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Early Jurassic Radiolarians from the Mt. Norikuradake Area, Mino Terrane, Central Japan

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(with 4 Figures, 4 Tables and 4 Plates)

Abstract

This paper focuses on the late early Jurassic radiolarian assemblage of bedded cherts and siliceous mudstones in the Mt. Norikuradake area, central Japan. Nine multi-segmented nassellarians of the assemblage including two new species, are described herein. They belong to the genera *Hsuum, Parahsuum* and *Parvicingula* and are characterised by forms possessing features of both *Parahsuum* and *Hsuum*, with also a form of *Parvicingula* having small tests. The assemblage containing these taxa, recognisable in various localities in Southwest Japan and North America, is regarded as a fauna of the transitional period from early Jurassic to middle Jurassic forms. This assumption is based on a consideration of the morphology of its component species. On the basis of its biostratigraphic position and faunal content, the assemblage is probably to be dated to a certain time in the late Early to early Middle Jurassic, at least including Toarcian time.

INTRODUCTION

Research on late early Jurassic, particularly Toarcian radiolarians is vital to construct the phylogeny of Jurassic radiolarians. Multi-segmented nassellarian phylogeny is an example as PESSAGNO and WHALEN (1982) have mentioned. Radiolarians of this time have not yet been investigated with emphasis on enough paleontology. Recently, YEH (1987) and CARTER *et al.* (1988) have revealed morphology and distribution of these radiolarians, through stratigraphic studies of Lower Jurassic formations of the east-central Oregon and Queen Charlotte Islands of North America. These formations are mainly composed of clastic sediments and yield radiolarians and assorted diagnostic fossils (*e.g.*, ammonites, foraminifers *etc.*).

Most of early Jurassic radiolarians contained in cherts are rarely well-preserved enough in Japan for this approach. In the area of Mt. Norikuradake in Southwest Japan, well-preserved late early Jurassic radiolarians can be obtained from bedded cherts and siliceous mudstones. Radiolarians from this area are useful in systematic descriptions and they compare well with the North American fauna.

The objectives of this paper are to describe late Early to early Middle Jurassic radiolarians, in particular species of genera *Hsuum, Parahsuum* and *Parvicingula*, and to remark biostratigraphic, phylogenic and tectonostratigraphic significances of the assemblage including these taxa from the Mt. Norikuradake area.

GEOLOGIC SETTING

The Norikuradake area is about 30 km west of Matsumoto City in Nagano Prefecture, central Japan (Fig. 1). The area is situated on the northeastern part of the Mino Terrane and is underlain mainly by a Jurassic accretionary complex associated with the Permian and Triassic (OTSUKA, 1988). Quaternary volcanic rocks of the Mt. Norikuradake volcano cover the Paleo-Mesozoic in the western part of the area.

The lithology of the Paleo-Mesozoic in the Norikuradake area was preliminarily presented by KANO (1975) *etc.* Recently, OTSUKA (1985, 1988) has investigated the Paleo-Mesozoic of the eastern Mino Terrane. He revealed the detailed lithologic distribution in the area and divided the Paleo-Mesozoic into three complexes, namely Sawando, Shirahone and Yukawa Complexes (Fig. 2; OTSUKA, 1988).

Radiolarians dealt with in this study were obtained from siliceous mudstone and chert of the Yukawa Complex, a complex also composing mudstone and sandstone. The Yukawa Complex is characterised by repeatedly exposed chert-clastics sequences (OTSUKA, 1985). In the Yukawa Complex, the chert-clastics sequence is composed of chert, siliceous mudstone and mudstone-sandstone units in ascending order. Cherts are laterally

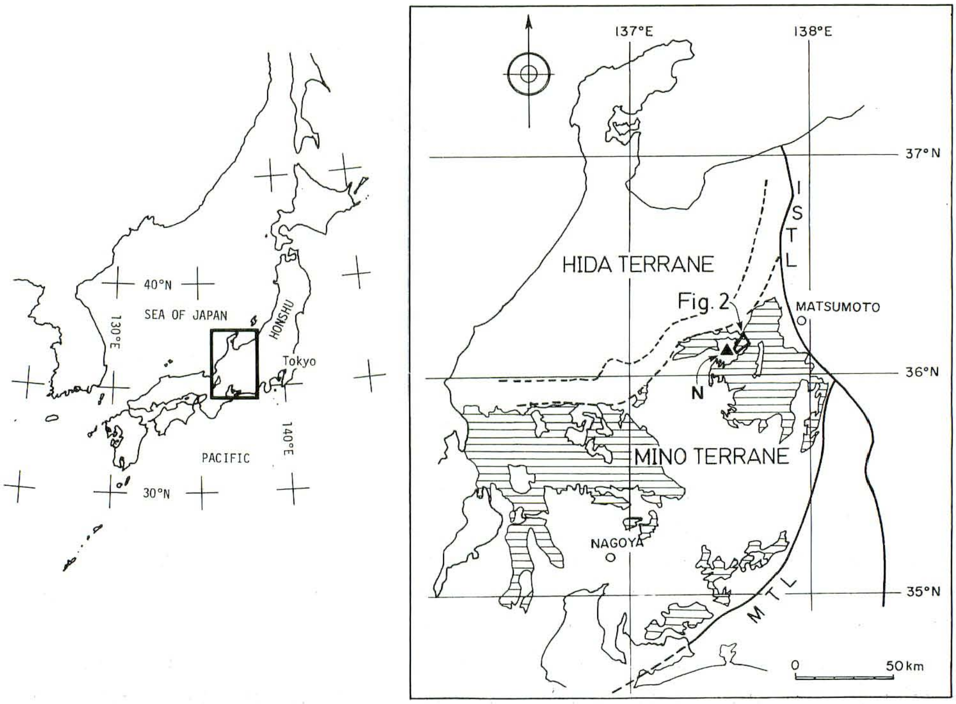

Fig. 1. Index map of the study area, central Japan. Distribution of the Paleo-Mesozoic accretionary complex of the Mino Terrane is shown as horizontal lines. N: Norikuradake area, MTL: Median Tectonic Line, ISTL: Itoigawa-Shizuoka Tectonic Line.

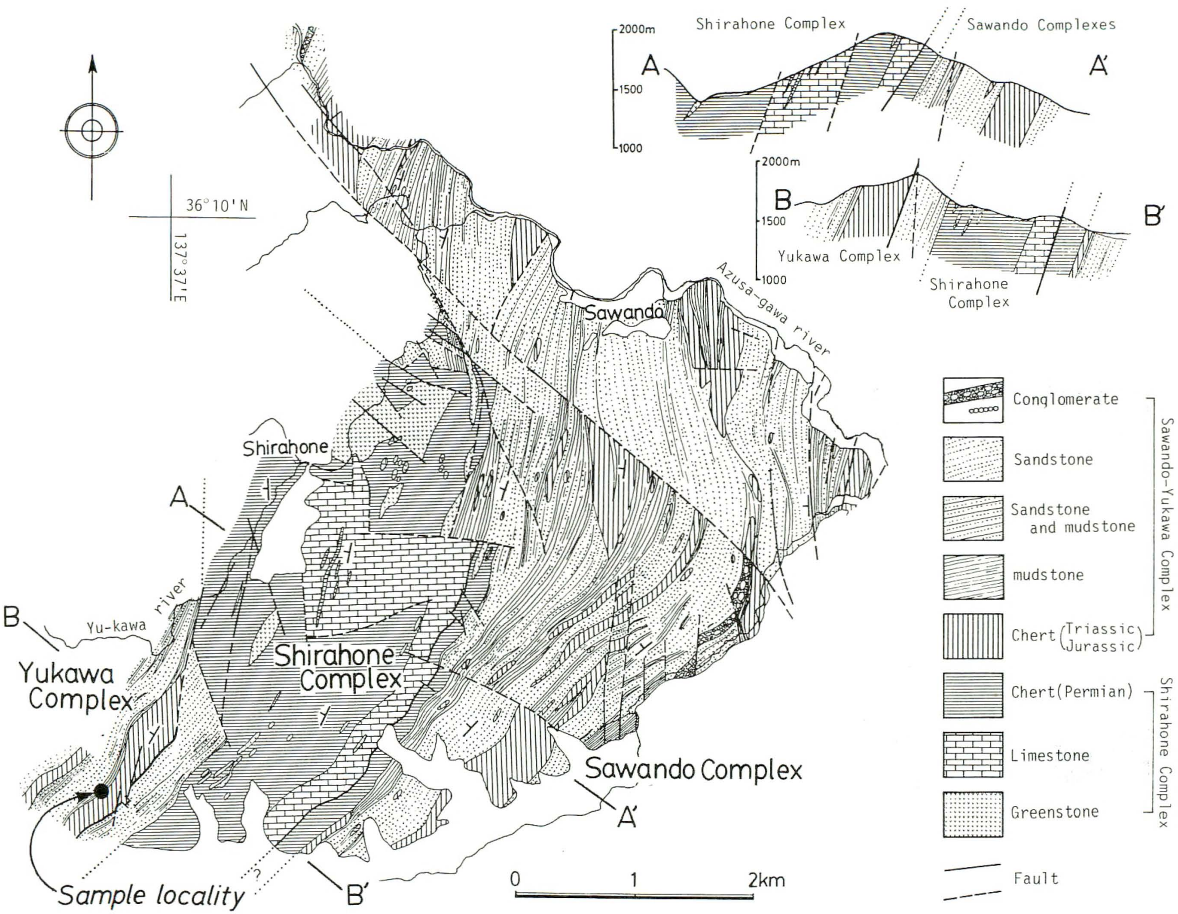

Fig. 2. Geologic map and profiles of the Mt. Norikuradake area and the sample locality. The Yukawa Complex is limitedly exposed in the southwestern area of this map. Modified from Otsuka (1988).

continuous in usual and thinly bedded (2 to 10 cm) intercalating with thinner (less than 2 mm) siliceous claystones. Cherts of this complex range in thickness from several meters to more than 50 m. The bases of cherts are generally intersected by faults, and are in contact with the clastic rocks beneath. In some cases, cherts occur as allochthonous

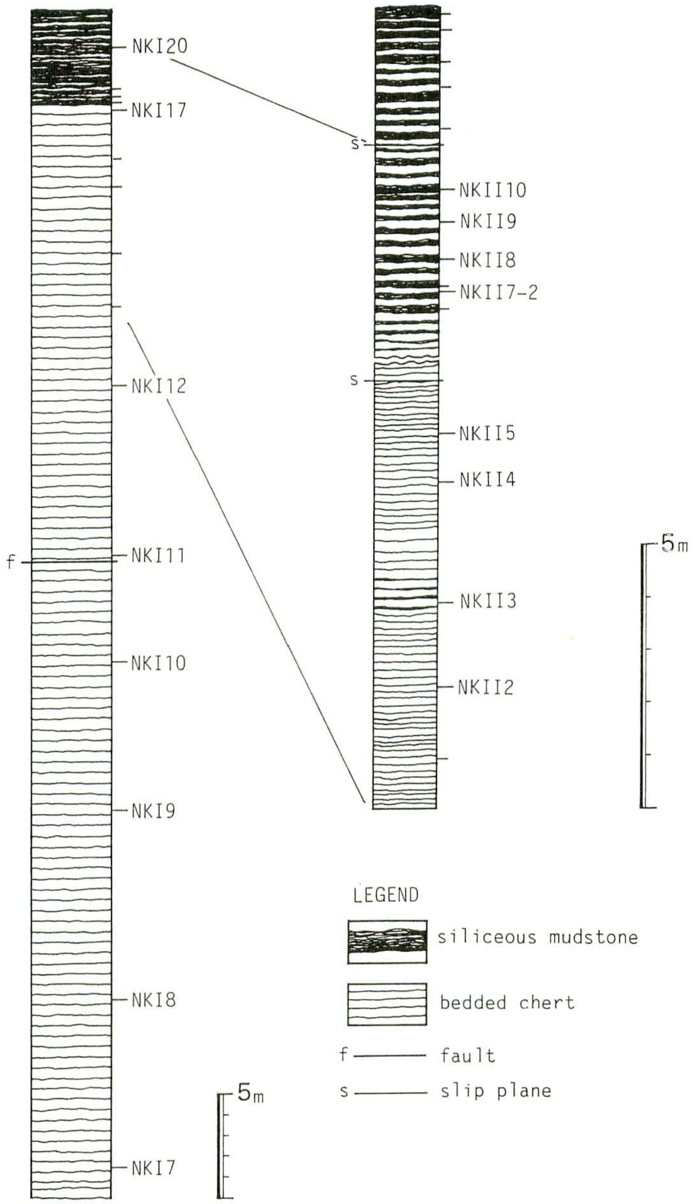

Fig. 3. Lithologic columns of the NK Section in the Mt. Norikuradake area.

blocks included in siliceous mudstone. Cherts of this complex contain only Early Jurassic radiolarians. Siliceous mudstones conformably overlie the laterally-continuous cherts, and these upwards change to overlying siliceous mudstones through units of interbedded cherts and siliceous mudstones in turn. Siliceous mudstones are usually characteristic reddish brown in color, they yield abundant late Early to early Middle Jurassic radiolarians dealt in this study. Siliceous mudstones gradually change to overlying interbedded mudstones and sandstones which quantitatively predominate in the Yukawa Complex. Mudstones yielded species of late Middle Jurassic radiolarian assemblage (*Guexella nudata* Assemblage; MATSUOKA, 1981) which is the youngest age in this complex.

Strata of this complex trend northeast and dip steeply northwest, showing northwestward younging in the Norikuradake area. The Yukawa Complex is in fault contact with the structurally underlying Shirahone Complex.

The sample locality (NK section) was situated at a latitude of 36° 7′36″ N and a longitude of 137° 27′30″ E (Fig. 2). In the NK Section, thin (2 m+) reddish-brown siliceous mudstone conformably overlies thick chert (over 50 m thick in appearance, Fig. 3). The chert grades uwpard into the siliceous mudstone through a unit of frequently interbedded cherts and siliceous mudstones.

METHODS AND MATERIALS

The following procedure was used in this study to extract radiolarians from cherts and mudstones: After washing with tap water, samples, each weighing about 1 kg, were treated with a 5% dilute solution of hydrofluoric acid for 18–20 hours at room temperature. After reaction, residue was carefully washed with fresh water.

Type and figured specimens were registered and deposited with the Department of Geosciences, Osaka City University, under numbers OCU MR 4020 to OCU MR 4067. The number following F or FL represents the photograph number, and unaccompaning number refers to the specimen.

SYSTEMATIC PALEONTOLOGY

Subclass RADIOLARIA MÜLLER, 1858
Superorder POLYCYSTINA EHRENBERG, 1838, emend. RIEDEL, 1967
Order NASSELLARIA EHRENBERG, 1875

Genus ***Hsuum*** PESSAGNO, 1977

Hsuum PESSAGNO, 1977, p. 81

Type species: *Hsuum cuestaensis* PESSAGNO, 1977, p. 81 (pl. 7, figs. 12–13)

Remarks: TAKEMURA (1986) divided *Hsuum* PESSAGNO, 1977 into two groups; one with distinct continuous costae, *Hsuum s.s.* and another with discontinuous costae, *Transhsuum*. However, it is difficult to draw an exact line between these two groups because some species have both characters, as mentioned below (Pl. 3, Figs. 1–4). Thus, the interpretation used in this study follows PESSAGNO and WHALEN's (1982) broad sense of *Hsuum* PESSAGNO, 1977.

Hsuum altile sp. nov.

(Pl. 1, Figs. 1–6)

1982: *Hsuum* sp. — MATSUDA and ISOZAKI, pl. 1, figs. 1, 2
1982: "*Lithostrobus*" sp. b — KIDO, pl. IV, figs. 9, 10
?1983: *Lithostrobus*? sp. A — ISHIDA, pl. 2, fig. 5
1985: *Hsuum* sp. A — KISHIDA and HISADA, pl. 4, figs. 11, 14, 13?
?1986: *Hsuum* sp. A — KISHIDA and HISADA, fig. 6–2
1984: *Hsuum* sp. B — MURCHEY, pl. 1, fig. 23
1988: *Hsuum* (?) *matsuokai* ISOZAKI and MATSUDA, 1985 — HATTORI, pl. 13, fig. E

Description: Test multi-segmented, exact number of chambers unknown, possibly less than 8 or 9. Outline of test gourd-shaped with a weak to strong stricture in proximal 1/3 portion. Cephalis hemispherical with an apical horn; horn, solid and mostly polygonal in cross-section. The proximal portion of test, above stricture, possessing irregularly arranged pores and circular to polygonal pore frames; surfaces of pore frames smooth to rough, occasionally spiny (Pl. 1, Fig. 1c). The distal portion below stricture inflated and having longitudinally and transversally aligned pores and 14 to 19 longitudinal continuous costae; longitudinal costae mostly long, developed at an interval of 2 or 3 rows of pores, and frequently having branches. Immediately below stricture, some discontinuous costae occasionally observed. In complete specimens, costae disappeared at the distal end of test (Pl. 1, Figs. 3a, b, 5).

Measurements: (in micron; based on 9 specimens shown in Table 1).

Remarks: *Hsuum altile* sp. nov. is very similar to *Hsuum* (?) *matsuokai* ISOZAKI and MATSUDA, 1985b on its form and costal arrangement. The former, however, differs from

Table 1. Measurements of *Hsuum altile* sp. nov.

Specimen	Pl.	Fig.	Height	Width	H/W	Number of Costae
**NKI20II-64	1	1a-c	306+	141	2.2+	16?
NKI20II-77	1	3a,b	326	154	2.1	15
NKI20II-78	1	2a-c	293+	148	2.0+	16
NKI20II-73	1	5	262+	136	1.9+	17?
NKI20II-74	1	4	249+	135	1.9+	18
NKI17II-52			241+	153	1.6+	19
NKI20II-79			271+	130	2.1+	14
NKI20II-75			236+	142	1.7+	--
*NKI20IINo.1(40.5x94.9)	1	6a,b	294+	165	1.8+	15?
Average			275	145	1.9	
Maximum			326	165	2.2+	
Minimum			236+	130	1.6+	

** : Holotype, *: Paratype

the latter by lacking robust massive apical horn which is tetraradiate cruciform in cross-section and possessing irregular arranged pores on proximal portion of test. On the basis of morphological resemblances and stratigraphic positions, *H.* sp. α (=the provisional name of *H. altile*) is regarded as the ancestor of *H.* (?) *matsuokai*.

This speices also resembles *Hsuum* sp. B of TAKEMURA (1986) and *Hsuum parvulum* YEH, 1987 but differs in having irregular pore frames on proximal part of test and in being larger and gourd-shaped.

Hsuum sp. aff. *H. mirabundum* of PESSAGNO and WHALEN (1982) and *Hsuum* sp. A of CARTER in CARTER *et al.* (1988) are similar to *H. altile*. However, the former two species can be distinguished from the latter by possessing costae on proximal portion of test.

Etymology: The name is derived from the Latin adjective *altilis*, meaning stout.

Type specimen: Holotype, OCU MR 4020 (NKI20II-64) from the Mt. Norikuradake area. Paratype, OCU MR 4025 (NKI20II No. 1 (40.5×94.9)) from the Mt. Norikuradake area.

Type locality: The Mt. Norikuradake area, Azumi village, Azumi-gun, Nagano Prefecture, central Japan.

Occurrence: Southwest Japan; Mt. Norikuradake, Inuyama, Kamiaso* and Nanjo areas (Mino Terrane), Kuzu area (Ashio Terrane), Kuma and Ueno-mura* areas and Konose Valley* (Chichibu Terrane). North America; Marin Headlands (Franciscan Complex)*.

The asterisk marked areas are referred to studies of MATSUDA and ISOZAKI (1982), ISOZAKI and MATSUDA (1985b), KISHIDA and HISADA (1985, 1986), ISHIDA (1983) and MURCHEY (1984), and the others are the present senior author's data.

Range: Late Early Jurassic to early Middle Jurassic?

This species first appeared in the same time that the assemblage from the Mt. Norikuradake area indicates; see extended remarks for details. The upper limit of its range probably extends in Middle Jurassic because this form is rarely found in the *Unuma echinatus* Assemblage (YAO, MATSUDA and ISOZAKI, 1980), recognised and described as an important Middle Jurassic radiolarian assemblage in Japan.

Hsuum sp. X

(Pl. 3, Figs. 1–4)

Remarks: This form morphologically resembles *H. altile* sp. nov. but differs in having many discontinuous costae and weak developed longitudinal costae, additionally conical outline of test and smaller average of height to width, 1.6.

Occurrence: Southwest Japan; Mt. Norikuradake area (Mino Terrane).

Hsuum sp. β

(Pl. 3, Fig. 5)

Remarks: This form has a relatively large cephalis with a small horn and distinct discontinuous costae. Because of poor preservation, it is difficult to identify with other described species of *Hsuum*; *e.g., H. robustum* PESSAGNO and WHALEN, 1982, *etc.* Stratigraphic distribution of *H.* sp. β was also shown in the report of radiolarians from the Inuyama area (HORI, 1988; fig. 3).

Occurrence: Southwest Japan; Mt. Norikuradake and Inuyama areas (Mino Terrane).

Hsuum (?) sp. Y

(Pl. 3, Figs. 6–7)

Remarks: This form shows conical outline and has a solid apical horn. Several circumferential ridges which comprise cruciform costae are observed.

Occurrence: Southwest Japan; Mt. Norikuradake area (Mino Terrane).

Hsuum (?) sp. Z

(Pl. 3, Fig. 8)

Remarks: This form possesses an elongated conical tset and remarkable developed costae. The costal element is common to *Hsuum* sp. B of CARTER in CARTER *et al.* (1988) and *Hsuum infirmum* SASHIDA, 1988.

Occurrence: Southwest Japan; Mt. Norikuradake area (Mino Terrane).

Genus ***Parahsuum*** YAO, 1982

Parahsuum YAO, 1982, p. 61

Type species: *Parahsuum simplum* YAO, 1982, p. 61 (pl. 4, figs. 1–8)

Parahsuum (?) sp. aff. *P.* (?) *magnum* TAKEMURA, 1986

(Pl. 3, Figs. 13–15)

1982: *Parahsuum*? sp. — MATSUDA and ISOZAKI, pl. 1, figs. 18, 19

Remarks: This form is very similar in characteristics of outer layer (arrangement of pores and pore frames and development of circumferential ridges) to *P.* (?) *magnum*. It differs from this form in having larger test and well developed, rectangular or round-pointed and tetraradiate apical horn.

This form was recognised from bedded cherts of the Inuyama and Kamiaso areas, Southwest Japan (MATSUDA and ISOZAKI, 1982; HORI, 1988).

Occurrence: Southwest Japan; Mt. Norikuradake, Inuyama and Kamiaso areas (Mino Terrane).

Parahsuum (?) sp. A

(Pl. 3, Figs. 9–10)

Remarks: This form has characteristic circumferential ridges which are frequently nodose on distal half portion. The other features generally fit to that of genus *Parahsuum*.

Occurrence: Southwest Japan; Mt. Norikuradake area (Mino Terrane).

Parahsuum (?) sp. B

(Pl. 3, Figs. 11–12)

Remarks: The apical part generally is hemispherical with a solid horn and possesses irregularly arranged pores. On the other part of test, pores align longitudinally and transversely. Weak developed discontinuous costae and/or nodes superimpose on that outer layer. This form exhibits a wide range of ornamentation on outer layer. Some of this form likely resemble *Hsuum minoratum* SASHIDA, 1988. Thus, this form has characters both of *Parahsuum* and of *Hsuum*. In some specimens, 1 to 3 circumferential ridges are observed on the distal portion of test. Abundant in the study samples.

Occurrence: Southwest Japan; Mt. Norikuradake area (Mino Terrane).

Genus ***Parvicingula*** PESSAGNO, 1977

Parvicingula PESSAGNO, 1977, p. 84–85

Type species: *Parvicingula santabarbaraensis* PESSAGNO, 1977, p. 86 (pl. 9, figs. 11–13)

Remarks: BAUMGARTNER (1984) mentioned the interpretation of *Parvicingula* with the emendation of *Ristola*; Conical forms, lacking an outer layer, which similar as with *Mirifusus*, are included with *Parvicingula*, whether they have a horn or not, and/or forms without or with weakly developed horn, which otherwise fit to PESSAGNO's (1977) definition. The present authors follow the sense of BAUMGARTNER (1984).

Parvicingula nanoconica sp. nov.

(Pl. 2, Figs. 1–6)

1982: *Parvicingula* sp. — MATSUDA and ISOZAKI, pl. 1, figs. 13, 16
1984: *Parvicingula* sp. A — MURCHEY, pl. 1, fig. 22

Description: Test consisting of 5 to 7 chambers, possibly more, conical with developed circumferential ridges. Cephalis hemispherical with long apical horn; horn, solid, elongated cone. Thorax and subsequent chambers, truncated cone, increasing in width except distalmost chamber. Surface of cephalis having irregularly arranged pores.

Table 2. Measurements of *Parvicingula nanoconica* sp. nov.

Specimen	Pl.	Fig.	Height	Width	H/W	Length of Apical horn
**NKII9-21	2	1a-d	198+	98	2.0+	55+
NKI20I-26	2	3a, b	193+	113	1.7+	55+
NKI20I-29	2	2	233	110	2.1	55
NKII10-31	2	4	173+	110	1.6+	58
NKII9-35			167+	134	1.3+	--
NKII20II-21			191+	80	2.4+	63
NKII10-29			167+	95	1.8+	56
NKI20II-25			168+	82	2.1+	37
NKI20II-35			186+	95	2.0+	60
NKI20II-32			186+	107	1.7+	47
NKI20II-38			186+	100	1.9+	64
NKII8-33			175+	103	1.7+	--
KKS7-90			161+	105	1.5+	--
KKS7-72			172+	120	1.4+	52+
*NKI20IINo.1(41.3x96.8)	2	6a, b	192	100	1.9+	61
NKI20IINo.1(42.0x90.1)			208+	101	2.1+	55
NKI17IINo.1(43.9x96.9)			179+	100	1.8+	55+
Average			184	103	1.8	55
Maximum			233	134	2.4+	64
Minimum			161+	80	1.3+	37

**: Holotype, *: Paratype

Meshwork of outer layer clearly, hexagonal symmetrically constructed by 3 rows of pore frames between two circumferential ridges; In some species, 4 rows of pore frames are served on distal part. Pores above and below adjoining circumferential ridges lined up in radius distance lag. Pore frames slope steeply away from ridges and formed wavy or nodose structure of circumferential ridges. In some specimens, proximal portion of test possessing nodose or spiny circumferential ridges.

Measurements: (in micron; based on 17 specimens shown in Table 2).

Remarks: *Parvicingula nanoconica* sp. nov. is apparently similar to *P. gigantocornis* KISHIDA and HISADA, 1985 but the former is distinguished from the latter by having clearly meshwork of outer layer and rather longer test. The present authors doubted whether this form was one of poor preserved specimens of *P. gigantocornis* at the first. Resulting from comparison between the two from siliceous mudstones, this form was considered the different species from *P. gigantocornis*. Both species, *P. nanoconica* and *P. gigantocornis*, differ from all other species of *Parvicingula* by possessing a very small test and a long horn. *P. nanoconica* also morphologically resembles *P. vera* PESSAGNO and WHALEN, 1982 and *P. profunda* PESSAGNO and WHALEN, 1982. The latter two species are distinguished from the former in these following features additionally by lacking of a small test and a very long horn; by having more weakly developed circumferential ridges and by possessing chamber comprised of a central row of smaller pores than that of other two rows respectively. Almost pores in each chamber of *P. nanoconica* are about equal in size.

Etymology: The name is derived from the Latin adjective *nano-conicus*, meaning small coned.

Type specimen: Holotype, OCU MR 4026 (NKII9–21) from the Mt. Norikuradake area. Paratype, OCU MR 4031 (NKI20II No. 1 (41.3×96.8)) from the Mt. Norikuradake area.

Type locality: The Mt. Norikuradake area, Azumi village, Azumi-gun, Nagano Prefecture, central Japan.

Occurrence: Southwest Japan; Mt. Norikuradake, Inuyama, Kamiaso* and Nanjo areas (Mino Terrane), Kuzu area (Ashio Terrane), Kuma area (Chichibu Terrane). North America; Marin Headlands (Franciscan Complex)*.

The asterisk marked areas are referred to studies of MATSUDA and ISOZAKI (1982) and MURCHEY (1984), and the others are the present senior author's data.

Range: Late Early Jurassic to early Middle Jurassic?

The range of this species is probably in the late Early to early Middle Jurassic, at least including Toarcian time, that is the same time of the assemblage studied mentioned below.

EXTENDED REMARKS

The radiolarian assemblage from the Mt. Norikuradake area

Various kinds of multi-segmented nassellarians and spumellarians were obtained in the Mt. Norikuradake area from samples (NKI17, 20; NKII2–10) near the horizon where chert gradually changes into siliceous mudstone (Table 3). The radiolarian assemblage is characterised by *Hsuum* with variously arranged costae, *Parahsuum* (?) with some developed circumferential ridges and *Parvicingula* with a small test and a long horn, and others. These representative radiolarians are shown in Table 4.

Multi-segmented nassellarians of this assemblage are shown in Plates 1–3, and the other nassellarians and spumellarians are given in Plate 4.

Age

The radiolarian assemblage including species of *Hsuum, Parahsuum* (?) and *Parvicingula* possessing a small test was recognised first by MATSUDA and ISOZAKI (1982), and KISHIDA and SUGANO (1982). Resulting from the co-occurrence of conodonts and radiolarians in the Kamiaso area of Southwest Japan, MATSUDA and ISOZAKI (1982) tentatively concluded that the age was latest Triassic to earliest Jurassic.

In some continuous sequences in the Inuyama and other areas of Southwest Japan, this assemblage is stratigraphically situated above the *Parahsuum simplum* Assemblage (early Early Jurassic; YAO, 1982) and below the *Parahsuum* (?) *grande* Assemblage (late Early Jurassic?; YAO, MATSUOKA and NAKATANI, 1982) (Fig. 4). These early Jurassic radiolarian assemblages were established on the basis of their specific contents and biostratigraphic data, mainly in the Inuyama area (Mino Terrane), Southwest Japan. The upper portion of the *P. simplum* Assemblage-zone might be assigned to the

Table 3. List of radiolarian fossils from the NK Section in the Mt. Norikuradake area. P: poor, G: good.

Section name	NKI								NKII							
Sample number	07	08	09	10	11	12	17	20	02	03	04	05	7-2	08	09	10
Rock	ch	ch	ch	ch	ch	ch	ch	ms	ch	ch	ch	ch	ch	ms	ch	ms
Preservation	P	P	P	P	P	P	G	G	P	P	G	G	G	G	G	G
Parahsuum (?) sp.							+	+	+	+	+					+
P. sp.			+					+		+				+	+	+
P. simplum Yao	+		+		+	+	+	+					+	+		
P. transiens Hori & Yao								+					+			
P.(?) aff. *magnum* Takemura							+	+	+	+	+	+		+	+	+
P.(?) sp. B							+	+				+		+	+	+
P.(?) sp. A															+	
Syringocapsa coliforme Hori	+	+														
Gigi (?) sp.		+														
Gorgansium sp.	+		+													
Xenorum sp.			+													
Stichocapsa sp. B of Yao(1982)			+	+	+		+	+								
Katroma (?) sp.					+											
Parvicingula (?) sp.									+	+	+	+				
P. spp.							+	+						+	+	+
P. nanoconica sp. nov.							+	+				+		+	+	+
Napora sp.												+	+	+		
Eucyrtidiellum (?) sp.														+		+
E. sp.							+	+					+	+		+
Ares (?) sp. D							+							+		+
Canoptum (?) sp.								+						+	+	+
Laxtorum (?) sp.															+	
Hsuum sp. β							+	+			+					
H. altile sp. nov.							+	+					+			
H. sp. X							+	+						+	+	
H. (?) sp. Y								+								+
H. (?) sp. Z								+								
Tripocyclia sp.										+	+			+		
Trillus elkhornensis Pssagno & Blome								+		+	+	+			+	
Zartus aff. *imlayi* Pessagno & Blome															+	
Mesosaturnalis hexagonus (Yao)												+	+	+		
Tympaneides cf. *charlottensis* Carter												+				
Paronaella (?) spp.								+		+					+	
Pseudocrucella (?) sp. A								+						+	+	
Tritrabs (?) spp.							+							+		
Hagiastrum (?) sp.															+	

Table 4. List of representative species of the radiolarian assemblage from the Mt. Norikuradake area.

Hsuum altile sp. nov.
H. sp. β
H. sp. X
H. (?) sp. Y
H. (?) sp. Z
Parahsuum transiens Hori & Yao, 1988
P.(?) sp. aff. *P.*(?) *magnum* Takemura, 1986
P.(?) sp. A
P.(?) sp. B
Parvicingula nanoconica sp. nov.
Ares (?) sp. D
Mesosaturnalis hexagonus (Yao,1972)
Tympaneides sp. cf. *T. charlottensis* Carter,1988
Pseudocrucella (?) sp. A
Trillus elkhornensis Pssagno & Blome, 1980

late Sinemurian to late Pliensbachian in time (HORI, 1988). The determination of age of the *P.* (?) *grande* Assemblage is difficult because of lack of sufficient biochronological data, however, the age of the *Hsuum hisuikyoense* Assemblage (YAO and MATSUOKA, 1981) which is next to it in age has been discussed by ISOZAKI and MATSUDA (1985b). By referring to their conclusion, the *H. hisuikyoense* Assmeblage is probably attributable to a time in the Late Pliensbachian to Bajocian?. Considering the above-mentioned stratigraphic succession, the assemblage situated above the *P. simplum* Assemblage and below the *H. hisuikyoense* Assemblage can not be dated to the latest Triassic to earliest Jurassic assemblage but rather to the late Pliensbachian to Bajocian time.

On the other hand, some characteristic species of the assemblage (*e.g., Mesosaturnalis hexagonus* (YAO, 1972), *Trillus elkhornensis* PESSAGNO and BLOME, 1980 and *Tympaneides charlottensis* CARTER in CARTER *et al.*, 1988) have already been reported from the North American Jurassics. These data also make it possible to suggest the age of this assemblage.

CARTER *et al.* (1988) have revealed distribution of radiolarians in the Lower and Middle Jurassic formations of Queen Charlotte Islands, British Columbia. Because these formations of which framework has been proposed by CAMERON and TIPPER (1985) yield abundant macro and micro fossils (*e.g.*, ammonites, foraminifers and radiolarians *etc.*), the detailed stratigraphic study provides good control for dating radiolarian fauna. According to CARTER *et al.* (1988), *M. hexagonus* is not observed in the upper Pliensbachian to lower Toarcian Fannin Formation nor in the middle Toarcian Whiteaves Formation. It occurs from the upper middle Toarcian to Aalenian part of the Phantom Creek Formation. *T. elkhornensis* presents in the upper middle to lower upper Toarcian part of the Phantom Creek Formation and in the lower Bajocian Graham Island Formation. *T. elkhornensis* has been documented also from the Upper Pliensbachian part of the Nicely Formation (*Amaltheus margaritatus* Zone—*Pleuroceras spinatum* Zone) in eastern Oregon (PESSAGNO and BLOME, 1980).

T. charlottensis is described from the upper middle to upper Toarcian part of the Phantom Creek Formation by CARTER in CARTER *et al.* (1988).

M. hexagonus, T. elkhornensis and *T.* cf. *charlottensis* are observed in the assemblage studied. The co-occurrence of these three species suggests the range of this assemblage at least includes a certain Toarcian time.

Taking the above-mentioned facts into account, it is concluded that the assemblage of the Mt. Norikuradake area ranges from late Early to early Middle Jurassic, at least including one time of Toarcian.

Biostratigraphic and phylogenic Significances

This assemblage, reported preliminarily as "the *Acanthocircus hexagonus* (= *Mesosaturnalis hexagonus* in this paper) Assemblage" (HORI, 1988), can also be recognised in various other localities, such as the Inuyama, the Kamiaso, the Ueno-mura and other areas in Southwest Japan (HORI, 1988; MATSUDA and ISOZAKI, 1982; ISOZAKI and

MATSUDA, 1985b; KISHIDA and HISADA, 1985, *etc.*). Thus, it is a good marker assemblage of the late early Jurassic in Southwest Japan. Many characteristic species of the assemblage are also common to the MH-2 of MURCHEY (1984), documented from the Franciscan chert in North America; *e.g., Parvicingula* sp. A (=*P. nanoconica* sp. nov.), *Hsuum* sp. B (=*H. altile* sp. nov.), *Mesosaturnalis hexagonus, Trillus elkhornensis* and *Napora* spp. *etc.* These facts indicate that the diagnostic species probably including the two new ones described above are useful for both domestic and international correlation of late Early to early Middle Jurassic radiolarian zones.

Characteristic multi-segmented nassellarians of this assemblage from the Mt. Norikuradake area are abundant in *Hsuum* and *Parvicingula*, the dominant taxa of Middle and Late Jurassic radiolarians. Common *Parahsuum* which is a characteristic genus of Early Jurassic radiolarians is also present. While the *Parahsuum simplum* Assemblage, the penultimately old one of this assemblage, lacks *Parvicingula* and includes instead abundant *Parahsuum* and a little *Hsuum*. Taking the above-mentioned faunal contents into account, the present authors consider that the assemblage mentioned in this section is probably the transitional multi-segmented nassellarian fauna from early Jurassic to middle Jurassic forms, and that the faunal change had begun at least in Toarcian.

Tectonostratigraphic significance

Although almost all the Paleo-Mesozoic of the Mino Terrane are composed of melanges and broken formations, some areas of the terrane are underlain by coherent stratigraphic units characterised by the "chert-clastics sequence" (OTSUKA, 1985). This sequence is found in the Yukawa Complex and Sawando Complex (=Complex 3; OTSUKA, 1988) of the Mino Terrane. It is considered that the lithologic changes of the chert-clastics sequence reflects the landward drift of the sea floor from pelagic to hemipelagic environment, and further to the environment characterised by deposition of terrigeneous materials (MATSUOKA, 1984: OTSUKA, 1985).

As mentioned in the section on the geologic setting, radiolarians dealt in this study were obtained from some horizons of chert and overlying siliceous mudstone of the chert-clastics sequence of the Yukawa Complex. Occurrence of the present radiolarian assemblage from these horizons in the Mt. Norikuradake area indicates that the sedimentary environment changed from pelagic to hemipelagic in late Early to early Middle Jurassic, probably in Toarcian time. On the other hand, in the Sawando Complex (=Complex 3), the radiolarian assemblage obtained from the uppermost horizon of chert and lowermost horizon of overlying siliceous mudstone is younger than that from the Norikuradake area (HORI, 1988; ISOZAKI and MATSUDA, 1985a, b, *etc.*; see Fig. 4)—(1). As shown in Fig. 2, the Yukawa Complex is structurally situated higher than the Sawando Complex—(2). These two facts mean that the pelagic chert of the Yukawa Complex was carried into hemipelagic environment earlier than that of the Sawando Complex. These matters are consistent with the view that the complex of the Mino Terrane was formed by successive subduction-accretion of a oceanic plate in Jurassic time (OTSUKA, 1988).

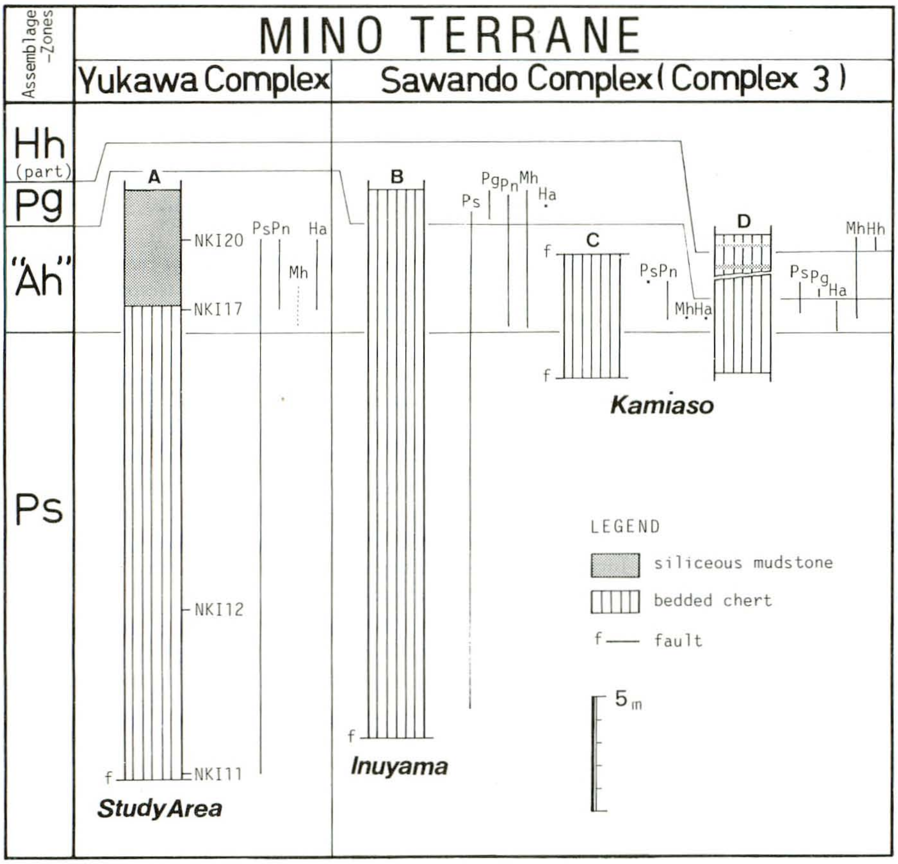

Fig. 4. Lithology and assemblage-zones recognised in the sections in the Yukawa and Sawando Complexes. Stratigraphic distribution of representative radiolarian species are also shown. A: NK Section of the Mt. Norikuradake area (study section in this paper). B: Iwayakannon Section of the Inuyama area after HORI (1988). C, D: Sections of the Kamiaso area after MATSUDA and ISOZAKI (1982), and ISOZAKI and MATSUDA (1985b) respectively. Other marks consisting of two letters indicate radiolarian species; "Ah", Mh=*Mesosaturnalis hexagonus* (YAO, 1972), Ha=*Hsuum altile* sp. nov., Hh=*Hsuum hisuihyoense* ISOZAKI & MATSUDA, 1985b, Pg = *Parahsuum* (?) *grande* HORI & YAO, 1988, Pn=*Parvicingula nanoconica* sp. nov., Ps = *Parahsuum simplum* YAO, 1982.

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*: in Japanese with English abstract
**: in Japanese

Explanation of Plate 1

Figs. 1–6. *Hsuum altile* sp. nov. ....P. 142

1a-c. Holotype, OCU MR 4020, NKI20II-64
(a) and (b) stereoscopic pair, (a) and (b) ×126, (c) ×283

2a-c. OCU MR 4021, NKI20II-78
(a) and (b) stereoscopic pair, (c) closer view of distal portion,
(a) and (b) ×126, (c) ×283

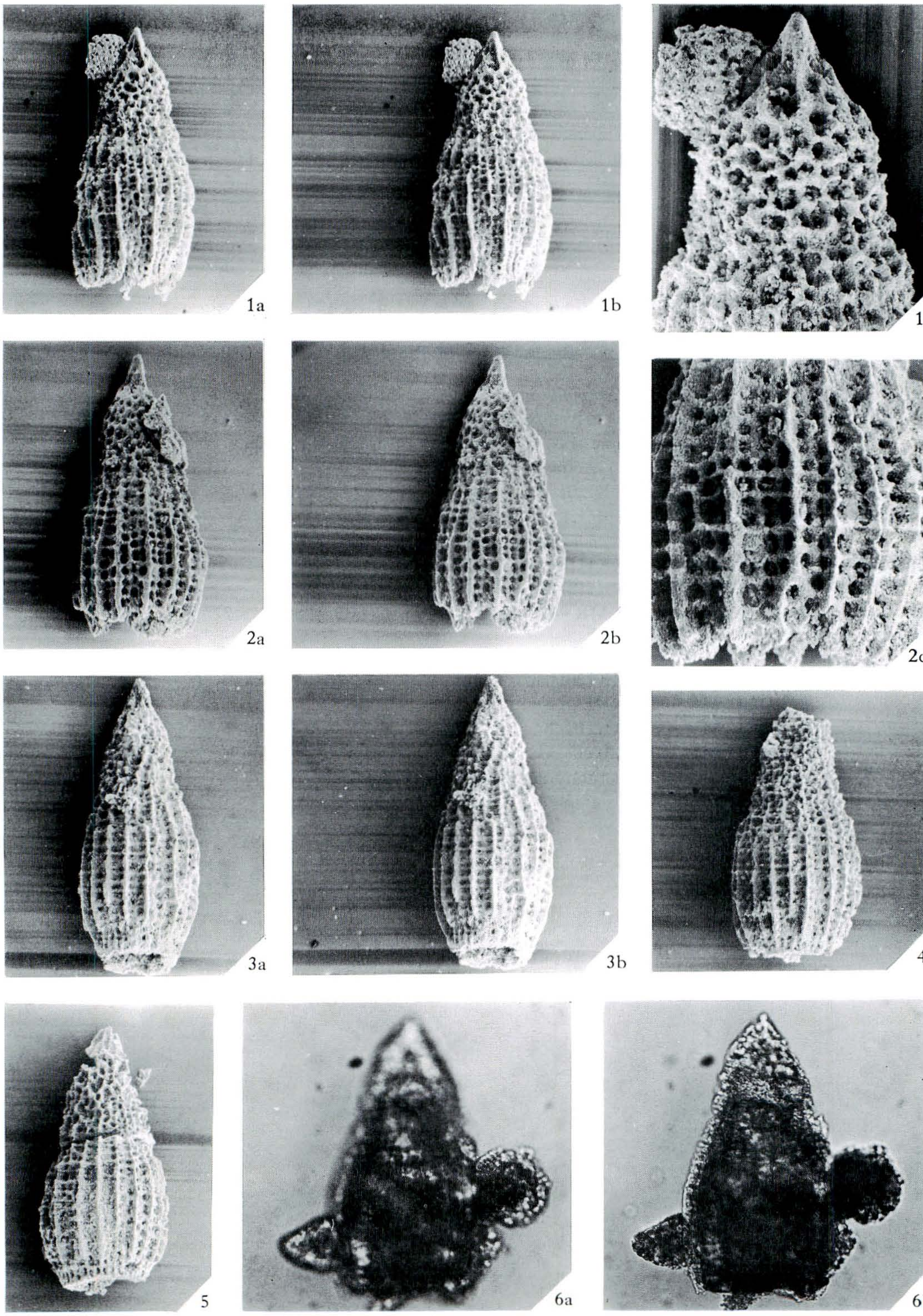
3a, b. OCU MR 4022, NKI20II-77
(a) and (b) stereoscopic pair, ×126

4. OCU MR 4023, NKI20II-74 ×126

5. OCU MR 4024, NKI20II-73 ×126

6a,b. Paratype, OCU MR 4025, NKI20II No. 1 (40.5×94.9) ×148

All Figures are scanning electron micrographs except for 6a,b transmitted light photomicrographs.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Explanation of Plate 2

Figs. 1–6. *Parvicingula nanoconica* sp. nov..P. 145

1a-d. Holotype, OCU MR 4026, NKII9–21
(a) and (b) stereoscopic pair, (c) closer view of proximal portion,
(a) and (b) ×148, (c) ×500, (d) ×225

2. OCU MR 4027, NKI20I-29 ×225

3a,b. OCU MR 4028, NKI20I-26
(b) closer view of outer layer, (a) ×225, (b) ×750

4. OCU MR 4029, NKII10–31 ×225

5. OCU MR 4030, NKII8–17 ×225

6a,b. Paratype, OCU MR 4031, NKI20II No. 1 (41.3×96.8) ×225

Figs. 7–10. *Parvicingula* spp.

7. OCU MR 4032, NKI20II-27 ×225
8. OCU MR 4033, NKI20II-60 ×225
9. OCU MR 4034, NKII9–26 ×225
10. OCU MR 4035, NKII9–44 ×225

All Figures are scanning electron micrographs except for 6a,b
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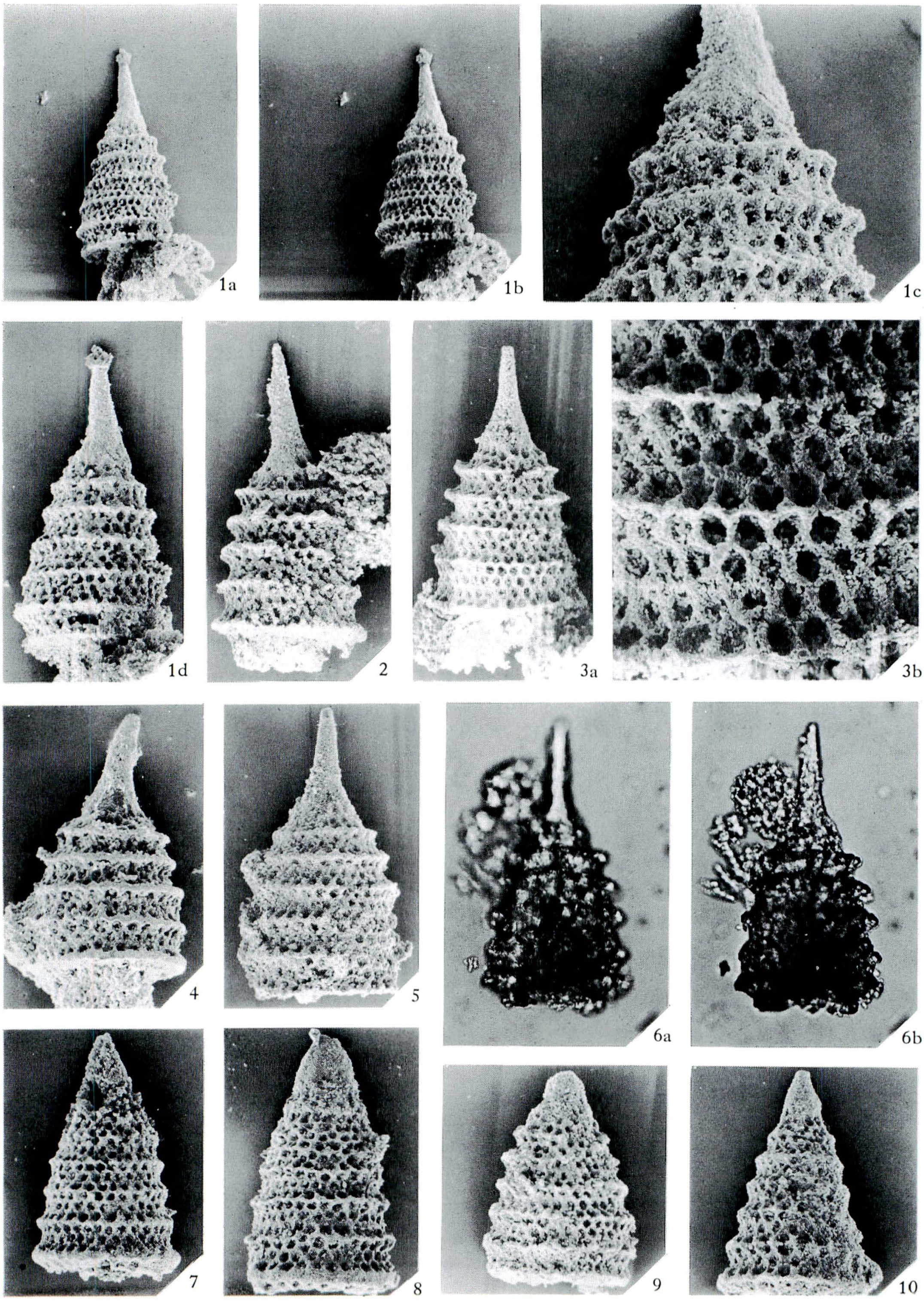
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Explanation of Plate 3

Figs. 1–4. *Hsuum* sp. X ....P. 143
1. OCU MR 4036, NKI17II-58 ×225
2. OCU MR 4037, NKI20II-46 ×225
3. OCU MR 4038, NKI20II-32 ×225
4. OCU MR 4039, NKI17I-47 ×150

Fig. 5. *Hsuum* sp. *β* ....P. 144
5. OCU MR 4040, NKI20II-43 ×225

Figs. 6,7. *Hsuum* (?) sp. Y..........P. 144
6. OCU MR 4041, NKI17II-47 ×225
7. OCU MR 4042, NKI17II-35 ×325

Fig. 8. *Hsuum* (?) sp. Z ....P. 144
8. OCU MR 4043, NKI20II-55 ×225

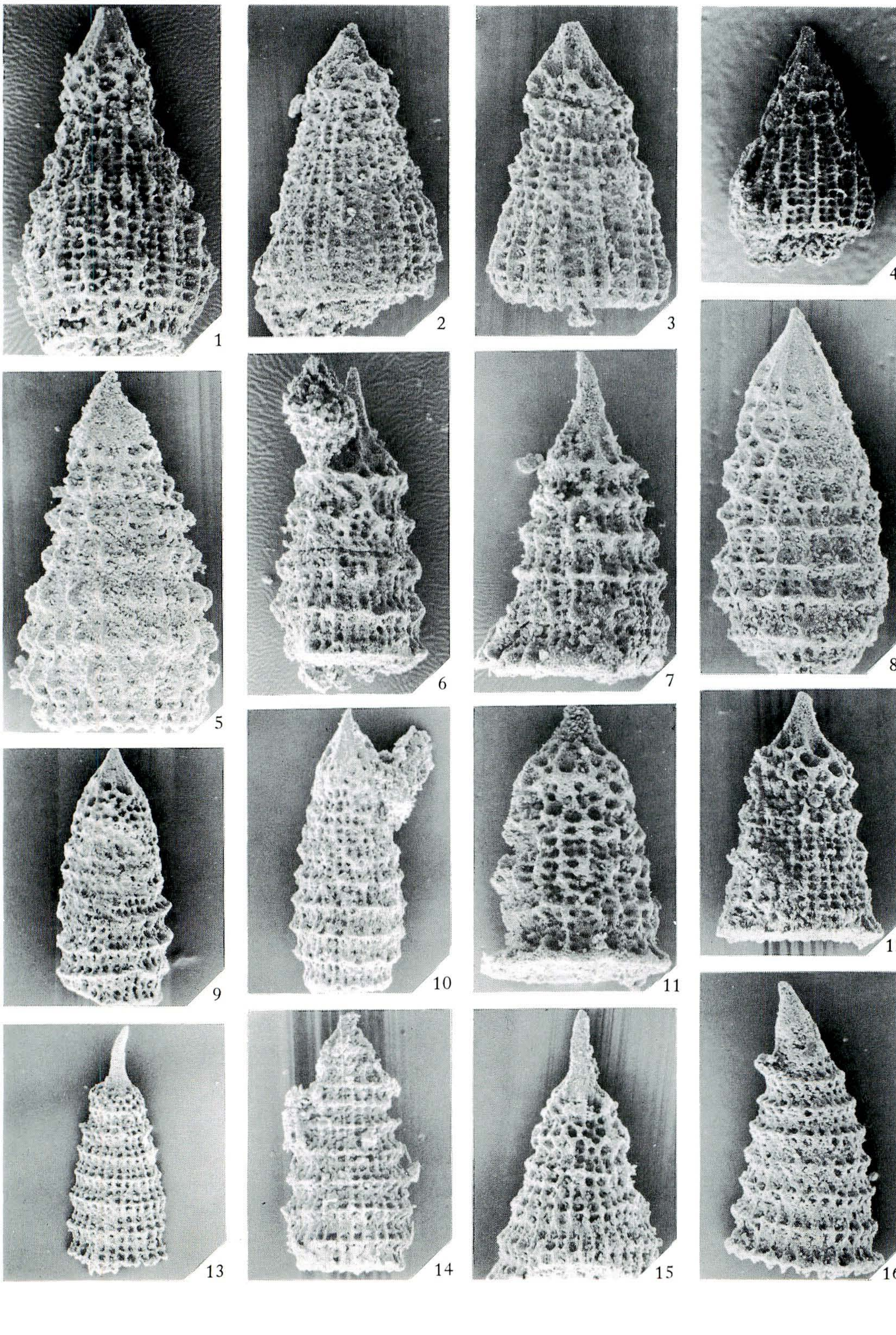
Figs. 9,10. *Parahsuum* (?) sp. A ....P. 145
9. OCU MR 4044, NKII9–49 ×148
10. OCU MR 4045, NKII8–31 ×148

Figs. 11,12. *Parahsuum* (?) sp. B ....P. 145
11. OCU MR 4046, NKI17II-31 ×225
12. OCU MR 4047, NKII9–41 ×225

Figs. 13–15. *Parahsuum* (?) sp. aff. *P.* (?) *magnum* TAKEMURA, 1986..........P. 144
13. OCU MR 4048, NKII8–12 ×148
14. OCU MR 4049, NKI17II-13 ×148
15. OCU MR 4050, NKII9–56 ×225

Fig. 16. *Wrangellium* sp.
16. OCU MR 4051, NKII9–36 ×225

All Figures are scanning electron micrographs.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Explanation of Plate 4

Figs. 1–3. *Eucyrtidiellum* spp.
1. OCU MR 4052, NKII8–43 ×225
2. OCU MR 4053, NKII8–41 ×225
3. OCU MR 4054, NKII10–80 ×225

Fig. 4. *Ares* (?) sp. D
4. OCU MR 4055, NKII8–62 ×225

Fig. 5. *Pseudocrucella* (?) sp. A
5. OCU MR 4056, NKII8–80 ×100

Figs. 6,7. *Tritrabs* (?) spp.
6. OCU MR 4057, NKI17II-61 ×125
7. OCU MR 4058, NKII8–78 ×125

Fig. 8. *Paronaella* (?) sp.
8. OCU MR 4059, NKII8–75 ×125

Fig. 9. *Mesosaturnalis* sp. cf. *M. hexagonus* (YAO, 1972)
9. OCU MR 4060, NKII5–13 ×112

Fig. 10. *Tympaneides* sp. cf. *T. charlottensis* CARTER in CARTER *et al.*, 1988
10. OCU MR 4061, NKII5–12 ×112

Fig. 11. *Tripocyclia* sp.
11. OCU MR 4062, NKII8–61 ×148

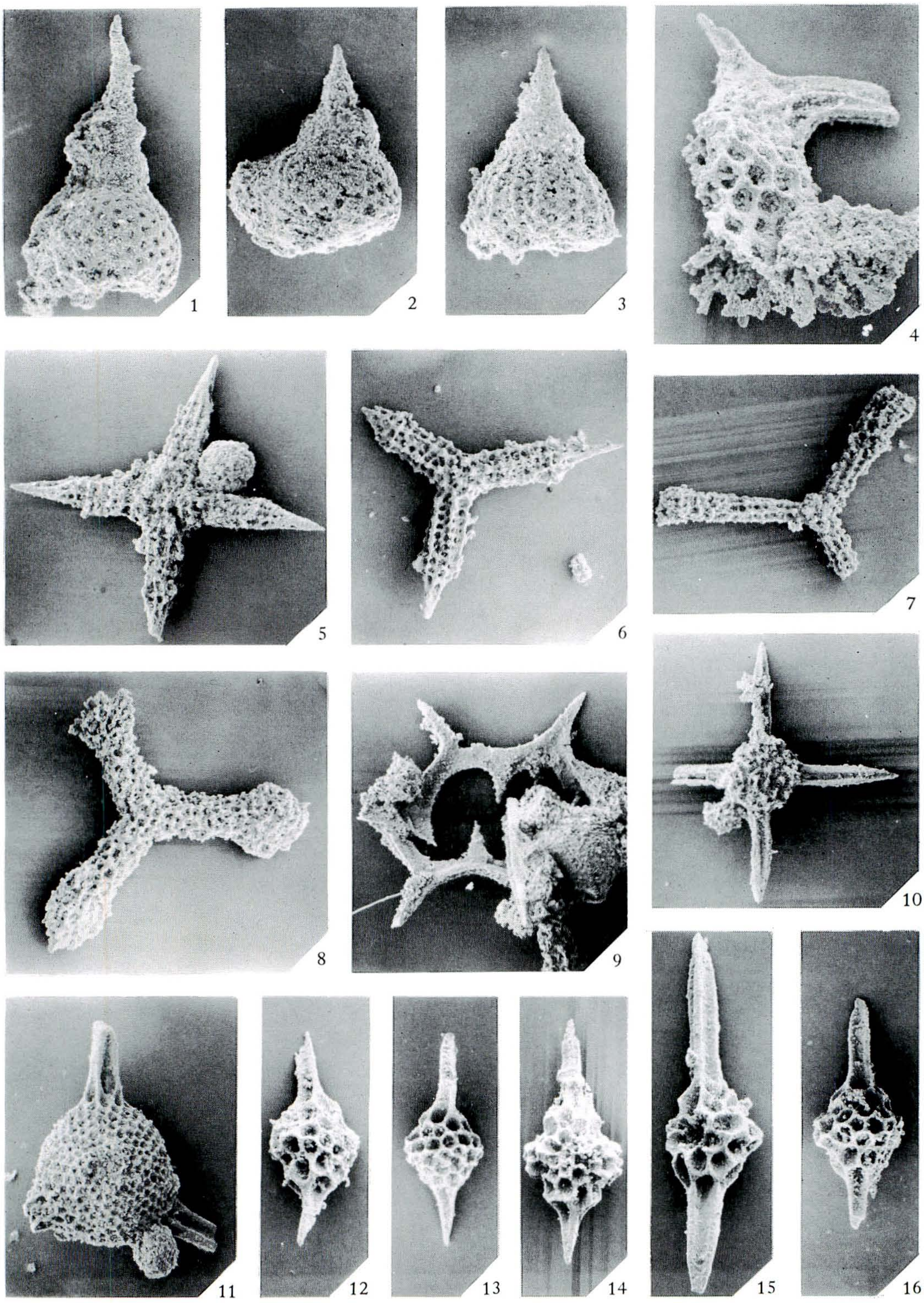
Figs. 12,13. *Pantanellium* spp.
12. OCU MR 4063, NKII9–81 ×148
13. OCU MR 4064, NKII9–90 ×148

Fig. 14. *Zartus* sp. aff. *Z. imlayi* PESSAGNO and BLOME, 1980
14. OCU MR 4065, NKII9–89 ×148

Fig. 15. *Trillus elkhornensis* PESSAGNO and BLOME, 1980
15. OCU MR 4066, NKII9–76 ×148

Fig. 16. *Trillus* sp.
16. OCU MR 4067, NKII9–82 ×148

All Figures are scanning electron micrographs.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