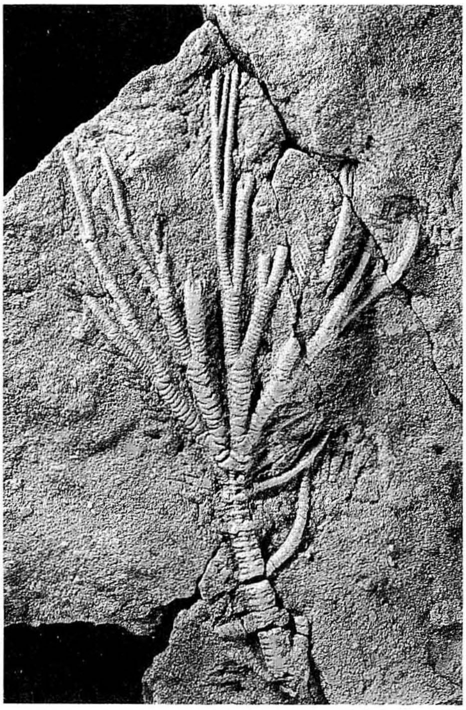
ISSN 0031-0204

日本古生物学會 報告・紀事

Transactions and Proceedings of the Palaeontological Society of Japan

New Series No. 171



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Palaeontological Society of Japan

September 30, 1993

The fossil on the cover is *Isocrinus* (*Chladocrinus*) *hanaii* Oji, an Early Cretaceous (Aptian) crinoid, which was described from the Hiraiga Formation exposed at Haipe, Tanohata-mura, Shimo-Hei County, Iwate Prefecture, Northeast Japan. (University Museum of the University of Tokyo coll. cat. no. ME6950, paratype specimen, length about 11 cm)

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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 171, pp. 213-228, 6 Figs., September 30, 1993

956. UPPER CARBONIFEROUS FORAMINIFERS FROM BAN NA DIN DAM, CHANGWAT LOEI, NORTHEASTERN THAILAND*

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Abstract. White to pale gray, massive to thickly bedded limestone crops out in Ban Na Din Dam, east of Loei, northeastern Thailand. This limestone belongs to the Lower Permian Nam Mahoran Formation. We newly discriminated two important fusulinacean species in this limestone; namely, *Triticites* (*T.*) *samaricus* Rauser-Chernoussova and *Jigulites grandis*, sp. nov. These species strongly indicate a Gzhelian (latest Carboniferous) age. The present discovery first confirms the presence of the Gzhelian fusulinacean fauna in Thailand. Smaller foraminifers coexisting with these fusulinaceans are also listed and illustrated.

Key words. Fusulinacean, Gzhelian, Loei, Thailand, Upper Carboniferous.

Introduction

The biostratigraphy of Carboniferous and Permian strata in Thailand was mainly established by means of fusulinaceans, and 20 almost continuously superposed zones were reported (Toriyama, 1984). Among them, zones indicating a Gzhelian (latest Carboniferous) age were uncertain, hence the boundary problem between the Carboniferous and Permian has never been fully discussed for this country. Igo (1972) established the *Protriticites tethydis* Zone and *Triticites ozawai-Paraschwagerina yanagidai* Zone in the Loei-Wang Saphung area, northeastern Thailand, and he concluded that the former should be correlated with the uppermost Myachkovian or lowermost Kasimovian and the latter with the Asselian. Namely, he regarded that the uppermost Carboniferous Gzhelian fusulinacean fauna is lacking in this area.

Recently, we discriminated interesting fusulinacean species which indicate a Gzhelian age in the limestone belonging to the Nam Mahoran Formation. The present fossil locality is about 2 km east of Ban Na Din Dam, Changwat Loei, northeastern Thailand (Figure 1). We describe these newly discriminated fusulinaceans and discuss the geologic age of this fauna.

Acknowledgments

The research was supported by a grant to H. Igo from the Monbusho International Scientific Research Program, No. 02140210. We thank Mr. Nikorn Nakornsri, Senior Geologist of the Geological Survey Division, Department of Mineral Resources, Thailand, for his field guidance. We also thank Drs. Katsuo Sashida, Ken-ichiro Hisada and Miss Apsorn Ampornmaha of the University of Tsukuba for their cooperation in the field.

Geologic Setting

Upper Paleozoic rocks distributed in the

*Received June 17, 1992; accepted April 19, 1993

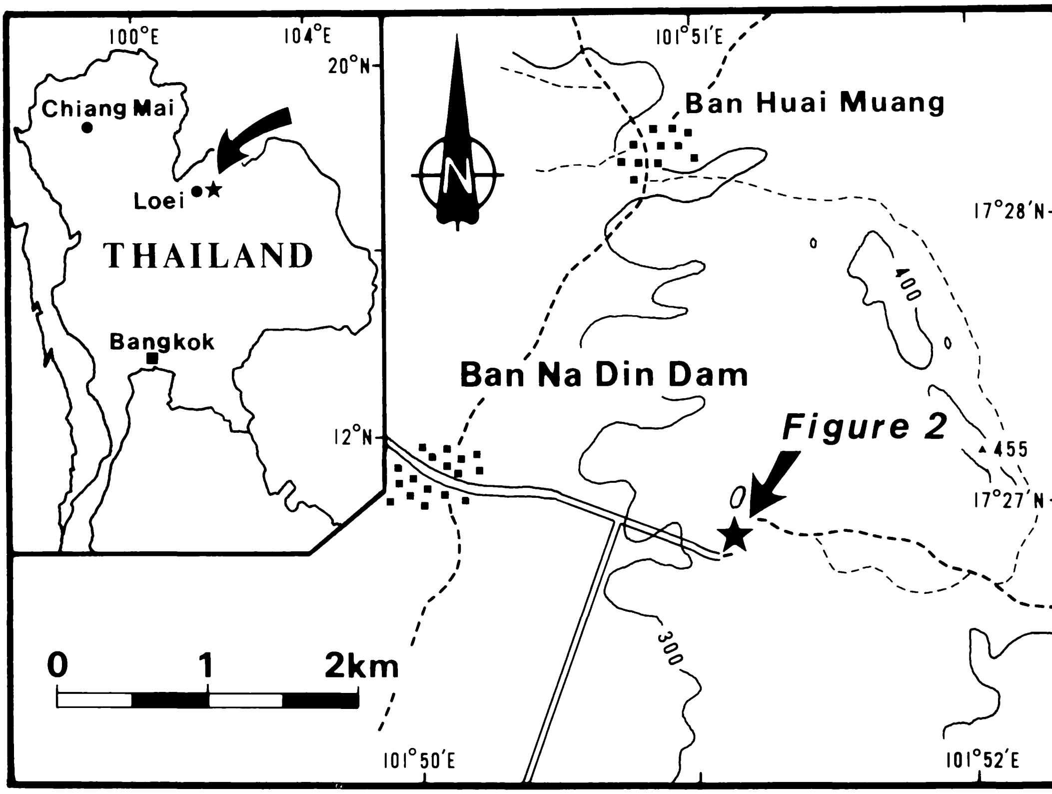

Figure 1. Index map of Ban Na Din Dam, east of Loei, northeastern Thailand.

Loei area are divided into the Carboniferous Wang Saphung Formation and the Permian Ratburi (or Rat Buri) Group (Charoenpravat *et al*., 1976). Although the Ratburi Group has long been used as one of the most important Permian lithologic units all over Thailand, it is in fact restricted to Permian limestones distributed in Peninsular Thailand, and the Saraburi Group (or Limestone) is commonly accepted to be in the Loei Folded Belt (Bunaᵛᵓas, 1983). The lowest division of the Saraburi Group is the Nam Mahoran Formation that consists mainly of white to pale gray, massive to thickly bedded limestone. This limestone constitutes the characteristic topography of occasionally isolated high hills surrounded by steep cliffs, with heavy tropical vegetation covering most of them. One of these hills, located east of Ban Na Din Dam, is partly exposed by recent felling (Figure 1). Igo collected the present materials from six different levels of this outcrop (Figure 2).

The lowest level, Loe-28, is white to pale gray, thickly bedded limestone containing abundant algae, fusulinaceans, and smaller foraminifers. Microfacies of this limestone is fusulinacean-algal packstone and grainstone.

The next higher level is Loe-29 and consists of pale gray, thickly bedded limestone containing hematitic matter and abundant dasycladacean algae, fusulinaceans, and smaller foraminifers. Goniatites and brachiopods are also present but less common compared with next higher levels.

The levels Loe-30, 31, and 32 are pale gray to white, thickly bedded limestone including particularly abundant brachiopods, bryozoans, goniatites, and crinoid columns

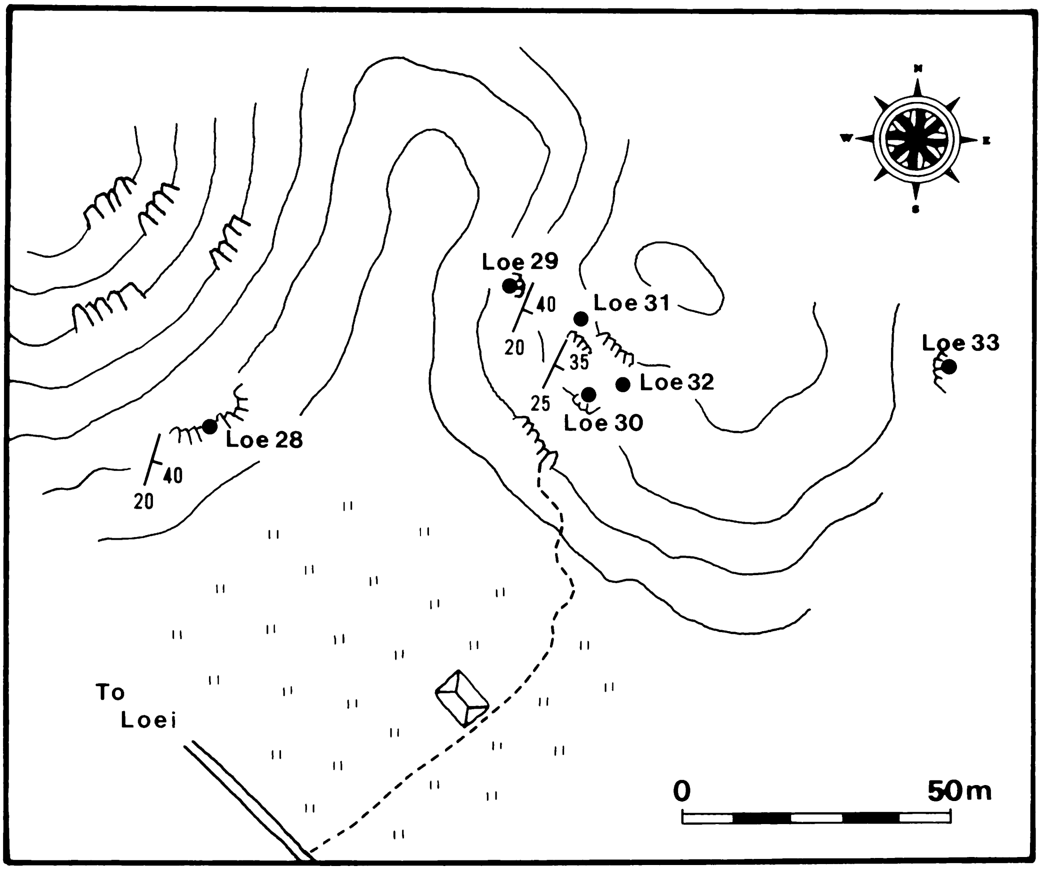

Figure 2. Map showing fossil localities studied herein. Contour interval about 10 m.

and less common gastropods, pelecypods, and tabulate corals. Brachiopod and goniatite shells are frequently heaped in particular beds as coquinoid limestone or sporadically embedded within wackestone. These limestone beds do not yield any fusulinaceans but rarely include smaller foraminifers.

The level Loe-33 represents the highest one in this section and consists of a pale gray, partly dark brownish, thickly bedded limestone containing abundant fragments of crinoid columns, bryozoans, and algae (*Tubiphytes* sp.). Fusulinaceans are rare but smaller foraminifers are rather abundant in this limestone. Microscopically, this is coarse-grained calcarenitic limestone.

The limestone exposed in this hill is lithologically very similar to that of the Nam Mahoran Formation typically exposed in Tham Nam Mahoran, about 45 km south of Loei from where Yanagida (1967) and Igo (1972, 1974) described Asselian brachiopods, fusulinaceans, and conodonts.

Appraisal of foraminiferal faunas

Fusulinaceans and smaller formainifers discriminated in the limestone exposed east of Ban Na Din Dam are listed in Tables 1 and 2.

The level Loe-28 yields abundant *Triticites* (*T.*) *samaricus* Rauser-Chernoussova associated with smaller foraminifers. This species was originally described from the Samara Bend of the Volga region by Rauser-Chernoussova (1938) as a variety of *secalicus*. Rozovskaya (1958) redescribed this species

Table 1. List of fusulinaceans from Loe-28, Loe-29, and Loe-33.

Species \ Level	Loe-28	Loe-29	Loe-33
Schubertella sp.			+
Biwaella ? sp.	+		
Triticites (*T.*) *samaricus* Rauser-Chernoussova	+++		
Jigulites grandis, sp. nov.		+++	
Rugosochusenella sp.			+
Rugosofusulina ? sp.			+
Nankinella spp.	+	++	

+++ : abundant ++ : common + : rare

from the Samara Bend and mentioned that the range of this species is restricted to C_3B and C_3C. These units are correlated to the upper Kasimovian to lower Gzhelian of the Russian standard. Mikhaylova (1974) also reported this species from the *Triticites arcticus* and *T. actus* Zones (C_3B) of the Pechora Urals.

Kanmera (1958) described this species from the *Pseudoschwagerina* Zone of the Yayamadake Limestone, Kyushu, Japan. Recently, Ozawa and Kobayashi (1990) pointed out that this species is one of the diagnostic species of Zone AK30 (*Daixina robusta*-"*Pseudoschwagerina*" *minatoi* Zone) of the Akiyoshi Limestone Group. They considered that the zone should be correlated with the uppermost Gzhelian of the Russian standard. According to Watanabe (1991), this species occurs from the lower Asselian *Sphaeroschwagerina fusiformis* Zone of the Akiyoshi Limestone Group.

Chen and Wang (1983) described this species as a subspecies of *Triticites secalicus* (Say) from the *Sphaeroschwagerina sphaerica gigas* Zone of the Maping Limestone of Yishan, Guangxi, South China.

Igo (1972) described *Triticites samaricus* Rauser-Chernoussova from Ban Nam Lum, south of Phetchabun in central Thailand. In Phetchabun this species is associated with *Quasifusulina tenuissima* (Schellwien), *Triticites* (*T.*) *ozawai* Kanmera, *T.* (*T.*) aff. *haydeni* (Ozawa), *Daixina lalaotuensis* (Sheng), *D. petchabunensis* (Igo), and *Paraschwagerina yanagidai* Igo. He correlated this fauna to those reported from the lower Asselian of the Tethys region.

Among the above mentioned faunas, those of Yayamadake and Phetchabun should be correlated with the uppermost Carboniferous

→ **Figure 3.** **1-3**: *Spiroplectammina* sp., longitudinal sections, IGUT-KU0380, IGUT-KU0381, IGUT-KU0382. **4**: *Tuberitina bulbacea* Galloway and Harlton, longitudinal section, IGUT-KU0383. **5**: *Eotuberitina reitlingerae* Miklukho-Maklay, longitudinal section, IGUT-KU0384. **6, 7**: *Eotuberitina* spp., longitudinal sections, IGUT-KU0385, IGUT-KU0386. **8**: *Diplosphaerina* sp., longitudinal section, IGUT-KU0387. **9, 10**: *Globivalvulina* spp., lateral sections, IGUT-KU0388, IGUT-KU0389. **11**: *Climacammina* sp., longitudinal section, IGUT-KU0390. **12-14**: *Hemigordius* sp. A, axial sections, IGUT-KU0391, IGUT-KU0392, IGUT-KU0393. **15, 16.** *Hemigordius* ? sp. B, **15**: axial section, IGUT-KU0394, **16**: oblique section, IGUT-KU0395. **17, 18.** *Eolasiodiscus* sp., **17**: tangential section, IGUT-KU0396, **18**: sagittal section, IGUT-KU0397. **19**: *Endothyranella* ? sp., longitudinal section, IGUT-KU0398. **20**: *Earlandia* sp., longitudinal section, IGUT-KU0399. **21-23**: *Tetrataxis* spp., axial sections, IGUT-KU0400, IGUT-KU0401, IGUT-KU0402. **24, 27, 29.** *Bradyina* spp., **24, 27**: axial sections, IGUT-KU0403, IGUT-KU0406, **29**: sagittal section, IGUT-KU0408. **25**: *Pachyphloia* ? sp., lateral section, IGUT-KU0404. **26**: *Endothyra* sp., axial section, IGUT-KU0405. **28**: *Pseudobradyina* sp., sagittal section, IGUT-KU0407. **11, 22, 29**: ×20, **1-10, 12-16, 19-21, 23, 24, 27, 28**: ×40, **17, 18, 25, 26**: ×100.

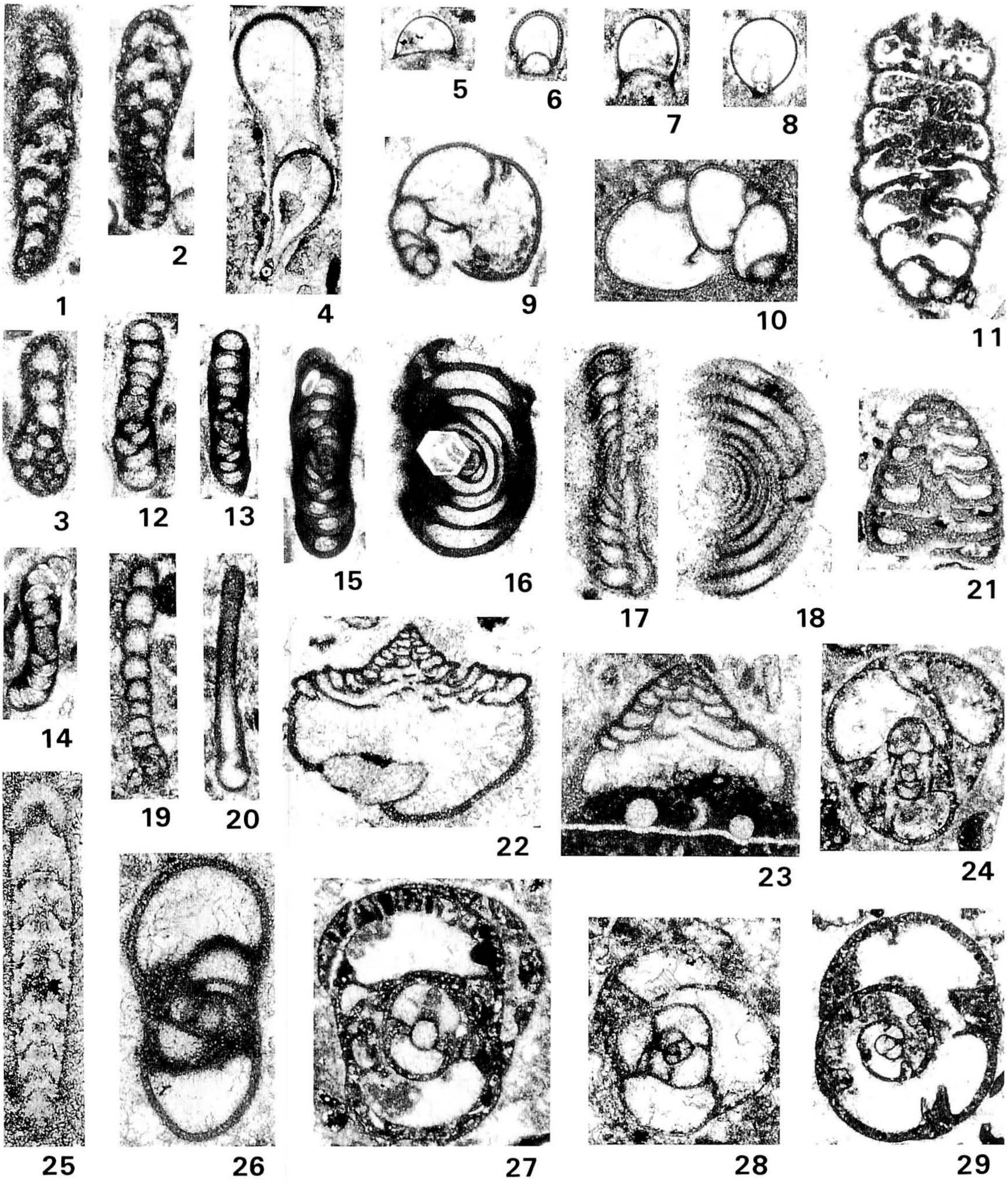
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Table 2. List of smaller foraminifers from Loe-28 to Loe-33.

Species \ Level	Loe-28	Loe-29	Loe-31	Loe-32	Loe-33
Spiroplectammina sp.	x	x	x		
Eotuberitina reitlingerae Miklukho-Maklay	x				x
E. spp.		x	x		x
Tuberitina bulbacea Galloway and Harlton	x	x	x	x	
T. sp.	x				
Diplosphaerina sp.	x		x		
Earlandia sp.			x		
Tetrataxis spp.	x	x			x
Bradyina spp.	x	x			x
Pseudobradyina sp.			x		
Eolasiodiscus sp.	x	x	x	x	
Globivalvulina spp.	x	x	x		
Climacammina spp.		x			x
Endothyra spp.			x		x
Endothyranella ? sp.			x		
Hemigordius sp. A	x				
H. ? sp. B		x			
Pachyphloia ? sp.				x	

based upon the recent revised opinions concerning the Carboniferous and Permian boundary which were advocated by Ozawa and Kobayashi (1990) and Watanabe (1991). According to our consideration, the specimens previously described as *Triticites samaricus* by several authors do not belong to the same species because these forms of *Triticites* lack diagnostic features.

The level Loe-29 yields abundant *Jigulites grandis*, sp. nov. which is similar to *Jigulites longus* (Rozovskaya) and *J. magnus* (Rozovskaya). These Russian species were described from the *Triticites* (*Rauserites*) *stuckenbergi* Zone (C_3C), *Jigulites jigulensis* Zone (C_3D), and *Daixina sokensis* Zone (C_3E) of the Gzhelian. *Daixina petchabunensis* Igo described from a limestone exposed south of Phetchabun is also similar to our *Jigulites grandis*, but the former has more intensely fluted septa and weakly developed chomata than the latter. This level does not yield any species similar to *Carbonoschwagerina morikawai* (Igo), "*C.*" *minatoi* (Kanmera), and *Paraschwagerina shimodakensis* Kanmera. These species commonly occur in association with *Triticites* (s.l.), *Jigulites*, and *Daixina* and are regarded as the index species of the upper Hikawan (uppermost Carboniferous) of Japan (*e.g.*, Ozawa and Kobayashi, 1990; Watanabe, 1991). Fusulinaceans from the level Loe-29 are slightly older than those reported from Ban Nam Lum. From the above mentioned paleontological data, this level should be correlated with the middle Gzhelian.

The next higher fusulinacean-bearing level is Loe-33 and rarely yields *Schubertella* sp., *Rugosochusenella* sp, and *Rugosofusulina* ? sp. Although we obtained only one well oriented axial section, the occurrence of the genus *Rugosochusenella* is worthy of note. This genus was originally proposed from the Wolfcampian (Lower Permian) of New Mexico, U.S.A. by Skinner and Wilde (1965). The present *Rugosochusenella* sp. is more or less similar to *Rugosochusenella* sp. A illustrated by Ozawa and Kobayashi (1990). The latter unidentified species was introduced as a dominant zonal species of Zone AK 30 (uppermost Gzhelian) of the Akiyoshi Limestone Group. It is also similar to several *Rugosochusenella* species reported from the uppermost Gzhelian to the "*Schwagerina* Horizon" of various sections of Russia, such as *R. sangoneliensis* Davydov, *R. kalaikuchnensis* Davydov, *R. paragregaria* (Rauser-Chernoussova), *R. hutiensis* (Chen), and others. Fossil contents are rather poor in level Loe-33, but it may be correlated with the *Daixina sokensis* Zone of the uppermost Gzhelian (C_3E).

As shown in Table 2 and Figure 3, we also discriminated smaller foraminifers in each level of the present section, but did not find any reliable species for detailed age assignment. Among them, *Hemigordius* sp. A and *H.* ? sp. B are similar to the species which are rather common in the post-Sakmarian levels of the Akiyoshi Limestone Group, but other species are similar to forms reported hitherto from the Carboniferous and Permian.

Systematic description

All specimens identified in this paper are deposited in the paleontological collections of the Institute of Geoscience, University of Tsukuba (IGUT).

Order Foraminiferida Eichwald, 1830
Suborder Fusulinina Wedekind, 1937
Superfamily Fusulinacea von Möller, 1878
Family Schubertellidae Skinner, 1931
Subfamily Schubertellinae Skinner, 1931
Genus *Schubertella* Staff and Wedekind, 1910

Schubertella sp.

Figure 4-8

Description.—Shell small with 4 volutions, 0.47 mm in length and 0.24 mm in width with a form ratio of 1.92. The first volution coiled perpendicularly to outer ones. Radius vectors of the first to fourth volution 0.03, 0.05, 0.08, and 0.13 mm, and form ratios 1.00, 1.22, 1.50, and 1.77, respectively. Outside diameter of proloculus 0.030 mm. Septa unfluted.

Remarks.—This species somewhat resembles *Schubertella rara* originally described by Sheng (1963) from the lower part of the Qixia (Chihsia) Limestone of Guizhou (Kueichow) in its small shell size. The former, however, has less developed chomata than the latter.

Material studied.—Axial section; IGUT-KU0416 from Loe-33.

Subfamily Biwaellinae Davydov, 1984
Genus *Biwaella* Morikawa and Isomi, 1960

Biwaella ? sp.

Figures 4-1—4

The follwing description is entirely based on one axial section illustrated on Figure 4-2.

Description.—Shell small and fusiform with bluntly pointed poles. Axial section of 4½ volutions 1.75 mm in length and 0.68 mm in width, giving a form ratio of 2.59. Shell expands gradually throughout growth. Radius vectors of the first to fourth, and fourth and a half volution 0.08, 0.12, 0.19, 0.29, and 0.39 mm, and form ratios 1.13, 1.50, 1.84, 2.21, and 2.31, respectively. Proloculus small and spherical, being 0.080 mm in outside diameter. Spirotheca thin and composed of a tectum and lower structureless layer in inner volutions, but of a tectum and fine alveolar keriotheca in outer ones. Thickness of spirotheca of the first to fourth volution 0.010, 0.020, 0.020, and 0.035 mm. Septa weakly fluted only in extreme polar regions. Chomata small and developed in all volutions except for the first one. Tunnel angles of the third and fourth volutions 32 and 40 degrees.

Remarks.—This unidentified species closely resembles some species of *Biwaella*, especially *B.*? *tshelamtshiensis* originally described by Davydov (1984) from the Gzhelian *Jigulites altus* Zone of southwestern Darvas. The exact identification, however, is postponed until sufficient materials are accumulated.

Material studied.—Axial sections; IGUT-KU0409, IGUT-KU0410, IGUT-KU0411. Sagittal section; IGUT-KU0412. All specimens from Loe-28.

Family Schwagerinidae Dunbar and Henbest, 1930

Subfamily Chusenellinae Kahler and Kahler, 1966

Genus *Rugosochusenella* Skinner and Wilde, 1965

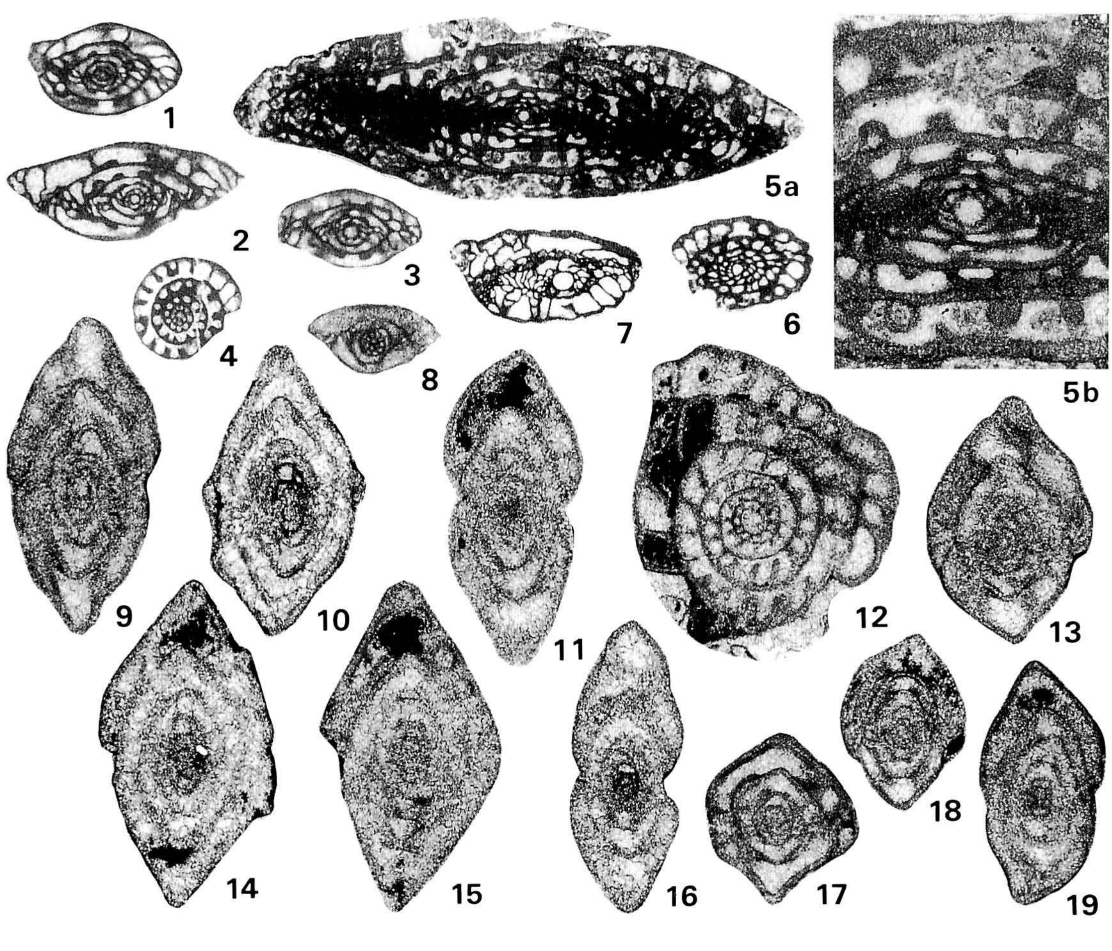

Figure 4. **1-4**. *Biwaella*? sp., **1-3**: axial sections, IGUT-KU0409, IGUT-KU0410, IGUT-KU0411, **4**: sagittal section, IGUT-KU0412. **5, 6.** *Rugosochusenella* sp., **5a**: axial section, IGUT-KU0413, **6**: sagittal section, IGUT-KU0414, **5b**: enlarged part of **5a**. **7**: *Rugosofusulina*? sp., axial section, IGUT-KU0415. **8**: *Schubertella* sp., axial section, IGUT-KU0416. **9-19**. *Nankinella* spp., **9-11, 13-19**: axial sections, IGUT-KU0417, IGUT-KU0418, IGUT-KU0419, IGUT-KU0421, IGUT-KU0422, IGUT-KU0423, IGUT-KU0424, IGUT-KU0425, IGUT-KU0426, IGUT-KU0427, **12**: sagittal section, IGUT-KU0420. **7**: ×10, **5a, 6**: ×15, **1-4**: ×20, **9-19**: ×30, **5b, 8**: ×40.

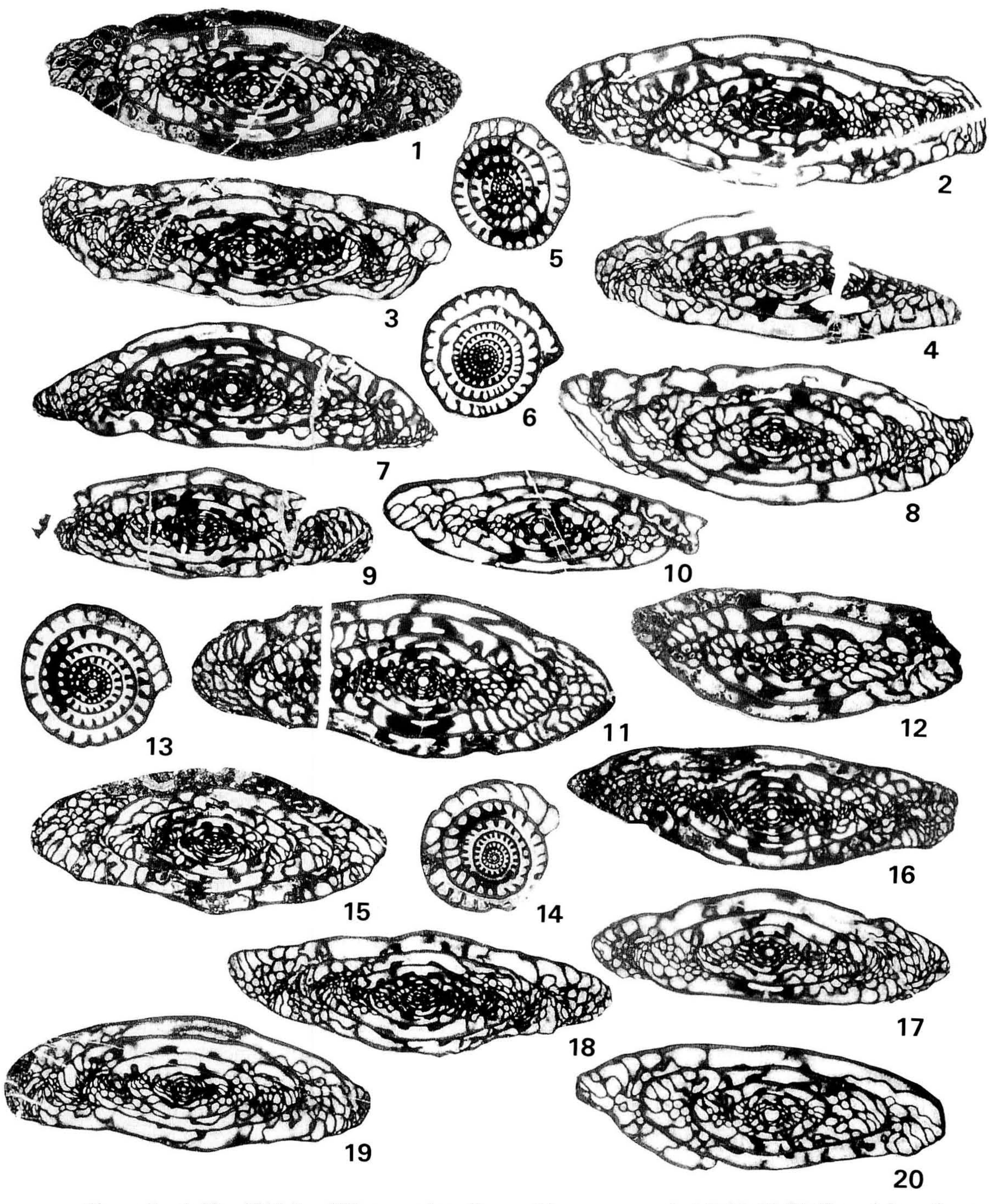

Figure 5. 1–20. *Triticites* (*T.*) *samaricus* Rauser-Chernoussova, **1–4, 7–11, 15–17, 19**: axial sections, IGUT-KU0428, IGUT-KU0429, IGUT-KU0430, IGUT-KU0431, IGUT-KU0434, IGUT-KU0435, IGUT-KU0436, IGUT-KU0437, IGUT-KU0438, IGUT-KU0442, IGUT-KU0443, IGUT-KU0444, IGUT-KU0446, **5, 6, 13, 14**: sagittal sections, IGUT-KU0432, IGUT-KU0433, IGUT-KU0440, IGUT-KU0441, **12, 20**: slightly oblique axial sections, IGUT-KU0439, IGUT-KU0447. All ×10.

Rugosochusenella sp.

Figures 4-5—6

Description.—Shell small in schwagerinid fusulinaceans and elongate fusiform with bluntly pointed polar ends. Axial section of 6½ volutions (Figure 4-5a) 4.88 mm in length and 1.63 mm in width, giving a form ratio of 3.00. Early few volutions rather tightly coiled. Radius vectors of the first to sixth volution 0.09, 0.12, 0.20, 0.31, 0.49, and 0.72 mm, and form ratios 1.55, 2.25, 2.38, 3.09, 2.76, and 2.86, respectively. Proloculus small and spherical, being 0.120 mm in outside diameter. Spirotheca thin and composed of a tectum and keriotheca. Weak and irregular rugosity observed on surface of spirotheca. Thickness of spirotheca of the first to fifth volution 0.010, 0.020, 0.035, 0.050, and 0.075 mm. Septa moderately fluted throughout shell length. Small chomata developed in all volutions. Tunnel angles of the second to sixth volution 36 ?, 28, 31, 37, and 27 degrees. Axial fillings restricted to polar regions.

Remarks.—This unidentified species can be distinguished from *Rugosochusenella zelleri*, the type species of the genus, described by Skinner and Wilde (1965) from the Lower Permian Horquilla Limestone in the Big Hatchet Mountains of southwestern New Mexico, in having a smaller shell, less tightly coiled inner volutions and less developed rugosity on the surface of spirotheca.

Rugosochusenella sp. A (Ozawa and Kobayashi, 1990) reported from Zone AK 30, uppermost Carboniferous, of the Akiyoshi Limestone Group, Japan is similar to our present unidentified species but the former has a larger shell than does the latter.

The present *Rugosochusenella* sp. is similar to *R. sangoneliensis* Davydov, *R. kalaikuchnensis* Davydov, and *R. paragregaria* (Rauser-Chernoussova) reported from the *Daixina bosbytauensis-D. robusta* Zone (uppermost Gzhelian) of Darvas (Chuvashov *et al*., 1986). Our present species has a smaller shell than these Russian species but more detailed comparison is difficult because we obtained only one axial section.

Material studied.—Axial section; IGUT-KU0413. Sagittal section; IGUT-KU0414. Both specimens from Loe-33.

Subfamily Schwagerininae Dunbar and Henbest, 1930
Genus *Triticites* Girty, 1904
Subgenus *Triticites* Girty, 1904

Triticites (*Triticites*) *samaricus* Rauser-Chernoussova, 1938

Figures 5-1—20

Triticites secalicus var. *samarica* Rauser-Chernoussova, 1938, p. 112-113, 156, pl. 4, figs. 1-2.

Triticites (*Triticites*) *secalicus samaricus* Rauser-Chernoussova. Rozovskaya, 1958, p. 83, pl. 2, figs. 7-8.

Triticites samaricus Rauser-Chernoussova. Kanmera, 1958, p. 168-171, pl. 26, figs. 1-13; Igo, 1972, p. 97-98, pl. 14, figs. 8-14; Ozawa and Kobayashi, 1990, pl. 5, fig. 5; Watanabe, 1991, figs. 4-6—13.

Triticites secalicus samaricus Rauser-Chernoussova. Mikhaylova, 1974, p. 53-54, pl. 4, fig. 1; Chen and Wang, 1983, p. 71, pl. 11, fig. 15.

Description.—Shell medium for genus and fusiform to elongate fusiform with bluntly pointed polar regions and gently arched periphery. Mature specimens having 5½ to 7, rarely 7½ volutions, 5.03 to 6.88 mm in length and 1.60 to 2.53 mm in width. Form ratio ranges from 2.51 to 3.29, averaging 2.94 for 14 specimens.

Axis of coiling straight throughout growth. Inner few volutions somewhat tightly coiled. Radius vectors of the first to sixth volution of well oriented axial section (Figure 5-1) 0.15, 0.24, 0.38, 0.58, 0.82, and 1.09 mm, and form ratios 1.87, 1.80, 1.74, 2.43, 2.65, and 2.95, respectively.

Proloculus small and spherical, sometimes irregular in shape. Outside diameter of proloculus ranges from 0.105 to 0.207 mm, averaging 0.179 mm for 29 specimens.

Table 3. Measurements of *Triticites* (*Triticites*) *samaricus* Rauser-Chernoussova. (in mm)

	Reg. no.	Figure	Length	Width	F.R.	D.P.	Radius vectors						
							1	2	3	4	5	6	7
1	IGUT-KU0428	5-1	6.43	2.35	2.73	0.195	0.15	0.24	0.38	0.58	0.82	1.09	
2	IGUT-KU0429	5-2	6.88	2.33	2.96	0.125	0.11	0.18	0.27	0.49	0.81	1.13	
3	IGUT-KU0430	5-3	6.45	1.98	3.27	0.180	0.15	0.24	0.38	0.56	0.81	1.05	
4	IGUT-KU0431	5-4	6.00	2.05	2.93	0.130	0.11	0.17	0.27	0.43	0.65	0.98	
5	IGUT-KU0434	5-7	6.43	1.95	3.29	0.205	0.16	0.28	0.46	0.56	0.91		
6	IGUT-KU0435	5-8	6.53	2.20	2.97	0.180	0.15	0.22	0.39	0.59	0.85	1.17	
7	IGUT-KU0436	5-9	5.03	1.75	2.87	0.140	0.12	0.19	0.28	0.44	0.67	0.92	
8	IGUT-KU0438	5-11	6.63	2.53	2.62	0.195	0.16	0.24	0.35	0.53	0.76	1.06	1.35
9	IGUT-KU0443	5-16	5.78	1.98	2.92	0.210	0.16	0.27	0.42	0.58	0.79	1.05	
10	IGUT-KU0446	5-19	5.53	2.10	2.63	0.140	0.13	0.20	0.30	0.46	0.63	0.92	

	Form ratio							Thickness of spirotheca						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	1.87	1.80	1.74	2.43	2.65	2.95		0.020	0.035	0.040	0.065	0.060	0.040	
2	1.55	1.79	2.21	1.92	2.08	2.60		—	0.030	0.045	0.040	0.080	0.060	
3	1.33	1.96	2.03	3.16	3.10	2.97		0.025	0.030	0.045	0.040	0.050	0.060	
4	1.82	1.89	2.11	2.23	2.31	2.78		0.015	0.025	0.025	0.030	0.045	0.060	
5	1.76	2.07	2.04	3.14	2.90			0.015	0.025	0.035	0.070	0.085		
6	1.53	2.13	2.45	2.51	2.99	2.71		0.020	—	0.040	0.055	0.065	0.085	
7	1.25	1.65	1.97	2.77	2.65	—		0.015	0.020	0.020	0.030	0.070	0.060	
8	1.19	1.60	1.75	2.16	2.74	2.61	2.68	—	0.025	0.035	0.055	0.080	0.080	0.090
9	1.18	1.61	1.86	2.20	2.47	2.67		0.025	0.045	0.055	0.045	0.070	0.075	
10	1.00	1.52	1.65	1.98	2.52	2.45		—	0.025	0.030	0.035	0.040	0.065	

F.R. : Form ratio
D.P. : Diameter of proloculus

	Tunnel angle (degrees)						
	1	2	3	4	5	6	7
1	24	21	36	39	43	36	
2	32	29	51	—	34	—	
3	21	34	30	33	76	—	
4	21	24	40	33	39	47	
5	25	25	31	35	41		
6	25	21	25	38	46	78	
7	21	25	29	35	42	—	
8	25	28	30	34	36	36	37
9	22	26	28	31	42	52	
10	27	24	27	33	36	45	

Spirotheca thin and consists of a tectum and keriotheca. Thickness of spirotheca of the first to sixth volution of above-mentioned axial section 0.020, 0.035, 0.040, 0.065, 0.060, and 0.040 mm.

Septa thin and fluted only in extreme polar regions. Septal counts of the first to sixth volution of one sagittal section (Figure 5-13) 10, 16, 19, 21, 22, and 22.

Chomata massive and developed in all volutions except for the last one in some specimens. Tunnel path narrow and almost straight. Tunnel angles of the first to sixth volution of well oriented specimen mentioned above 24, 21, 36, 39, 43, and 36 degrees. No axial fillings present.

Remarks.—This species is almost identical with *Triticites* (*T.*) *samaricus* originally described by Rauser-Chernoussova (1938) from the Upper Carboniferous of the Samara Bend in the Russian Platform. Subsequently, Rozovskaya (1958) and Mikhaylova (1974) also described this species from the Russian Upper Carboniferous. The present specimens, however, have a slightly larger shell than those described in Russia.

In Thailand, *Triticites* (*T.*) *samaricus* was reported by Igo (1972) from Ban Nam Lum, south of Phetchabun, where such fusulinaceans as *Quasifusulina tenuissima* (Schellwien), *Triticites* (*T.*) *ozawai* Kanmera, *T.* (*T.*) aff. *haydeni* (Ozawa), *Daixina lalaotuensis* (Sheng), *D. petchabunensis* (Igo), and *Paraschwagerina yanagidai* Igo are associated.

Triticites (*T.*) *samaricus* is closely similar to *T.* (*T.*) *noinskyi* Rauser-Chernoussova but differs from the latter in having a more tightly coiled juvenarium.

The present species somewhat resembles *Triticites* (*T.*) *variabilis* described by Rozovskaya (1950) in general shell shape. The former, however, can be distinguished from the latter in having more massive chomata.

Material studied.—Axial sections; IGUT-KU0428, IGUT-KU0429, IGUT-KU0430, IGUT-KU0431, IGUT-KU0434, IGUT-KU0435, IGUT-KU0436, IGUT-KU0437, IGUT-KU0438, IGUT-KU0442, IGUT-KU0443, IGUT-KU0444, IGUT-KU0446. Sagittal sections; IGUT-KU0432, IGUT-KU0433, IGUT-KU0440, IGUT-KU0441. Slightly oblique axial sections; IGUT-KU0439, IGUT-KU0447. All specimens from Loe-28.

Measurements.—See Table 3.

Genus *Jigulites* Rozovskaya, 1948

Jigulites grandis Ueno and Igo, sp. nov.

Figures 6-1—16

Diagnosis.—Large *Jigulites* having a fusiform to elongate fusiform shell, fluted septa restricted to polar regions, well developed massive chomata and narrow tunnel path.

Description.—Shell large for genus and fusiform to elongate fusiform with bluntly pointed polar ends and almost straight lateral slopes. Mature specimens have 6 to 7½ volutions, 5.63 to 9.38 mm in length and 2.33 to 3.28 mm in width. Form ratio varies from 2.32 to 3.05, averaging 2.51 for 13 specimens. The holotype of 7½ volutions 8.25 mm in length and 3.20 mm in width with a form ratio of 2.58.

Shell expands uniformly throughout growth. Axis of coiling straight. Radius vectors of the first to seventh volution of the holotype 0.13, 0.21, 0.33, 0.53, 0.81, 1.13, and 1.48 mm, and form ratios 1.23, 1.55, 1.59, 1.64, 2.16, 2.35, and 2.69, respectively.

Proloculus spherical and 0.130 to 0.230 mm

→ **Figure 6. 1-16**. *Jigulites grandis*, sp. nov., **1**: axial section of the holotype, IGUT-KU0448, **2-6, 9-12, 15, 16**: axial sections of paratypes, IGUT-KU0449, IGUT-KU0450, IGUT-KU0451, IGUT-KU0452, IGUT-KU0453, IGUT-KU0456, IGUT-KU0457, IGUT-KU0458, IGUT-KU0459, IGUT-KU0462, IGUT-KU0463, **7, 8, 13**: sagittal sections of paratypes, IGUT-KU0454, IGUT-KU0455, IGUT-KU0460, **14**: tangential section of paratype, IGUT-KU0461. All ×10.

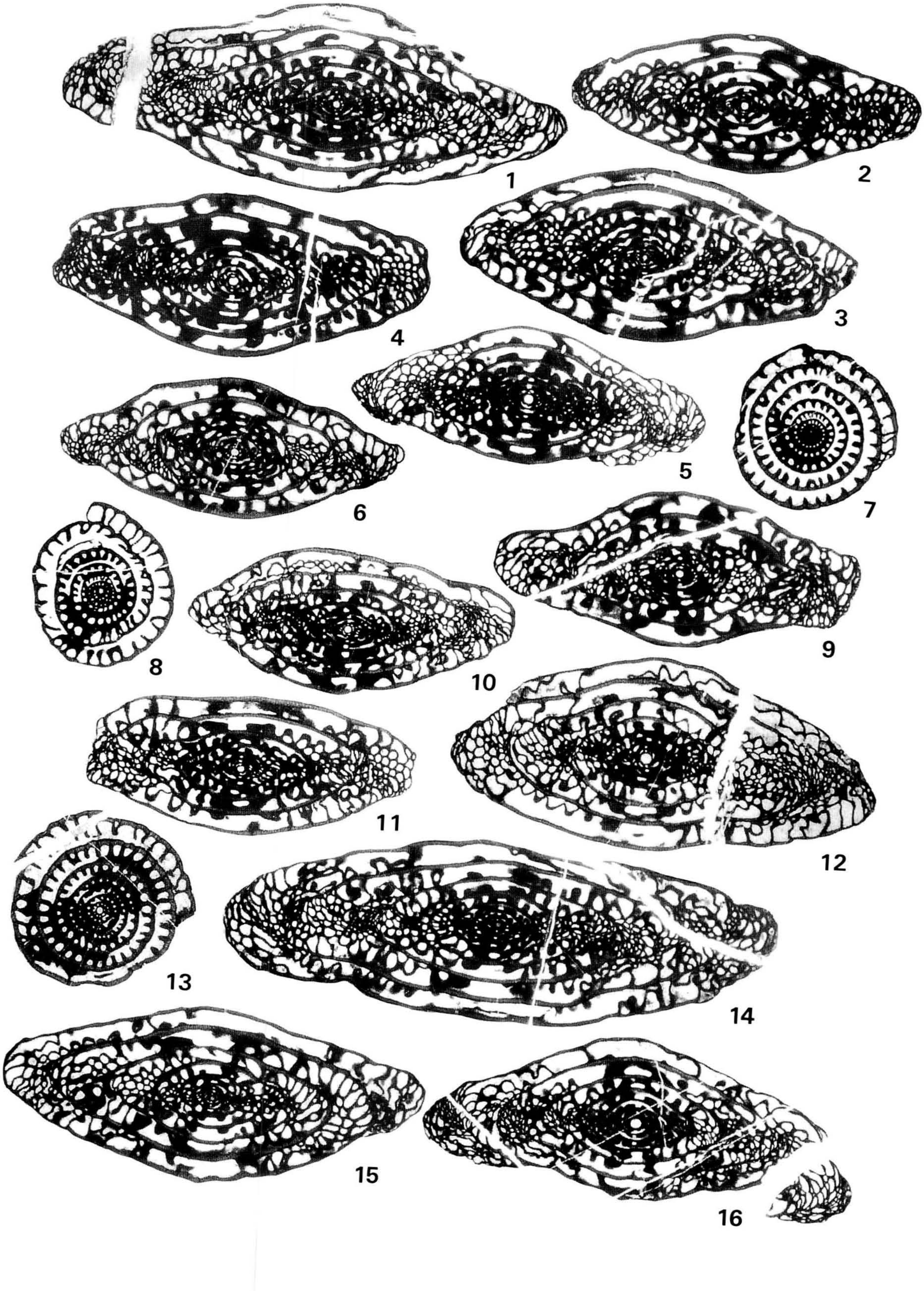
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Table 4. Measurements of *Jigulites grandis*, sp. nov. (in mm)

	Reg. no.	Figure	Length	Width	F.R.	D.P.	Radius vectors						
							1	2	3	4	5	6	7
1	IGUT-KU0448	6-1	8.25	3.20	2.58	0.160	0.13	0.21	0.33	0.53	0.81	1.13	1.48
2	IGUT-KU0449	6-2	6.00	2.38	2.53	0.180	0.16	0.24	0.38	0.63	0.91	1.24	
3	IGUT-KU0450	6-3	6.85	2.95	2.32	0.155	0.15	0.24	0.35	0.53	0.74	1.07	1.42
4	IGUT-KU0451	6-4	6.43	2.73	2.36	0.180	0.14	0.23	0.36	0.52	0.73	0.96	1.27
5	IGUT-KU0452	6-5	6.15	2.33	2.65	0.210	0.17	0.28	0.43	0.68	0.93	1.20	
6	IGUT-KU0453	6-6	5.90	2.35	2.51	0.145	0.13	0.21	0.36	0.56	0.86	1.11	
7	IGUT-KU0456	6-9	6.30	2.63	2.40	0.190	0.15	0.26	0.45	0.61	0.88	1.22	
8	IGUT-KU0458	6-11	5.63	2.35	2.39	0.155	0.13	0.21	0.35	0.52	0.77	1.13	
9	IGUT-KU0462	6-15	7.33	3.03	2.42	0.130	0.13	0.20	0.35	0.54	0.80	1.10	1.44
10	IGUT-KU0463	6-16	7.40	2.80	2.64	0.230	0.19	0.31	0.46	0.70	0.96	1.29	

	Form ratio							Thickness of spirotheca						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	1.23	1.55	1.59	1.64	2.16	2.35	2.69	0.030	0.035	0.040	0.060	0.055	0.095	0.095
2	1.44	1.68	1.72	1.91	2.18	2.42		0.025	0.020	0.075	0.055	0.075	0.110	
3	1.27	1.36	1.89	1.85	2.01	2.25	2.27	0.030	0.040	—	0.065	0.060	0.090	0.100
4	1.14	1.42	1.51	1.85	1.88	2.15	2.46	0.020	0.035	0.045	0.055	0.070	0.080	0.130
5	1.28	1.93	1.95	2.03	2.26	2.53		0.030	0.035	0.040	0.060	0.075	0.060	
6	1.23	1.41	1.65	1.76	2.34	2.26		0.025	0.040	0.060	0.060	0.070	0.115	
7	1.27	1.74	1.67	2.14	2.27	2.15		0.025	0.035	0.055	0.080?	0.085	0.085	
8	1.54	2.36	2.08	2.37	2.80	2.65		0.030	0.040	0.045	0.070	0.075	0.085	
9	1.38	1.57	1.36	1.66	2.24	2.54	2.53	0.025	0.030	0.045?	0.070	0.070	0.095	0.105
10	1.15	1.47	1.89	2.07	2.56	—		0.030	0.035	0.050	0.050	0.080	0.060	

	Tunnel angle (degrees)						
	1	2	3	4	5	6	7
1	18	16	17	21	22	34	40
2	12	16	21	28	34	31	
3	—	20	22	24	30	31	45
4	21	20	21	34	34	38	41
5	—	22	17	22	31	32	
6	23	21	25	19	20	27	
7	18	21	17	24	18	25	
8	29	24	24	20	27	40	
9	—	23	31	29	36	43	51
10	24	19	15	21	32	40	

in outside diameter, averaging 0.185 mm for 25 specimens.

Spirotheca thin and composed of a tectum and keriotheca. Thickness of spirotheca of the first to seventh volution of the holotype 0.030, 0.035, 0.040, 0.060, 0.055, 0.095, and 0.095 mm.

Septa thin, numerous and fluted rather intensely in polar regions, but with decreasing intensity toward central part of shell. Septal counts of the first to seventh volution in typical sagittal section of paratype (Figure 6-13) 10, 13, 20, 28, 28, 32, and 30 ?.

Chomata broad, massive and well developed in all volutions. Tunnel path narrow and almost straight. Tunnel angles of the first to seventh volution of the holotype 18, 16, 17, 21, 22, 34, and 40 degrees. Axial fillings not developed.

Remarks.—Jigulites longus originally described by Rozovskaya (1950) is the closest to the present new species. The former, however, can be distinguished from the latter in having more intensely fluted septa and smaller chomata.

The present new species is also related to *Jigulites magnus* (Rozovskaya) but differs from the latter in having a larger form ratio, less fluted septa in the central part of the shell and more well developed chomata throughout growth.

Jigulites grandis, sp. nov. somewhat resembles *Daixina petchabunensis* described by Igo (1972) from Ban Nam Lum, south of Phetchabun, central Thailand. The former, however, is distinguished from the latter in having less fluted septa and massive chomata even in the outer volutions.

Etymology.—This specific name is derived from the Latin *grandis*, meaning grand, great or large.

Material studied.—Axial section of the holotype ; IGUT-KU0448. Axial sections of paratypes ; IGUT-KU0449, IGUT-KU0450, IGUT-KU0451, IGUT-KU0452, IGUT-KU0453, IGUT-KU0456, IGUT-KU0457, IGUT-KU0458, IGUT-KU0459, IGUT-KU0462, IGUT-KU0463. Sagittal sections of paratypes ; IGUT-KU0454, IGUT-KU0455, IGUT-KU0460. Tangential section of paratype ; IGUT-KU0461. All specimens from Loe-29.

Measurements.—See Table 4.

Genus *Rugosofusulina* Rauser-Chernoussova, 1937

Rugosofusulina ? sp.

Figure 4-7

Remarks.—Presence of rugosity in the spirotheca of this species seems to suggest that it is referable to the genus *Rugosofusulina*.

Material studied.—Axial section ; IGUT-KU0415 from Loe-33.

Family Staffellidae Miklukho-Maklay, 1949
Genus *Nankinella* Lee, 1934

Nankinella spp.

Figures 4-9—19

Remarks.—Several forms such as a lenticular shell with angular periphery (*e.g.*, Figure 4-10), a lenticular shell with shallow umbilicus (*e.g.*, Figure 4-11), and a thick lenticular shell with angular periphery (*e.g.*, Figure 4-17) are identified, which are possibly split into several distinct species. In this study, however, they are all treated as *Nankinella* spp.

Material studied.—Axial sections ; IGUT-KU0417, IGUT-KU0418, IGUT-KU0419, IGUT-KU0421, IGUT-KU0422, IGUT-KU0423, IGUT-KU0424, IGUT-KU0425, IGUT-KU0426, IGUT-KU0427. Sagittal section ; IGUT-KU0420. All specimens from Loe-29.

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タイ国北東部ロエイ郡ナディンダム村の上部石炭系産有孔虫：タイ国では最上部石炭系グゼリアン統を指示する紡錘虫化石はこれまで報告されていない。今回ロエイ付近の下部ペルム系ナムマホラン層とされる石灰岩から，グゼリアンを積極的に指示するとみられる紡錘虫および小型有孔虫化石を識別したので記載報告する。主要な種は *Triticites* (*T.*) *samaricus* Rauser-Chernoussova と新種の *Jigulites grandis* である。今回の発見によりタイ国でも石炭系とペルム系の境界問題が詳細に論じられる可能性が強くなった。

上野勝美・猪郷久義

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 171, pp. 229-236, 3 Figs., September 30, 1993

957. SPATHIAN AMMONOIDS *METADAGNOCERAS* AND *KEYSERLINGITES* FROM THE OSAWA FORMATION IN THE SOUTHERN KITAKAMI MASSIF, NORTHEAST JAPAN*

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Abstract. Two ammonoid species, *Metadagnoceras motoyoshiense*, sp. nov. and *Keyserlingites* cf. *K. middendorffi*, are described from the middle part of the Osawa Formation of the Kitakami Massif. They are associated with *Columbites* and *Subcolumbites*. Both *Metadagnoceras* and *Keyserlingites* are described herein from Japan for the first time. They are index fossils of the Spathian Stage (uppermost Lower Triassic) and support the previous opinion that the Osawa Formation is correlative with the Spathian or upper Olenekian. The significance of the ammonoid fauna of the Osawa Formation is also discussed with its relationship to the zonal subdivision of the Spathian.

Key words. *Metadagnoceras, Keyserlingites*, ammonoid, Triassic, Kitakami Massif, Northeast Japan

Introduction

This paper reports the occurrence of ammonoid species belonging to the genera *Metadagnoceras* and *Keyserlingites* in association with the *Columbites-Subcolumbites* fauna from Lower Triassic strata in the Southern Kitakami Massif, Northeast Japan. In 1991, Miyuki Numakura, Atsushi Numakura and Makoto Kumagai collected some ammonoid fossils, in which two specimens are described herein as *Metadagnoceras motoyoshiense*, sp. nov. and *Keyserlingites* cf. *K. middendorffi* (Keyserling), from the Osawa Formation exposed at Yamaya, Motoyoshi District. One additional specimen belonging to the former and many specimens of some other ammonoid species were collected later by the author. The discovery of *Metadagnoceras* and *Keyserlingites* from the Osawa Formation provides not only a basis for world-wide correlation of the formation but also data for reexamination of the zonal scheme of the Spathian.

The Osawa Formation and its ammonoid fauna

The Lower to Middle Triassic strata in the Southern Kitakami Massif are called the Inai Group. This group is divided into the Hiraiso and Osawa Formations of Scythian age, and the Fukkoshi and Isatomae Formations of Anisian age, in ascending order. The Osawa Formation, about 300 m in thickness, consists of dark gray, finely banded shales, which are intercalated with medium- to fine-grained sandstones. Two ammonoid zones have been recognized in the formation: the lower *Subcolumbites* Zone and the upper *Arnautoceltites* Zone (Bando and

*Received December 11, 1992; revised manuscript accepted April 19, 1993

Shimoyama, 1974). From the *Subcolumbites* Zone, such ammonoid fossils as *Preflorianites* aff. *P. sulioticus* (Arthaber), *Columbites parisianus* Hyatt and Smith, *Subcolumbites perrinismithi* (Arthaber), *Eophyllites* cf. *E. dieneri* (Arthaber) and *Leiophyllites* sp. have been described (Bando and Shimoyama, 1974). The *Arnautoceltites* Zone yields *Procarnites kokeni* (Arthaber), *Arnautoceltites* sp., *Isculitoides* aff. *I. originis* (Arthaber), *Prenkites* cf. *P. timorensis* Spath, *Eosturia towaensis* Bando and Ehiro and others (Bando and Shimoyama, 1974; Bando and Ehiro, 1982). On the basis of these ammonoids, the Osawa Formation is correlated with the Columbitan to Prohungaritan or the Spathian of the Scythian (Bando and Shimoyama, 1974; Bando and Ehiro, 1982).

The ammonoid fossils, *Metadagnoceras motoyoshiense*, sp. nov. and *Keyserlingites* cf. *K. middendorffi*, described herein were collected from shale beds in the middle part of the Osawa Formation exposed at a location to the northwest of Yamaya, about 1.5 km northeast of Hiraiso Coast, which is the type locality of the formation (Figure 1). The present fossil horizon belongs to the upper part of the *Subcolumbites* Zone of Bando and Shimoyama (1974) and yields, in addition to the above-mentioned two species, *Columbites parisianus, Subcolumbites perrinismithi* and some other indeterminable species. *Columbites* is common, but *Subcolumbites* is rare.

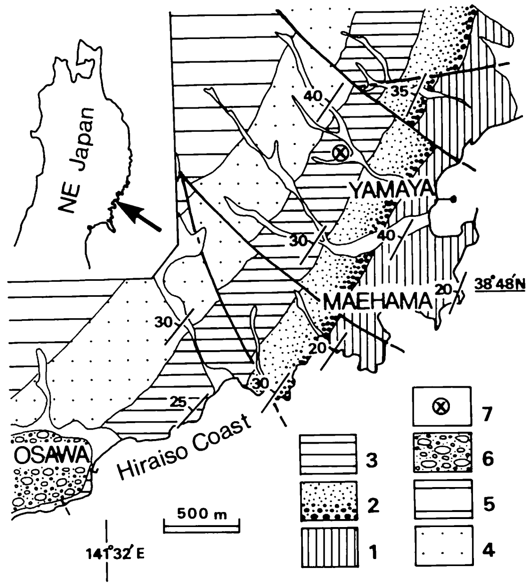


Figure 1. Geologic map of the Motoyoshi District in the Southern Kitakami Massif, Northeast Japan (Compiled and simplified from various sources).
1: Upper Permian Toyoma Formation, 2-5: Lower-Middle Triassic Inai Group (2: Hiraiso Formation, 3: Osawa Formation, 4: Fukkoshi Formation, 5: Isatomae Formation), 6: Pleistocene terrace deposits, 7: fossil locality.

On the genera *Metadagnoceras* and *Keyserlingites*

Metadagnoceras motoyoshiense, sp. nov. is a stratigraphically important species, because species belonging to the genus *Metadagnoceras* have been known only from Spathian formations as was stressed by Tozer (1965). They are reported from British Columbia in western Canada, Nevada in western United States, Primorye in eastern Russia, Albania, Chios, Central Iran, Timor and Guizhou Province of China (Tozer, 1965, 1972; Kummel, 1969; Wang, 1978). *Metadagnoceras* is described herein for the first time from Japan.

Species belonging to the genus *Keyserlingites* have been reported from Siberia, Spitsbergen, Arctic region of and British Columbia, Canada, Idaho in the USA, Southern Primorye, Himalayas, and Timor (Kummel, 1969; Zakharov, 1968). They are treated as index fossils of Spathian or late Olenekian age (Tozer, 1965, 1971). There are, however, different proposals with regard to the ages of *K. dieneri* (Mojsisovics) from the Himalayas, which was once described as *Durgaites dieneri* by Diener (1905), and of *K. angustecostatus* Welter described from Timor. For example, Kummel (1969) assigned them to the lower Anisian. These two "*Durgaites*" type species differ from other species in having more prominent ribs across the venter. A recent discovery of *K. dieneri* and its related species in Qinghai Province of China (Wang, 1985) may indicate that the age of *Keyserlingites* from these three districts (Himalayas, Timor and China) is early Anisian rather than Spathian, because they are associated with many Anisian ammonoids in Qinghai. If we accept the opinion of Wang (1985), the age of the *Keyserlingites* faunas of the Boreal Province, including Southern Primorye, should be considered to be Spathian, whereas that of the "*Durgaites*" type faunas in the Tethys Province should be considered to be early Anisian.

No species of the genus *Keyserlingites* has so far been described from Japan, although Bando (1968) listed *K.* sp. from the Oro Formation of the Yakuno Group in Kyoto Prefecture. *Keyserlingites middendorffi,* to which the Kitakami specimen is compared, is known from late Olenekian beds of Siberia in association with *K. subrobustus*, which is an index species of the *K. subrobustus* Zone, the uppermost ammonoid zone in the Spathian of Canada (Tozer, 1965, 1967).

Thus, the present discovery of *Metadagnoceras* and *Keyserlingites* enables a correlation of the Osawa Formation directly with the type Spathian Stage in Arctic Canada (Tozer, 1967), another important reference section of the Spathian beds in western Canada (Silberling and Tozer, 1968), and the upper Olenekian (Kiparisova and Popov, 1964) or Olenekian (Vavilov and Lozovsky, 1970) in Siberia and Primorye.

Problems of zonal correlation of the Spathian Stage

Silberling and Tozer (1968) and Tozer (1981) divided the Spathian Stage in western North America into three biostratigraphic units, the lower *Columbites* Beds, the middle *Subcolumbites* Beds and the upper *Neopopanoceras haugi* Zone, and they correlated the *Kazakhstanites pilaticus* (= *Olenikites pilaticus*) and *Keyserlingites subrobustus* Zones in the Arctic region with the first and the last unit, respectively. However, opinions differ with regard to the biostratigraphic subdivision of the Spathian and correlation of subdivided units. Kummel (1969) divided the Spathian into only two zones, the lower *Columbites* Zone and the upper *Prohungarites* Zone. He correlated the *K. subrobustus* Zone of Canada with his *Prohungarites* zone, which contains *Subcolumbites*. On the other hand, Zakharov (1978) regarded the *K. subrobustus* Zone as older than the beds with *Subcolumbites*.

Concerning the correlation of the Spathian ammonoid zones, it must be remembered that the genera *Columbites*, *Subcolumbites* and *Keyserlingites* have never been found in a consecutive sequence in North America. *Columbites parisianus*, which is an index species of the *Columbites* Zone (Smith, 1932) or *Columbites* and *Tirolites* Beds (Silberling and Tozer, 1968), has been only reported from southeastern Idaho, *Subcolumbites* only from western Nevada, and *Keyserlingites* only from British Columbia and the Arctic region of Canada. Although Kummel (1969) regarded *C. parisianus* to occur only from Idaho, the species came to be known from Mangyshlak in Kazakhstan (Shevyrev, 1968), from the Primorye (Zakharov, 1968) and from the Osawa Formation in the Southern Kitakami Massif (Bando and Shimoyama, 1974). In the latter two districts, the above-mentioned three ammonoid genera occur in a successive sequence. In the Primorye, *Columbites* is associated with *Keyserlingites* and occurs in a horizon below that of *Subcolumbites* (Zakharov, 1968; Zharnikova, 1985). In the Kitakami Massif, however, Bando and Shimoyama (1974) already reported, though not specifically discussing its significance, that *Columbites* and *Subcolumbites* cooccur at many stratigraphic horizons in the Osawa Formation with the exception of its lowermost and uppermost parts. The occurrence of *Keyserlingites* there overlaps with the stratigraphic ranges of *Columbites* and *Sub-*

columbites. Therefore, the ammonoid zonal scheme of the Spathian should be studied further in detail.

Systematic Description

Specimens described in this paper are kept in the Iwate Prefectural Museum, Morioka (IPPM).

Order Ceratitida Hyatt, 1884
Superfamily Dinaritaceae Mojsisovics, 1882
Family Dinaritidae Mojsisovics, 1882
Subfamily Khvalynitinae Shevyrev, 1968
Genus *Metadagnoceras* Tozer, 1965

Type species: *Metadagnoceras pulcher* Tozer, 1965

Metadagnoceras motoyoshiense, sp. nov.

Figures 2a; 3-2a, 2b, 3

Material: —Two specimens, IPPM 60015 (holotype) collected by M. Kumagai in 1991 and IPPM 60032 collected by M. Ehiro, 1992.

Diagnosis: —*Metadagnoceras* of a large size, with a small umbilicus. The surface is ornamented with slightly sinuous growth lines and spiral lirae.

Description: —One specimen (IPPM 60015) is a right side of the inner mould. The shell is laterally compressed due to tectonic deformation and also slightly deformed to make an ellipse. The body chamber, apparently complete, is about two-third of a whorl. The conch is involute and lenticular in outline, with slightly convex sides and acutely rounded venter. Maximum whorl width lies near the centre. It attains a diameter of 185 mm, in the deformed state, and at the adoral end its height and umbilical diameter are about 101 mm and 7 mm, respectively. The side of the body chamber is ornamented with faint, slightly sinuous growth lines and indistinct, coarse spiral lirae. Another specimen (IPPM 60032) is a fragmented inner mould of the body chamber.

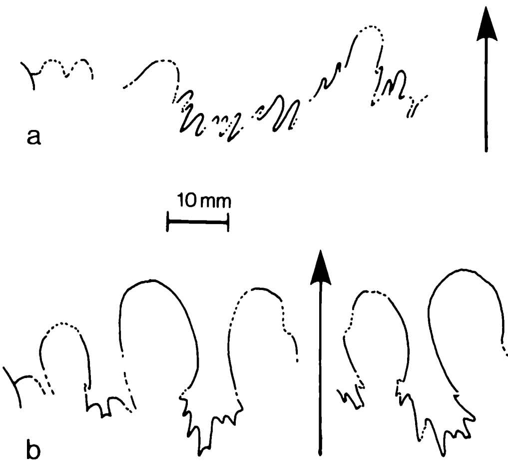


Figure 2. Suture lines of *Metadagnoceras* and *Keyserlingites*.
a: *Metadagnoceras motoyoshiense* Ehiro, sp. nov., IPPM 60015
b: *Keyserlingites* cf. *K. middendorffi* (Keyserling), IPPM 60013

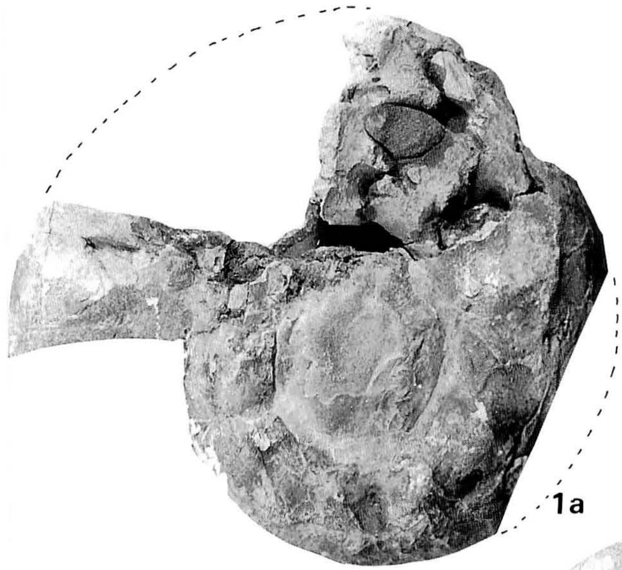
The suture is not perfectly preserved as shown in Figure 2a. It has a narrow and rounded (?) first lateral saddle, a large lateral lobe with prominent denticulations, and a rounded second lateral saddle.

Comparison: —On account of its lenticular shell form and possession of spiral lirae, the present new species is somewhat comparable with *Metadagnoceras pulcher* (Tozer, 1965, p. 29, plate 1, figs. 11a-d), but it differs from the latter in being of larger size, in having an acute venter and in having a smaller umbilicus. Other species of *Metadagnoceras* are also distinguished easily from the present species for the same reasons and by having no spiral lirae.

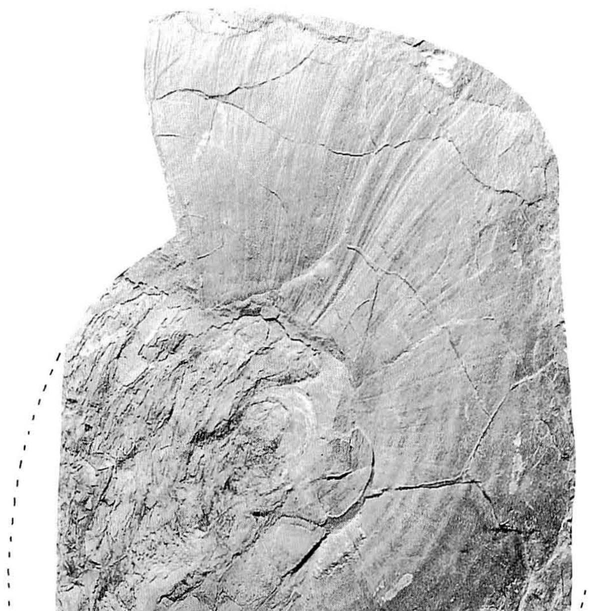
Occurrence and geological age: —Dark gray shale of the middle part of the Osawa

⟶ **Figure 3. 1a-b**: *Keyserlingites* cf. *K. middendorffi* (Keyserling), IPPM 60013, lateral (a) and ventral (b) views, ×0.64. **2a-b, 3**: *Metadagnoceras motoyoshiense* Ehiro, sp. nov. **2**, holotype (IPPM 60015), lateral view (a) and cross section (b), ×0.64. Arrow marks the position of the cross section. **3**. IPPM 60032, lateral view, ×0.64.

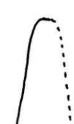
1b



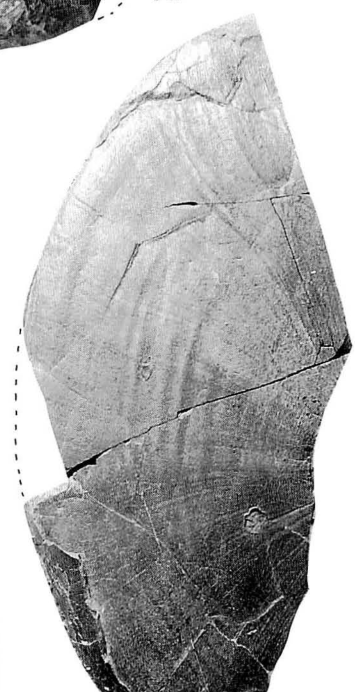
1a



2a



2b



3

Formation exposed at Yamaya, Motoyoshi-cho, Motoyoshi-gun, Miyagi Prefecture; Spathian Stage of the Scythian.

Etymology: —This species is named for Motoyoshi District, its type locality.

Superfamily Ceratitaceae Mojsisovics, 1879
Family Keyserlingitidae Zakharov, 1970
Genus *Keyserlingites* Hyatt, 1900

Type species: *Ceratites subrobustus* Mojsisovics, 1885

Remarks: —Six Spathian species (*K. meridianus, K. middendorffi, K. miroshnikovi, K. stephansoni, K. subrobustus* and *K. tebenkovi*) and seven Anisian species (*K. angustecostatus, K. dieneri, K. pahari, K. pagoda, K. planus, K. qinghaiensis* and *K. sinensis*) are presently recognized in this genus. The Anisian species have more prominent ventral ribs than the Spathian species.

K. bearlakensis Kummel and *K. bearriverensis* Kummel described from Idaho (Kummel, 1969) are not assignable to the genus *Keyserlingites*, because they lack such characteristic features of the genus *Keyserlingites* as bituberculation and deeply incised external lobe (Tozer, 1971). In the same way, *K. bearriverensis* and *K.* sp. described from the Himalayan region of China by Wang and He (1976) do not belong to *Keyserlingites*. In addition, as already pointed out by Guex (1978), *Keyserlingites* sp. of Kummel (1968) described from Afghanistan may also not belong to this genus.

Keyserlingites cf. *K. middendorffi* (Keyserling)

Figures 2b; 3-1a, 1b

Material: —One specimen, collected by M. Numakura and A. Numakura in 1991, IPPM 60013.

Description: —One incomplete specimen is examined. The conch is evolute and discoidal in outline, with convex sides and acutely rounded venter. The shell is thought to be essentially a compressed form, though the compression may be partially due to its lateral deformation. The conch attains a diameter of at least 125 mm with an umbilicus measuring about 2/5 of the diameter. The lateral areas near the umbilical shoulder bear widely spaced nodes. As the height increases, the nodes grow into radial ribs which extend from the umbilical to the ventral shoulder. There are five nodes or ribs on the half volution. On the ventral shoulders there are occasional and less prominent small tubercles whose arrangement alternates with the nodes.

The suture is partly preserved as shown in Figure 2b. It is ceratitic and consists of rounded lateral saddles and denticulated lateral lobes. The ventral lobe is unknown. The second lateral saddle is larger than the other lateral saddles.

Comparison: -The compressed shell form and shell ornamentation of the present specimen are similar to those of the specimens of *Ceratites middendorffi* (Keyserling, 1845, p. 170, pl. 1, fig. 1, pl. 2, figs. 1, 3; Mojsisovics, 1885, p. 153, pl. 6, fig. 2; 1886, p. 38, pl. 2, figs. 12, 13, pl. 3, figs. 1a-c, pl. 20, fig. 10; 1886, p. 47, pl. 4, fig. 1 described as *C. schrenki*; 1888, p. 6, pl. 1, figs. 12, 13 described as *C. nikitini*), all collected from Siberia. However, it differs from the Siberian species in the form of the suture and, except for the last-mentioned one, in the possession of a wider umbilicus. Some specimens of *Keyserlingites middendorffi* illustrated by Zakharov (1978, pl. 17, figs. 1, 3, 6-7), however, have a rather large umbilicus nearly the same size as that of the Kitakami specimen.

K. miroshnikovi Burij and Zharnikova (Zakharov, 1968, p. 129, pl. 24, fig. 2, pl. 25, figs. 2, 3, text-fig. 31-c), *K. meridianus* (Zakharov, 1968, p. 128, pl. 24, fig. 1, text-fig. 31-b) and *K. tebenkovi* (Zharnikova, 1985, p. 34, pl. 3, figs. 3a-b, text-fig. 1c) described from Southern Primorye are similar to the present specimen in having a compressed shell form and larger second lateral saddle. However, *K.*

miroshnikovi is distinguished from the Kitakami specimen in the furcated form of the ribs and in having a slightly smaller umbilicus, *K. meridianus* has a larger umbilicus and less conspicuous ribs compared with the Kitakami specimen, and *K. tebenkovi* differs in having a less compressed shell form and more numerous nodes.

Occurrence and geological age: — Same as those for *Metadagnoceras motoyoshiense*, sp. nov.

Acknowledgements

I would like to express my appreciation to Professor Tsunemasa Saito of Tohoku University for his critical reading of the manuscript. Thanks are also expressed to Messrs. Miyuki Numakura, Atsushi Numakura and Makoto Kumagai for making available their specimens to this study, and to Messrs. Eishiro Shoji and Hiroe Kuriyagawa for access to important specimens.

This study was supported in part by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture (no. 02452063), and by the Science Research Fund from the Saito Gratitude Foundation.

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北上山地の大沢層産スパース期アンモノイド *Metadagnoceras* および *Keyserlingites*: 南部北上山地の本吉地域に分布する下部三畳系大沢層の中部から産するアンモノイド2種, *Metadagnoceras motoyoshiense*, sp. nov. および *Keyserlingites* cf. *K. middendorffi* (Keyserling) を記載する。両属ともわが国からは初の記載である。これらは *Columbites* や *Subcolumbites* と共産し, スパース期 (前期三畳紀末期) の示準化石であり, その産出は大沢層がスパース階あるいはオレネック階上部に対比されるという従来の意見を支持するものである。北米北西部のスパース階は, 下位より, *Columbites* 層, *Subcolumbites* 層および *Neopopanoceras haugi* 帯に区分され, 後者はカナダ極地域の *Keyserlingites subrobustus* 帯に対比されている。しかし, 北上山地では *Columbites* と *Subcolumbites* のレンジはほとんど重複し, さらに *Keyserlingites* の産出層準もこれら2属のレンジ内にあるので, 上記のスパース階のアンモノイド化石帯区分は再考を要する。 永広昌之

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 171, pp. 237-248, 4 Figs., September 30, 1993

958. EARLY EVOLUTION AND DISTRIBUTION OF THE GASTROPOD GENUS *NUCELLA*, WITH SPECIAL REFERENCE TO MIOCENE SPECIES FROM JAPAN*

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Abstract. Several well preserved specimens of the muricid gastropod genus *Nucella* from Miocene strata in Hokkaido, Japan, are classified into two species, *N. tokudai* (Yokoyama) and *N. freycineti saitoi* Hatai et Kotaka. *N. tokudai* first appeared in California during the Early Miocene, and then spread westward to Japan and Kamchatka by the early Middle Miocene. *N. freycineti saitoi* first appeared in Japan during the Middle Miocene, and gave rise to a living species, *N. f. freycineti* (Deshayes) during the latest Miocene or Early Pliocene. A warm-water origin in the northeastern Pacific is postulated for the genus *Nucella,* based on the early geographical distribution of the genus and on the presence of a thick denticulated outer lip in all early species. The distributional history of *Nucella,* characterized by a warm-water origin in western North America and subsequent dispersal to eastern Asia, is similar to that of many other shallow-water temperate North Pacific molluscs and barnacles.

Key words. Miocene, *Nucella,* Gastropoda, evolution, biogeography.

Introduction

The modern muricid gastropod genus *Nucella* is commonly known and widely distributed on the shore of the North Pacific and North Atlantic Oceans. Its members are predators of barnacles (Cirripedia), mussels (Mytilidae), and limpets (Acmaeidae). In northern Japan, most authors recognize two Recent species, *N. freycineti* (Deshayes) and *N. heyseana* (Dunker) (*e.g.* Habe and Ito, 1965). Mitochondrial DNA sequences show that there are two species among the genus *Nucella* in northern Japan (Collins *et al*., in preparation). The small *N. freycineti* is living in the middle and upper intertidal zone, and the larger *N. heyseana* (Dunker) is in the lower intertidal and shallow sublittoral zones

*Received March 24, 1993 ; accepted June 21, 1993

(Collins *et al*., in preparation). It is possible that *N. elongata* Golikov et Kussakin is synonymous with *N. heyseana,* but the limits of the species of *Nucella* in the northwestern Pacific are not well understood.

Little is known about the early evolution and geographical distribution of *Nucella.* The genus first appeared in the Early Miocene of western North America (Loel and Corey, 1932). Some time later, *Nucella* reached the northwestern Pacific, but the scarcity of adequate fossil material has made it difficult to treat the history of the genus *Nucella* in Asia in detail. The earliest appearance of *Nucella* in the Atlantic was in the Late Pliocene of the North Sea Basin in Europe (Vermeij, 1991a, 1993; Collins *et al*., in preparation). *Nucella* is therefore one of a large number of cold-water animal and plant genera that invaded the North Atlantic from the North Pacific after Bering Strait opened during middle Pliocene time (Durham and MacNeil, 1967; Vermeij, 1991a).

Previous authors have figured only three specimens of *Nucella* from Miocene strata in Hokkaido. Yokoyama (1932) described *Coralliophila tokudai* from the Okada Beds (=early Middle Miocene Horoshin Formation?) in the Uryu coal-field, Northwest Hokkaido. Mizuno *et al.* (1969) illustrated *Nucella ishii* Uozumi (MS) from the Kushiro coal-field in eastern Hokkaido. Finally, Amano (1983) treated one poorly preserved specimen of *Nucella* from the Late Miocene Upper Togeshita fauna, but he was unable to assign the shell at the species level. These three specimens were not compared with each other, nor were they compared with fossil or living species found elsewhere in the North Pacific region.

We have had an opportunity to examine the holotype of *Coralliophila tokudai* and to collect additional well preserved materials belonging to *Nucella* from several Miocene formations in Hokkaido. Our purpose of this paper is to describe this Miocene material and to discuss the early evolution and geographical distribution of *Nucella* in the North Pacific.

Localities of the Miocene *Nucella* in Hokkaido

Two species of *Nucella* were distinguished among specimens from seven localities of Miocene age in Hokkaido (Figure 1). These localities, together with stratigraphical and facies details, are described briefly below.

Loc. R-1. Small riverside cliff near Kasugacho-danchi, Rumoi, northwest Hokkaido; medium-grained sandstone; upper part of the Togeshita Formation.

Loc. R-2. Bank of Rumoi River near Owada (Rumoi-shinkawa, Loc. T24 of Amano, 1983); pebble-bearing muddy fine-grained sandstone; upper part of the Togeshita Formation.

Loc. C-1. Riverside cliff at about 1.1 km upstream of Tanzan-zawa, a small tributary of Chepotsunai River, Tomamae-cho, northwest Hokkaido; pebble-bearing fine-grained sandstone; Chikubetsu Formation.

Loc. U-1. Bank of Tokushibetsu River near Kotobuki Bridge, Utanobori-cho, northeast Hokkaido; muddy fine-grained sandstone; Tachikaraushinai Formation.

Loc. A-1. Roadside cliff at about 5.2 km upstream of Sarusarube River, Urahoro-cho, eastern Hokkaido; muddy fine-grained sandstone; Ishiizawa Formation.

Loc. A-2. River bank at about 1.6 km upstream of Ishii-zawa; pebble-bearing muddy fine-grained sandstone; Ishiizawa Formation.

Loc. A-3. Streamside cliff at about 1.2 km upstream of Tanzan-no-sawa; pebble-bearing medium-grained sandstone; Ishiizawa Formation.

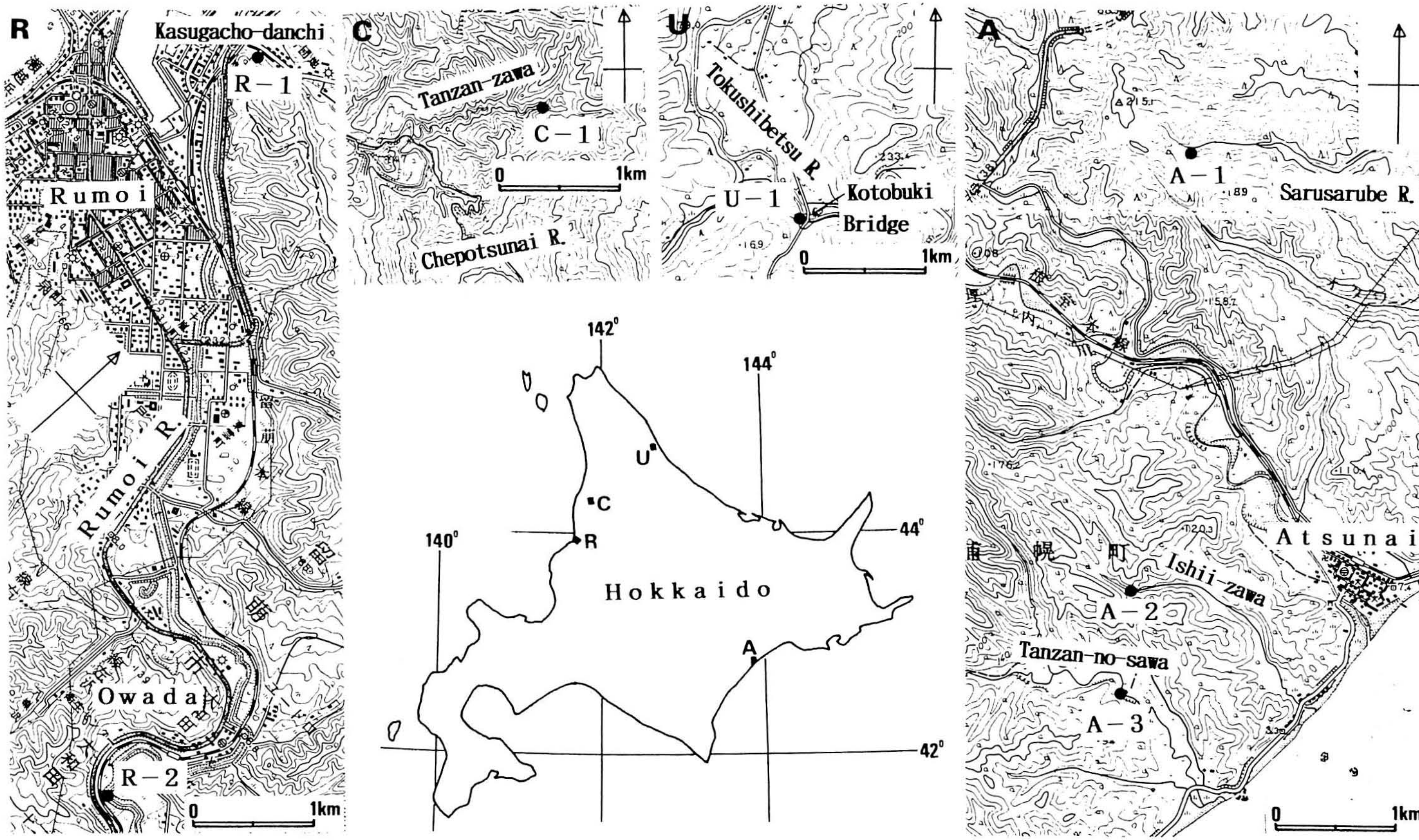


Figure 1. Localities of Miocene *Nucella* in Hokkaido (using the topographical maps of "Rumoi", "Sankei", "Occhube", "Atsunai" and "Ombetsu," scale 1 : 50,000 published by Geographical Survey Institute of Japan).

Systematic description

Family Muricidae Rafinesque, 1815
Subfamily Ocenebrinae Cossmann, 1903
Genus *Nucella* Röding, 1798

Nucella tokudai (Yokoyama, 1932)

Figure 2-2a-b, 4a-b, 5, 7a-b, 8

Coralliophila tokudai Yokoyama, 1932, p. 235-236, pl. 2, fig. 1.
Thais (*Stramonita*) *carrizoensis* Loel and Corey, 1932, p. 249-250, pl. 47, figs. 2, 3a-b.
Nucella packi (Clark) var. *talea* Stewart, 1946, p. 102, pl. 17, fig. 11.
Thais sp., Lutz, 1951, p. 392, pl. 18, figs. 2, 5.
Thais lima (Gmelin). Hall, 1958, pl. 9, figs. 7, 10.
Thais packi Clark. Addicott, 1965, fig. 3R.
Nucella ishii Uozumi (MS). Mizuno *et al.,* 1969, pl. 28, fig. 2.
Thais (*Nucella*) *packi* Clark. Addicott, 1970, p. 84-85, pl. 9, figs. 1-4, 19.
Nucella packi (Clark). Addicott, 1980, pl. 1, fig. 6; Gladenkov and Sinelnikova, 1990, p. 126-127, pl. 19, figs. 4, 16.

Type locality.—Gengoro-sawa, Numata-cho, Hokkaido. CM no. 26003 (Figure 2-8).

Materials.—Two specimens from the Togeshita Formation (Loc. R-1), one specimen from the Chikubetsu Formation (Loc. C-1), and seven specimens from the Ishiizawa Formation (Loc. A-1, 2, 3).

Description.—Shell small to medium, heavy, bucciniform, with very low spire. Whorls more than four. Suture poorly defined. Surface ornamented with flat-topped spiral ribs and weak growth lines. Spiral ribs 15 to 19 on body whorl, 4 to 8 on penultimate. Aperture large, ovate. Siphonal canal very short and deep. Outer lip thick with 13 to 16 teeth.

Measurements (in mm).—

Shell height	Height of aperture	Breadth	NS*	Localities
—	25.8	20.3	18	A-1
27.0	21.5	19.6	16	A-1
57.7	41.3	33.7	19	R-1
49.3	33.1	30.4	17	R-1
12.7	—	8.5	16	C-1

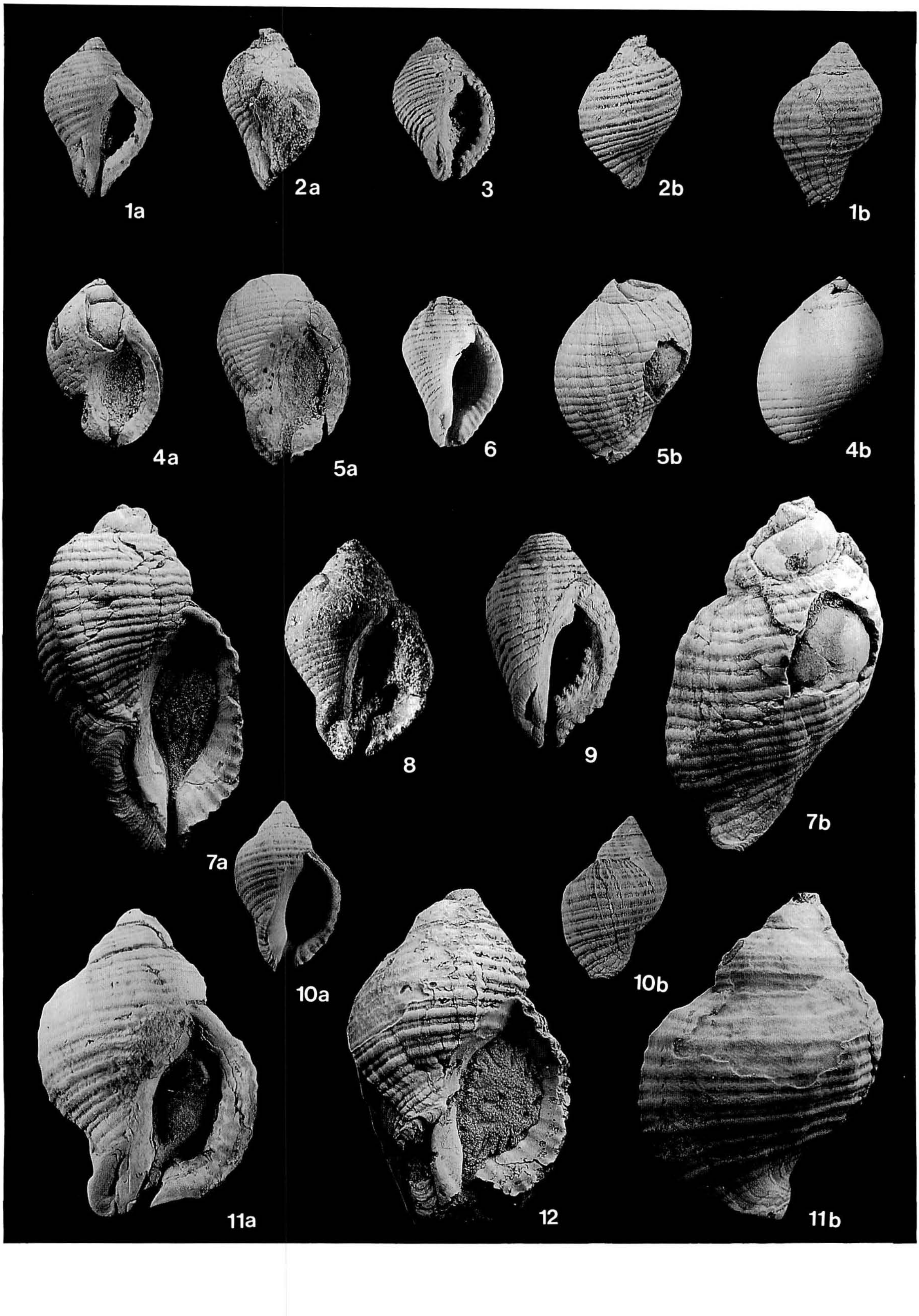
*number of spiral cords on body whorl.

Remarks.—The present species was originally described by Yokoyama (1932, August) from the Middle Okada Beds in Hokkaido under the genus name *Coralliophila.* The species has subsequently been mentioned by Hatai and Nisiyama (1952), Uozumi (1962), Ohara (1966) and Ohara and Kanno (1973). *N. tokudai* is characterized by very low spire, thick outer lip with numerous small teeth and numerous flat-topped spiral ribs of even strength, which are separated by rather deep grooves.

Loel and Corey (1932, December) proposed *Thais* (*Stramonita*) *carrizoensis* from the Early Miocene Vaqueros Formation in California. The holotype of this species has 11 flat-topped spiral ribs on the body whorl. Although this number of ribs is smaller than the typical *N. tokudai,* all other characters of *T. carrizoensis* conform with those of *N. tokudai.* Moreover, according to Addicott (1970) and our own observations, other specimens of *T. carrizoensis* have more numerous ribs. We therefore regard Loel and Corey's species as a junior subjective synonym of *N. tokudai.*

Addicott (1970) considered *Thais carrizoensis* to be a junior subjective synonym of

→ **Figure 2.** **1a-b, 3, 11a-b, 12**: *Nucella freycineti saitoi* Hatai et Kotaka. **1a-b**: ×1, Loc. R-1, Togeshita Formation, IGUT no. 11801. **3**; ×2, Loc. U-1, Tachikaraushinai Formation, JUE no. 15402. **11a-b**: ×1, Loc. R-2, Togeshita Formation, JUE no. 15403. **12**; ×1, Loc. R-2, Togeshita Formation, IGUT no. 11803. **2a-b, 4a-b, 5a-b, 7a-b, 8**: *Nucella tokudai* (Yokoyama). **2a-b**; ×2, Loc. C-1, Chikubetsu Formation, JUE no. 15404. **4a-b, 5a-b**; ×1, Loc. A-1, Ishiizawa Formation, JUE no. 15405. **7a-b**; ×1, Loc. R-1, Togeshita Formation, IGUT no. 11802. **8**; ×2, holotype (CM no. 26003). **6, 9**: *"Nucella" tokishiensis* Itoigawa et Shibata. **6**; ×1.5, paratype (MFM no. 10078). **9**; ×1.5, holotype (MFM no. 10076). **10**: *Nucella freycineti* (Deshayes), ×1, Loc. Rumoi, Recent, JUE no. 15406.


1a
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11b

Thais packi, which was described by Clark (1918) from the Late Oligocene or earliest Miocene San Ramon Formation in California. *T. packi,* which was assigned to *Nucella* by Stewart (1946), is very similar to *T. carrizoensis* in shell outline and sculpture. The holotype of *T. packi,* however, possesses a small labral tooth near the base of the outer lip. This feature is also preserved on several other specimens from the San Ramon Formation. The presence of this labral projection indicates that *T. packi* belongs to either *Acanthina* or *Acanthinucella.* Because of the position of the spine and the nature of the shell sculpture, we tentatively assign the species to the genus *Acanthinucella* (for a discussion of distinctions among *Nucella, Acanthina, Acanthinucella,* see Vermeij, 1993). Specimens assigned to *T. packi* from other Miocene strata in western North America and Kamchatka by Addicott (1965, 1970, 1980) and Gladenkov and Sinelnikova (1990) lack the labral projection. They can therefore be assigned to *N. tokudai.*

Polytropa ishii was listed by Uozumi (1962) as a representative species of the Miocene Atsunai-Togeshita fauna, but Uozumi neither illustrated nor described the material upon which this name was based. In their survey of the fauna of the Atsunai area in eastern Hokkaido, Mizuno *et al.* (1969) figured one specimen from the "Atsunai Formation" (= Ishiizawa Formation) as *Nucella ishii* Uozumi (MS). In our examination of specimens from this formation, we were unable to detect differences between *N. ishii* and *N. tokudai.* Therefore, we regard *N. ishii* as a junior subjective synonym of *N. tokudai.*

Comparison.—The present species is similar to the northeastern Pacific Recent species *Nucella canaliculata* (Duclos), especially, to the form described by Dall (1915) as the variety *compressa.* The latter form has a low spire and numerous flat-topped spiral ribs with narrow interspaces. However, *N. canaliculata* differs from *N. tokudai* by having fewer spiral cords on the body whorl (12 to 13 in *N. canaliculata* as compared to 15 to 19 in *N. tokudai*), and by having generally thin outer lip without denticles on the inner surface.

Several species of "*Nucella*" or "*Polytropa*"

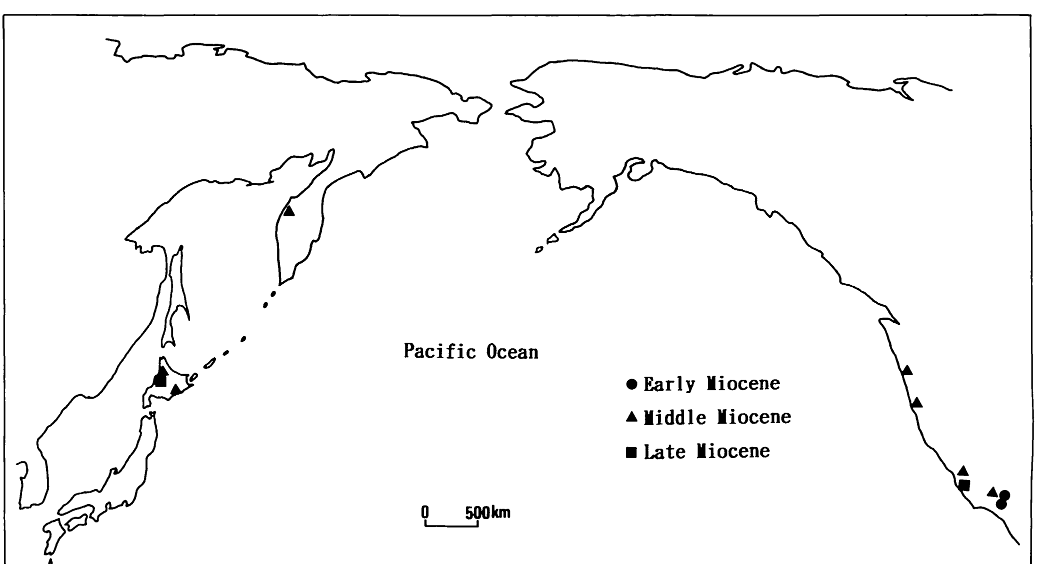

Figure 3. Distribution of *Nucella tokudai* (Yokoyama).

have been recorded from early Middle Miocene deposits in Honshu, but none belongs to *Nucella*. Among them, "*Nucella*" *tokishiensis* (Figure 2-6, 9) was described from the Nataki Conglomerate and the Shukunohora Sandstone in Gifu Prefecture by Itoigawa and Shibata (1976). This species resembles *N. tokudai* in having 16 to 17 flat-topped spiral cords on the body whorl, but it differs by being more slender, by the presence of 9 to 12 low axial ribs on the penultimate whorl, especially by the presence of a knob at the posterior end of the inner lip (see also Horikoshi, 1983). The inner-lip knob is absent in nearly all species of *Nucella*; it is present only in the Californian *N. emarginata* (Deshayes), a highly derived member of the genus (Vermeij, 1993; Collins *et al.*, in preparation).

Distribution.—Early Miocene Vaqueros Formation and Jewett Sand, California; early Middle Miocene Chikubetsu and Middle Okada Beds, Hokkaido, and Kakert Suite, western Kamchatka; Middle Miocene Temblor Formation, Sobrante Sandstone, California, and Astoria Formation and Sandstone of Floras Lake, Oregon, and Ishiizawa Formation, Hokkaido; Late Miocene upper part of the Togeshita Formation, Hokkaido, and Cierbo Sandstone, California (Figure 3).

Nucella freycineti saitoi Hatai et Kotaka, 1959

Figure 2-1a-b, 3, 11a-b, 12.

Nucella freycincti [*sic*] (Deshayes) *saitoi* Hatai and Kotaka, 1959, p. 9-10, figs. 2, 5.
Nucella sp., Amano, 1983, p. 33, pl. 8, fig. 25.
Thais lima (Martyn). Gladenkov *et al.*, 1984, p. 245, pl. 62, figs. 4a-b

Type locality.—Okamami-zawa, Obanazawa-machi, Yamagata Prefecture. IGPS no. 77797.

Materials.—Four specimens from the Togeshita Formation (Loc. R-1, 2) and one specimen from the Tachikaraushinai Formation (Loc. U-1)

Description.—Shell large for the genus, solid, bucciniform, with low spire. Whorls more than four. Surface ornamented with round-topped spiral cords, weak growth lines; low secondary spiral riblets in broad interspaces between cords; 18 to 20 cords and riblets on body whorl, 3 to 8 on penultimate whorl. Aperture large, ovate. Siphonal canal narrow and short. Fasciole rather prominent. Inner lip smooth, covered with thin callus. Outer lip thick, with 8 denticles on its inner surface. These denticles distinct on young specimens, obsolete on adults.

Measurements (in mm).—

Shell height	Height of aperture	Breadth	NS*	Localities
26.9	19.9	19.1	20	R-1
52.1	36.4	36.9	19	R-2
53.9	37.8	37.4	20	R-2
37.3	29.6	28.9	18	R-2
12.1	8.5	8.6	18	U-1

*number of spiral cords and riblets on body whorl.

Remarks and comparison.—The present subspecies was proposed by Hatai and Kotaka (1959) for material from the Middle Miocene Ginzan Formation in Yamagata Prefecture, Northeast Honshu. In their paper, they misspelled the specific name, as *freycincti*. *N. f. saitoi* is distinguished from the Recent *N. f. freycineti* (Figure 2-10) and *N. heyseana* by the thicker outer lip, narrower aperture, and by the presence of 8 denticles on the inner side of the outer lip. As pointed out by Hatai and Kotaka (1959), the shell length : breadth ratio of Recent adult specimens is greater than that of the fossil *N. f. saitoi*. The fossil species lacks the axial sculpture often observed in *N. heyseana*. In other respects, however, *N. f. saitoi* is very similar to the Recent *N. f. freycineti*.

Amano (1983) described and illustrated one poorly preserved specimen of *Nucella* from the Late Miocene upper part of the Togeshita Formation in Rumoi, northwest Hokkaido, but did not assign the shell at the species level. Several well preserved specimens have been collected since from the same site (Loc. R-2 = T24 of Amano, 1983). These conform in characters of sculpture and outer lip to *N. f. saitoi.*

Gladenkov *et al.* (1984) recorded *Thais lima* (Martyn) from the Middle Miocene Etolon Suite in western Kamchatka. Judging from their description and illustration, we believe the material from Kamchatka should be referred to *Nucella freycineti saitoi.* Gladenkov *et al.* (1984) described it as having 14 to 15 round-topped spiral cords with some interstitial riblets, and possessing a thick outer lip with some crenulations. The figured specimen has a lower spire than does the type of *N. f. saitoi*, but, as spire height tends to be a highly variable character within

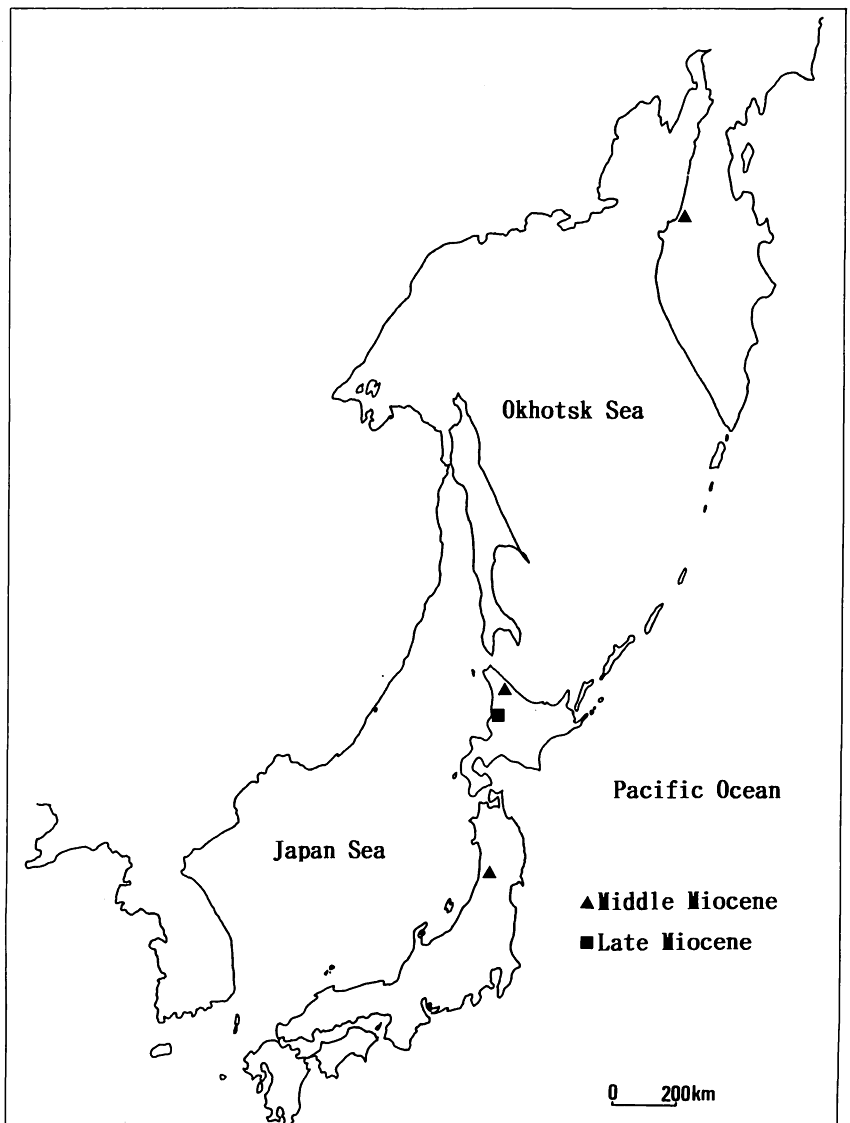

Figure 4. Distribution of *Nucella freycineti saitoi* Hatai et Kotaka.

species of *Nucella*, it is therefore unreliable for distinguishing among species. Typical *Nucella lima* (Gmelin) has a thin outer lip without denticles.

Distribution.—Middle Miocene Ginzan and Tachikaraushinai Formations, northern Japan, and Etolon Suite, western Kamchatka ; Late Miocene upper part of the Togeshita Formation, Hokkaido (Figure 4).

Early evolution and migration of *Nucella* in Miocene

The evolutionary origins of *Nucella* remain obscure, but the available evidence indicates that the genus arose in the warm-temperate northeastern Pacific. The earliest record of *Nucella* is of *N. tokudai* from the Vaqueros Formation and Jewett Sand (Early Miocene) in California (Loel and Corey, 1932 ; Addicott, 1965, 1970). *N. tokudai* is extremely similar to Clark's (1918) *Thais packi* from the San Ramon Formation (Late Oligocene or earliest Miocene) in California. *Thais packi,* which we here tentatively assign to *Acanthinucella*, differs from *N. tokudai* only by the presence of a small labral projection. In view of this similarity, it is likely that the two species share a common ancestry.

The earliest northwestern Pacific records of *Nucella* are those of *N. tokudai* from the early Middle Miocene in Hokkaido and Kamchatka. These records indicate that *N. tokudai* spread westward from California to Japan by the early Middle Miocene, which corresponds to the time of the so-called climatic optimum of the Miocene. Hokkaido at this time lay in a mild- to cool-temperate zone (Ogasawara, 1988). Many warm-water species extended quite far north in the Pacific at that time (Marincovich, 1984). Exactly when and how the dispersal of *N. tokudai* occurred is not known. Miocene records of *Nucella* are lacking in Alaska, possibly because the warm-water populations of early *Nucella* were not adapted to the cold conditions postulated to have existed in parts of Alaska during the early Middle Miocene by Marincovich (1990).

Several other shallow-water gastropod genera had invasion histories similar to that of *Nucella*. These include *Littorina* (Reid, 1989, 1990) and the buccinid *Lirabuccinum* (Vermeij, 1991b). These genera had earlier records in western North America than in eastern Asia, and evidently crossed the North Pacific westward by early Middle Miocene time. The same may be true for several genera of barnacles, including *Chirona* and *Hesperibalanus* (Zullo and Marincovich, 1990). Large rugose mussels of the genera *Plicatomytilus* and *Tumidimytilus* also achieved a broad amphi-Pacific distribution during the early Middle Miocene (Allison and Addicott, 1976 ; Kafanov, 1987 ; Uozumi and Akamatsu, 1988). Thus, by the Middle Miocene, many of the shallow-water organisms with which *Nucella* lives and upon which it feeds were widespread throughout the North Pacific.

The second species of *Nucella* to appear in the northwestern Pacific was *N. freycineti saitoi*, which is known from the Middle Miocene Tachikaraushinai and Ginzan Formations in Japan and the Etolon Suite in Kamchatka. Shibata *et al.* (1981) assigned an age of 13.7–13.8 Ma to the Tachikaraushinai Formation by K/Ar dating method.

N. f. saitoi persisted into the Late Miocene upper part of the Togeshita Formation, which contains some molluscs in common with those from the Pliocene Sannohe Group in Northeast Honshu and the Plio-Pleistocene Omma-Manganji fauna in the Japan Sea Borderland (Amano, 1986). The oldest *N.f. freycineti* was described by Chinzei (1961) from the Togawa Formation of the Sannohe Group. It is likely that this form evolved from *N. f. saitoi* during latest Miocene or Early Pliocene time.

The Miocene species of *Nucella* from Japan differ from their living counterparts in the northwestern Pacific by having an exceptionally thick outer lip whose inner side is denticulate. An outer lip of this kind is commonly seen in tropical gastropods and is suspected to have an antipredatory function (Vermeij, 1987). It is likely that *Nucella* arose and spread in relatively warm waters, where predators are abundant. Subsequently, several lineages of *Nucella* became adapted to cooler waters, where the outer lip became thinner and the denticulation was lost, as in *N. f. freycineti*, *N. heyseana, N. lima,* and most populations of *N. canaliculata.* However, other lineages of *Nucella* retained or reacquired thick denticulate lips. This applies to the northeastern Pacific *N. lamellosa* (Gmelin) and the north Atlantic *N. lapillus* (Linnaeus). The Californian *N. emarginata* has secondarily adapted to warmer waters and, at least in populations from sheltered sites, has evolved a very thick, strongly denticulate lip (Collins *et al*., in preparation).

The early evolution of *Nucella* illustrates the important point that many shallow-water elements of the present-day temperate North Pacific fauna arose in relatively warm waters and soon thereafter spread throughout the North Pacific Basin. Because most previous studies of the fossil faunas of this region have been restricted to particular areas, comparisons of specimens from different parts of the North Pacific have often not been made. As a result, the number of groups like *Nucella* whose geographical distributions came to encompass large parts of both the eastern and western North Pacific is probably much larger than the available literature now indicates. Many more examples will doubtless come to light when detailed comparisons are made between faunas of western North America and eastern Asia.

Acknowledgements

We are grateful to Prof. Hiroshi Noda of the University of Tsukuba, Prof. David Lindberg of the University of California at Berkeley, Emeritus Prof. Junji Itoigawa of Nagoya University, Prof. Itaru Hayami and Dr. Minoru Utada of the University of Tokyo, Mr. Yoshitsugu Okumura of the Mizunami Fossil Museum, for their help in enabling us to examine type material and other fossils in their care. Prof. Noda and Emeritus Prof. Saburo Kanno of the University of Tsukuba provided much useful advice and helpful suggestions. Finally, we thank Dr. Janice Cooper and Dr. Edith Zipser of the University of California at Davis for technical assistance.

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Nucella 属（腹足類）の初期進化と分布，特に日本産中新世種について： 北海道の中新統から産出したアクキガイ科の腹足類，*Nucella* の保存の良い標本は *N. tokudai* (Yokoyama) と *N. freycineti saitoi* Hatai et Kotaka に同定される。*N. tokudai* は中新世前期にカリフォルニアに出現し，中期中新世初期までに，西方へ日本およびカムチャッカに分布を広げた。*N. freycineti saitoi* は中新世中期に日本に出現し，本亜種から中新世末期または鮮新世前期に現生の *N. freycineti* (Deshayes) が進化した。初期の地理的分布や初期のすべての種に小歯をともなう厚い外唇が見られることから，*Nucella* 属は北東太平洋の温暖水起源であることが推定される。北米西岸の温暖水に起源をもち，その後東アジアに分散した *Nucella* の分布の変遷は，北太平洋の温帯浅海域の他の多くの貝類やフジツボの分布の変遷史に類似している。

天野和孝・ゲーラト フェルメイ・成田 健

PROCEEDINGS OF THE PALAEONTOLOGICAL SOCIETY OF JAPAN

日本古生物学会　第142回例会

日本古生物学会第142回例会が，6月26-27日に大阪教育大学で開催された (参加者130名).

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夜間小集会

IGCP 350 "Cretaceous Environmental Change, E. & S. Asia" 研究打ち合わせ (世話人　岡田博有)

Palaeontological Society of Japan (PSJ) Council Actions

During its meeting on June 26, 1993, the PSJ Council enacted the following changes to its membership.

New members elected:

Yuichi Asano, Vladimur I. Davydov, Christopher John Hollis, Nobuharu Hori, Yoshiaki Ishida, Takuya Itaki, Kenji Kashiwagi, Kaoru Kitao, Toshifumi Komatsu, Masahiko Konomatsu, Toshihiro Minami, Tokuji Mitsugi, Takahiko Nonaka, Yong Ho Shin, Norimichi Souji, Masahiko Takata, Yasufumi Tsuchiya, Atsushi Yabe, Yoshihiro Yamasaki, Toshiyuki Wakida.

New patron member:

Museum of Nature and Human Activities, Hyogo.

Resigned members:

(Ordinary member)

Mika Sato.

(Fellow)

Toru Onoe, Seiji Sato, Tatsuya Yamasaki, Saburo Yoshida.

(Patron member)

Social Education Division, Itoigawa Municipal Board of Education.

行事予定

◎1994年年会総会は，1994年1月27日～29日に，国立科学博物館上野本館(27日：シンポジウム，総会，懇親会）および同館新宿分館（28～29日：年会）で開催されます。講演申込は**12月10日**（必着）締切です。講演申込の方法や予稿集原稿の書き方については，「化石」48号または54号をご覧下さい。

1994年年会総会ではシンポジウム「生きている化石」（世話人：山口寿之，棚部一成，加瀬友喜）が行われます。

◎1994年例会（第143回例会）は，熊本大学理学部で6月後半に開催の予定です。

申込先：
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本誌の発行に要する費用は，会員の会費以外に，文部省科学研究費補助金ならびに賛助会員からの会費が当てられています。現在の賛助会員は下記の通りです。

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○文部省科学研究費補助金（研究成果公開促進費）による。

1993年9月25日　印刷
1993年9月30日　発行

ISSN　0031-0204
日本古生物学会報告・紀事
新篇171号
2,500円

発行者　日本古生物学会
〒113　東京都本駒込5－16－9
日本学会事務センター内
電話　03－5814－5801
編集者　斎藤常正・森　啓
編集幹事　島本昌憲
印刷者　仙台市若林区六丁の目西町8-45
笹氣出版印刷株式会社　笹氣幸緒
本社022-288-5555　東京03-3455-4415

Transactions and Proceedings of the Palaeontological Society of Japan

New Series No. 171 September 30, 1993

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