む)	03-3815-9490
小泉　　格 (北　大):	
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中森　　亨 (東北大):	
サンゴ礁学，地圏環境	022-217-6634
小澤　智生 (名　大):	
分子系統，古生物一般	052-789-3033
瀬戸口烈司 (京　大):	
古脊椎動物	075-753-4189
植村　和彦 (科　博):	
古植物	03-3364-7104

　委員の選考にあたっては，1. 多くの専門分野を代表する，2. 大学ならびに博物館関係者を含め選ぶ，3. 広い地域から年齢層も考え選ぶ，4. 外国で博士を取得した人を含める，5. 他の自然史関連学会の編集を経験した人を含める，と言った点を考慮して上記の委員を決定しました。

欧文誌タイトル選考委員会の目的とこれまでの活動。 1997年4月から新タイトルの欧文誌を発刊することを前提に，本年12月はじめまでに，新タイトル名を選定し，それを決定するプロセスについて案を作成し会長に答申すること。また表紙についてもあるデザインを学会誌の表紙にするプロセス (具体的には学会員からのコンペにするとか，専門のデザイン工房に作成を依頼するとかについて) についても原案を考え，学会長に答申すること。

　なお，名称選定にあたっての基本方針は，古生物学と言う科学の内容を良く伝え，しかも国際誌としてふさわしい名称であることである。また表紙については印刷費用を考慮すると単色あるいは2色のカラー刷りの範囲で斬新な魅力的なデザインであることとする。

　横須賀での学会評議員会の翌日 (6月24日)，委員会を持ち，これまでの経緯の整理と，本委員会が今後なすべき仕事の内容 (新タイトル名の選定とその決定プロセスについての原案を考えること，また表紙のカラーデザインについても決定プロセスの原案を決める) について確認を行い，今後の活動について話し合いました。これまでに，タイトル選定にあたっての基本的な考え方を，それぞれの委員か

ら提示していただきました。委員の中からは欧文誌のタイトル名の提案も現在なされております。今後、会員の皆様からのご提案のあった名称をも含めタイトルの絞り込みを行っていく予定です。

会員の皆様へのお願い。 新欧文誌のタイトルに関しては、会員全員に魅力的な名称を考えていただくのが、最も望ましく、本来ならば公募をすべきであると思いますが、今回は答申までの時間の制約の関係で正式な公募の形はとりません。しかし、下記の期限までに会員からご提案のあった名称はタイトル選考委員会で名称選考の対象とさせていただきますので、会員の皆様には魅力的な名称のご提案を賜りますようお願い申しあげます。

学会誌の名称：古生物学という科学の内容をよく伝え、しかも国際誌としてふさわしい欧文の名称。

送付先：〒464-01　名古屋市千種区不老町
名古屋大学理学部地球惑星科学教室
小澤智生 (欧文誌タイトル選考委員会委員長)
まで郵送のこと。

締め切り：1995 年 8 月 30 日

日本古生物学会報告・紀事：Transactions and Proceedings of the Palaeontological Society of Japan にご提案のあった名称、選考のプロセスと結果については報告していきますので会員の皆様には注意深く見守っていただくとともにご支援をお願いいたします。

　タイトルを考慮していただく上での参考までに以下の情報をお伝えします。

　日本古生物学会とほぼ時を同じく発足した、日本動物学会、日本植物学会、日本人類学会、日本遺伝学会は既に新学会誌名に変更し、外国人の co-editor, associate editor をも迎え、国際誌化をはかっている。これらの学会の欧文誌タイトルは以下のとおりです。

日本動物学会　Zoological Science
日本植物学会　Journal of Plant Research
日本人類学会　Anthoropological Science
日本遺伝学会　The Japanese Journal of Genetics
(欧文誌タイトル選考委員会)

「自然史学会連合」シンポジウム・学術講演会のお知らせ

　すでに「化石」58 号でお知らせしたように、以下のような「自然史学会連合」主催のシンポジウム・学術講演会が行われます。聴講は無料ですので、会員の皆様のご参加を歓迎します。

日　時：10 月 7 日 (土) 午前 10 時〜午後 5 時
会　場：早稲田大学国際会議場　井深大記念ホール (早稲田大学西早稲田キャンパス北門前、最寄り駅都電早稲田駅または東西線早稲田駅、JR 高田馬場駅から学バスもあります。)
テーマ：「自然と人間の共生 ― 21 世紀の自然史科学の研究と教育の展望 ―」
演　者：古生物学会から速水　格、斎藤常正両会員のほか、日高敏隆 (滋賀県立大)、赤澤　威 (東大資料館)、大場秀章 (東大資料館)、青木淳一 (横浜国立大) の方々が予定されています。

Transactions and Proceedings of the Palaeontological Society of Japan

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