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Original article

Tithonian–Berriasian foraminiferal faunas from the Torinosu-type calcareous blocks of the southern Kanto Mountains, Japan: their implications for post-accretionary tectonics of Jurassic to Cretaceous terranes

Faunes de foraminifères du Tithonien–Berriasien dans les calcaires de type Torinosu au sud des Monts Kanto, Japon : conséquences pour la tectonique post-accrétionaire des terranes jurassiques à crétacées

Fumio Kobayashi[a,*], Valery Ja. Vuks[b]

[a] *Institute of Natural and Environmental Sciences, University of Hyogo, Sanda 669-1546, Japan*
[b] *All-Russian Geological Research Institute (VSEGEI), Sredny pr., 74, Saint Petersburg 199106, Russia*

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Abstract

The Torinosu-type limestones, having many lithologic characters showing their original deposition on shallow shelves, are widely distributed in the Jurassic to Cretaceous terranes of Japan. The foraminiferal faunas from the Jurassic to the lowermost Cretaceous of Japan were first revealed in the calcareous blocks of the southern Kanto Mountains. Distinguished microfaunas consist of 39 species including many marker species of the Upper Jurassic to Lower Cretaceous in Europe, West Asia, and North Africa such as *Melathrokerion spirialis*, *Charentia evoluta*, *Freixialina planispiralis*, *Nautiloculina oolithica*, *Everticyclammina* cf. *virguliana*, *Haplophragmium lutzei* and *Pseudocyclammina lituus*. These faunas suggest a Tithonian to Berriasian age of Torinosu-type limestones. They are contained in four tectonostratigraphic units (Kamiyozawa, Hikawa and Gozenyama Formations; Ogouchi Group) continuously accreted from Middle Jurassic to Late Cretaceous. The younger deposition age of Torinosu-type limestones than the accretion age (Bajocian to Bathonian) in the Kamiyozawa Formation and their older age than the accretion age of the Ogouchi Group (late Albian to middle Maastrichtian) are important to date the post-accretionary tectonics of Jurassic to Cretaceous terranes of Japan and to explain the emplacement process of Torinosu-type limestones.

Résumé

Les calcaires de type Torinosu, à nombreuses caractéristiques lithologiques liées à leur dépôt sur des plate-formes peu profondes, sont largement représentés dans les terranes jurassicocrétacés du Japon. Les faunes de foraminifères du passage Jurassique–Crétacé furent découvertes pour la première fois au Japon dans les blocs de calcaire affleurant dans les montagnes méridionales de Kanto. Les taxons reconnus correspondent à 39 espèces comprenant de nombreux marqueurs stratigraphiques du Jurassique supérieur-Crétacé inférieur d'Europe, Asie de l'Ouest, Afrique du Nord, tels que *Melathrokerion spirialis*, *Charentia evoluta*, *Freixialina planispiralis*, *Nautiloculina oolithica*, *Everticyclammina* cf. *virguliana*,

* Corresponding author.
E-mail address: kobayasi@nat-museum.sanda.hyogo.jp (F. Kobayashi).

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Haplophragmium lutzei et *Pseudocyclammina lituus*. Ces foraminifères suggèrent un âge tithonien à berriasien pour les calcaires de type Torinosu. Ils sont présents dans quatre unités tectonostratigraphiques (Formations Kamiyozawa, Hikawa et Gozenyama, ainsi que le groupe d'Ogouchi) accrétées en continu depuis le Jurassique moyen jusqu'au Crétacé supérieur. L'âge du dépôt des calcaires de type Torinosu, plus récent que l'âge de l'accrétion de la Formation Kamiyozawa (Bajocien–Bathonien), et plus ancien que l'âge de l'accrétion du Groupe d'Ogouchi (Albien supérieur–Maastrichtien moyen) est important pour situer dans le temps la tectonique post-accrétion des terranes jurassiques à crétacés du Japon et pour expliquer les processus de mise en place des blocs de calcaires de type Torinosu.

Keywords: Foraminifera; Tithonian–Berriasian; Torinosu-type limestone; Allochthonous origin; Accretionary complexes; Southern Kanto Mountains; Japan

Mots clés : Foraminifères ; Tithonien–Berriasien ; Calcaires de type Torinosu ; Origine allochthone ; Complexes d'accrétion ; Montagne méridionale de Kanto

1. Introduction

Only two species of Jurassic foraminifers have been originally described in Japan. One is *Cyclammina lituus* by Yokoyama (1890) and the other is *Choffatella peneropliformis* by Yabe and Hanzawa (1926). They were observed within the Torinosu limestone of Sakawa, Kochi Prefecture (= Province of Tosa). Another species, "*Acervulina huzimotoi*" described from the Torinosu-type limestone of southern Kanto Mountains by Hanzawa (1939), however, is not referable to a foraminifer but probably to a bryozoan. These two agglutinated foraminifers are taxonomically and biostratigraphically important, because they are designated, respectively, as the type species of *Pseudocyclammina* Yabe and Hanzawa, 1926 and *Torinosuella* Maync, 1959. These genera are dominant and widespread in the Upper Jurassic to Lower Cretaceous of Europe, West Asia, and North Africa (Maync, 1959; Banner, 1966; Ramalho, 1971; Peybernès, 1976; Thodria, 1977; Septfontaine, 1980; Kuznetzova et al., 1996).

The age of the Jurassic formations from the Outer Zone of Southwest Japan (Chichibu Terrane) had been mainly determined by stromatoporoids, hexacorals and sclerosponges which are very characteristic in the Torinosu limestone and the lithologically similar Torinosu-type limestone (Yabe and Sugiyama, 1935; Eguchi, 1951). Locally it is supported by ammonoids and bivalves (Kimura, 1956; Tamura, 1960). Radiolarian biostratigraphy since 1980s has revealed that some siliciclastic rocks containing these limestones range upward to the lowermost Cretaceous and unconformably overlie the Jurassic accretionary complexes (Yao, 1984; Suyari and Ishida, 1985; Kashiwagi and Yao, 1999).

Foraminiferal microfaunas, first clarified in the Torinosu-type limestones of the southern Kanto Mountains, contain many index species and genera known from the Upper Jurassic to Lower Cretaceous of Europe. The faunal composition and lithology of the Torinosu-type limestones suggest their original deposition on shallow shelves from Tithonian to Berriasian. On the other hand, the remarkable discordance in depositional ages between these limestones and the siliciclastic rocks by tectonostratigraphic units in the southern Kanto Mountains is very important to characterize accretionary and post-accretionary tectonics of the basement rocks in the mountains.

The purpose of this paper is: (1) to briefly introduce the lithology and biofacies of the Torinosu-type limestones and the Mesozoic tectonostratigraphy of the southern Kanto Mountains; (2) to describe the foraminiferal assemblages and to discuss the age of the Torinosu-type limestones; (3) to point out the further need of examination on the tectonic evolution of Jurassic to Cretaceous terranes of Japan, especially on the post-accretionary tectonics including the emplacement process of the Torinosu-type limestone. About 550 thin sections used in this study are stored in the collection of the Museum of Nature and Human Activities, Hyogo, Japan (Fumio Kobayashi Collection).

2. Geologic setting

The Jurassic limestones of Japan are very characteristic in their lithology largely different from those of other ages. They were named the Torinosu limestone from the locality of Torinosu, Sakawa town, Kochi Prefecture. Lithologically similar the Torinosu-type limestone is widely distributed in the Middle Chichibu (Kurosegawa) and Southern Chichibu Terranes of Southwest Japan and their eastward extension in Northeast Japan (Fig. 1). Their sporadic occurrence is also known from the Northern Shimanto Terrane.

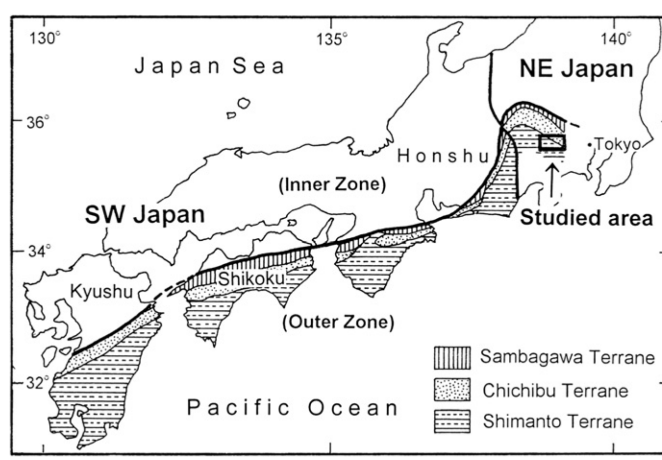

Fig. 1. Geologic components in the Outer Zone of Southwest Japan and its eastward extension in the Kanto Mountains of Northeast Japan. Based on differences of geologic structure and accretionary ages, the Chichibu Terrane is subdivided into Northern Chichibu, Middle Chichibu (Kurosegawa) and Southern Chichibu, and the Shimanto into Northern Shimanto and Southern Shimanto.

The Kanto Mountains are tectonically subdivided from north to south into the Sambagawa Terrane (high P/T metamorphic rocks), the Chichibu Terrane (Jurassic to Lower Cretaceous accretionary complexes) and the Shimanto Terrane (Cretaceous to Paleogene accretionary complexes). These terranes in the mountains are the eastern extensions of those of Southwest Japan (Fig. 1). Huzimoto (1932, 1939) first showed the zonal distribution of strata including the Torinosu-type limestones in the Kanto Mountains and their age ranging from Middle to Late Jurassic based on hexacorals and stromatoporoids. The tectonic subdivision of the Chichibu Terrane is largely different by authors working in the southern Kanto Mountains (Takashima and Koike, 1984; Ozawa and Kobayashi, 1985; Sakai, 1987). However, all the pre-Cretaceous tectonostratigraphic units containing the Torinosu-type limestones are assignable to the Southern Chichibu Terrane. They are located more southwestward than the distributional area of the serpentinites and the Permian to Triassic strata of the Nishitama Group, both of which are very characteristic in the Kurosegawa Terrane (Fig. 2; Ozawa and Kobayashi, 1985; Kobayashi and Ozawa, 1996).

According to Ozawa and Kobayashi (1985), accretionary complexes of southern Kanto Mountains are divided into the Kamiyozawa, Kawai, Unazawa, Ogawadani, Hikawa and Gozenyama Formations (Southern Chichibu Terrane), the Ogouchi Group (Northern Shimanto Terrane) and the Kobotoke Group (Southern Shimanto Terrane) (Fig. 2). All of these tectonostratigraphic units are bounded by fault one another. Accretion ages of them, which have been determined by radiolaria from mudstones, are, respectively, Bajocian to Bathonian in the Kamiyozawa Formation, Callovian to Oxfordian in the Kawai Formation and Unazawa Formation, Kimmeridgian in the Hikawa Formation, Tithonian to Barremian in the Gozenyama Formation, late Albian to middle Maastrichtian in the Ogouchi Group and Paleogene in the Kobotoke Group (Takahashi and Ishii, 1995; Takahashi, 1999). The Torinosu-type limestones are contained in the Kamiyozawa, Hikawa, and Gozenyama Formations and in the Ogouchi Group (Fig. 2).

Kamiyozawa and Gozenyama Formations are characterized by a melange of seamount limestones, basaltic rocks, cherts, and sheared pelitic rocks. Oceanic-affinity rocks are lacking in the Hikawa Formation mostly consisting of turbidity sediments. The Ogouchi Group is composed of dominant turbiditic sediments and accessory melange. Variegated hemipelagic mudstones and acidic tuffs are found in the Kamiyozawa and Gozenyama Formations and in the Ogouchi Group. These pelagic, hemipelagic, slope and trench-fill deposits whose ages become regularly younger southward (Takashima and Koike, 1984; Ozawa and Kobayashi, 1985; Takahashi and Ishii, 1995; Takahashi, 1999) are explained essentially by the accretionary tectonics in the active continental margin from Middle Jurassic to Late Cretaceous times.

3. Occurrence, lithology and fossils from Torinosu-type limestones

The Torinosu-type limestones are all included in sandstones and mudstones, and poorly laterally traceable. The largest

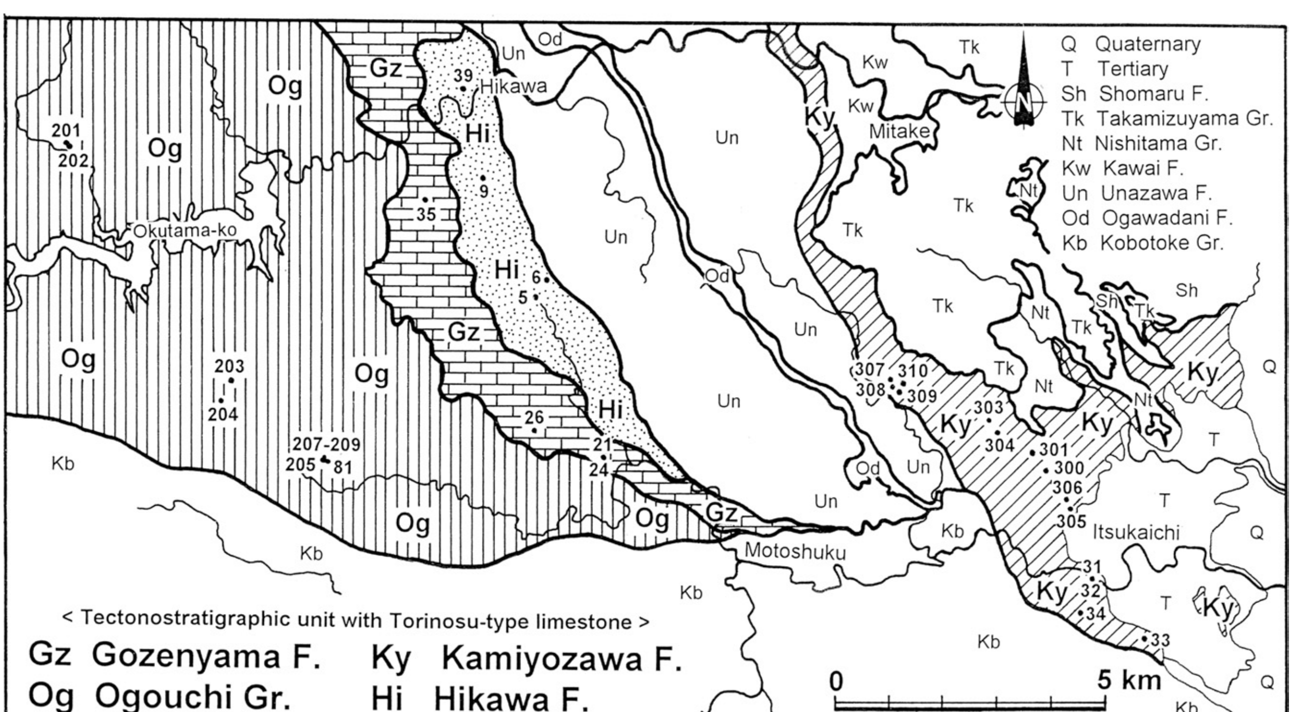

Fig. 2. Distribution of foraminifera in the Torinosu-type limestones of the Southern Kanto Mountains. The Kamiyozawa, Hikawa and Gozenyama Formations are assignable to the Southern Chichibu Terrane and the Ogouchi Group to the Northern Shimanto Terrane.

block reaches more than 100 m in its longer diameter and 50 m thick in the Kamiyozawa Formation, and 50 m length and 20 m thickness in the Ogouchi Group. Those present in the Hikawa and Gozenyama Formations are smaller and less than 5 m thick. Limestones appear to be conformable with the lower and upper siliciclastic rocks in the Hikawa Formation. They are surrounded by sheared mudstone containing blocks of seamount limestones, basaltic rocks, and cherts from the Gozenyama Formation.

Torinosu-type limestones are dark gray to black and mostly bituminous. They are lithologically variable and composed of boundstones, floatstones/rudstones, grainstones, packstones, wackestones, lime-mudstones, and calcarenites. Some of them are conglomeratic and many calcareous clasts and bioclasts are densely packed within a calcareous mudstone matrix. Detrital quartz grains are contained in many limestones and especially abundant in ooid-bearing grainstones and calcarenites. Calcareous sandstones and mudstones are thinly intercalated in bedded limestones and irregularly contained in some of massive limestones.

Characteristic fossils are represented by stromatoporoids such as *Parastromatopora japonica* Yabe, sclerosponges such as *Chaetetopsis crinata* Neumayr and various types of algae. Algae identified are particularly Dasycladales such as *Cylindroporella*? sp., *Heteroporella anici* (Sokac and Nikler), *Salpingoporella* sp., *Actinoporella podolica* (Alth), *Neogyroporella*? sp., *Pseudoepimastopora* cf. *jurassica* Endo and *Acicularia elongata* Carozzi in the Kamiyozawa Formation and *A. podolica* (Al-Thour), *H. anici* (Sokac and Nikler), *Salpingoporella* spp. and *Permocalculus deceneii* Bucur are distinguished in the Ogouchi Group. *Tubiphytes* sp. are present in the Kamiyozawa Formation. Foraminifers are less dominant than these macrofossils. In addition, are observed in the limestones hexacorals, crinoids, sponges, bryozoans, bivalves, gastropods, brachiopods, ammonoids and ostracods.

These lithologies and fossil assemblages strongly suggest the original deposition of the Torinosu-type limestones on the shallow shelf in a reefal environment. They are quite different from those of the Lower Carboniferous (Serpukhovian) to upper Triassic (Carnian) seamount limestones widely distributed in the southern Kanto Mountains (e.g. Kobayashi, 2005). The both limestones are easily distinguishable, even in the field.

4. Foraminiferal fauna and ages

Thirty-nine species, belonging to 24 genera and three of undetermined generic affinity, of foraminifera are distinguished after the microscopic observation of 550 thin sections (Fig. 3). Number of foraminifera contained are more or less linked to lithofacies. For example, in the Hikawa Formation, foraminifera are commonly found within argillaceous bioclastic packstones/wackestones at Loc. 5 (Fig. 2) but they are barren or very few in boundstones and rudstones/floatstones. Characteristic species of Upper Jurassic–Lower Cretaceous occur in some limestones of the Kamiyozawa and Hikawa Formations and of the Ogouchi Group. Foraminifera are most abundant in bioclastic packstones at Loc. 205 in the Ogouchi Group. Remarkable differences of faunal composition are not recognizable in these three units. Although lithologies of limestones in the Gozenyama Formation resemble those in other three units, age-diagnostic foraminifers have not been obtained from the formation.

Among the distinguished species, *Melathrokerion spirialis* (Fig. 4(35–45)) is the most dominant and widespread in Torinosu-type limestones of the Kamiyozawa and Hikawa Formations and of the Ogouchi Group. This species was originally described from the lower Berriasian of Crimea (Gorbachik, 1968). It is known from the Tithonian to the Berriasian of Crimea, Caucasus, Syria and Algeria, and from the Berriasian of Switzerland (Kuznetzova and Gorbachik, 1985; Kuznetzova et al., 1996; Vuks, 2002).

Biostratigraphic species such as *Charentia evoluta* (Fig. 4(27–32)), *Freixialina planispiralis* (Fig. 4(5–10)), *Nautiloculina oolithica* (Fig. 4(1–4)), *Everticyclammina* cf. *virguliana* (Fig. 4(46–50) and Fig. 5(1)), *Haplophragmium lutzei* (Fig. 4(14, 15)) and *P. lituus* (Fig. 5(7–14)) are found in limestones of Kamiyozawa and Hikawa Formations and of the Ogouchi Group. Although foraminifera are poor and these index species have not been distinguished, fragmentary specimens possibly assignable to *Pseudocyclammina* rarely occur in the bituminous limestone at Loc. 35 in the Gozenyama Formation

C. evoluta was first described by Gorbachik (1968) under the name of *Tonasia evoluta* from the Berriasian and the Valanginian of Crimea. Its stratigraphic range is Berriasian to lower Valanginian in southeast Crimea (Dulub and Zhabina, 1993), Tithonian to Neocomian in Syria (Kuznetzova et al., 1996) and Berriasian in Algeria (Kuznetzova et al., 1996). *F. planispiralis* is a marker species of the Kimmeridgian–Tithonian of Portugal (Ramalho, 1971) and Carpathians (Dulub, 1972) and also of the Berriasian of Crimea (Dulub and Zhabina, 1993). The genus *Nautiloculina* is known from the Middle Jurassic to Lower Cretaceous in Europe, North Caucasus, Egypt and Israel (Loeblich and Tappan, 1988), and from Jurassic to Lower Cretaceous in Europe and eastern Mediterranean regions (Peybernès, 1976; Kuznetzova et al., 1996). *N. oolithica* is common in the Upper Jurassic (Peybernès, 1976; Septfontaine, 1980). *E. virguliana* is an index species of Oxfordian to Tithonian and widely known from Europe including Portugal (Ramalho, 1971), France (Pélissié and Peybernès, 1983), southern Germany (Ebli and Schlagintweit, 1998) and Slovakia (Soták, 1987). This species also occurs in Turkey (Bassoullet and Poisson, 1975), Georgia (Thodria, 1977), Syria (Kuznetzova et al., 1996), Yemen (Simmons and Al-Thour, 1994), Morocco (Hottinger, 1967) and Algeria (Ramalho, 1971). *H. lutzei* and *P. lituus* range from the Upper Jurassic to Lower Cretaceous and have been reported from many limestones of Europe, west Asia and North Africa, as well as *E. virguliana*. Forms undoubtedly identified with *P. lituus* have been restrictedly observed in the Ogouchi Group in the southern Kanto Mountains.

	Kamiyozawa Formation														Hikawa Fm.				Gozenyama Fm.				Ogouchi Group								
	31	32	33	34	300	301	303	304	305	306	307	308	309	310	5	6	9	39	21	24	26	35	81	201	202	203	204	205	207	208	209
Glomospirella? sp.			X			?																									
Reophax sp.					?	X	?						X		X							?			?			X			
Nautiloculina oolithica Mohler		X		X	X		X								X										X	X	X	X			X
Freixialina planispiralis Ramalho																							X				X	X			
Acruliammina cf. *neocomica* Bartenstein				X			?		X	X	X	X	X										X								
Haplophragmium lutzei Hanzlikova	X	X										X	X	X	X							X						X			
Haplophragmium? sp.	X			X					X	X		X	X	X	X					?	X								X		
Charentia evoluta (Gorbachik)	X	X		X									X										X					X			
Charentia sp.	X	X																													
Melathrokerion spiralis Gorbachik	X	X		X	X			?			X		X	X	X								X				X	X			
Everticyclammina cf. *virguliana* (Koechlin)	X	X	X	X				X			X		X		X													X			
Everticyclammina? sp.				X	X				X				X					X		X								X			X
Pseudocyclammina lituus (Yokoyama)																							X			X		X			
Pseudocyclammina sp.				X														?				?									
Torinosuella? sp.	X																											X			
Ecougella sp. A				X																								X			
Ecougella sp. B		X											X																		
Trochammina sp. A				?																			X			X		X		X	
Trochammina sp. B	X	X	X						X	X					X				X	X			X		X	X	X	X		X	
Gaudryina? sp.			X	X										X																	
Valvulina spp.			X	X	X						X		X	X			X	X			X	X	X					X			
Siphovalvulina sp.				X	?		X		X				X	X	X													X			
Textularia sp. A	X			X					X		X		X		X													X			
Textularia spp.	X	X	X	X	X			X	X		X	X	X	X		X	X	X				X	X	X	X			X	X		X
Trocholina molesta Gorbachik	X	X																													
Spirillinidae gen. and sp. indet.											X		X																		
Ophthalmidium sp.				X		X	X	X			X																				
Ophthalmidium? sp.						X	X		X	X		X				X			X	X	X	X		X	X			X			
Istriloculina? sp. A																			?									X			
Istriloculina? sp. B				X																	X		X			X					
Quinqueloculina podlubiensis Terestschuk	X		X	X				?						X									X			X		X			
Quinqueloculina sp.	X			X		X													X				X			X	X	X		X	
Hauerinidae gen. and sp. indet.			X				X						X		X																
Lenticulina sp. A	X				X	X			X						X	X		X													
Lenticulina sp. B				?																						X					
Lenticulina sp. C																												X			
Astacolus ? sp.	?	?											X													X					
Polymorphinidae gen. and sp. indet.								X	X										X									X			X
Epistomina ? sp.													X																		

Fig. 3. Foraminifera of the Torinosu-type limestones in the southern Kanto Mountains. Locality numbers correspond to those in Fig. 2.

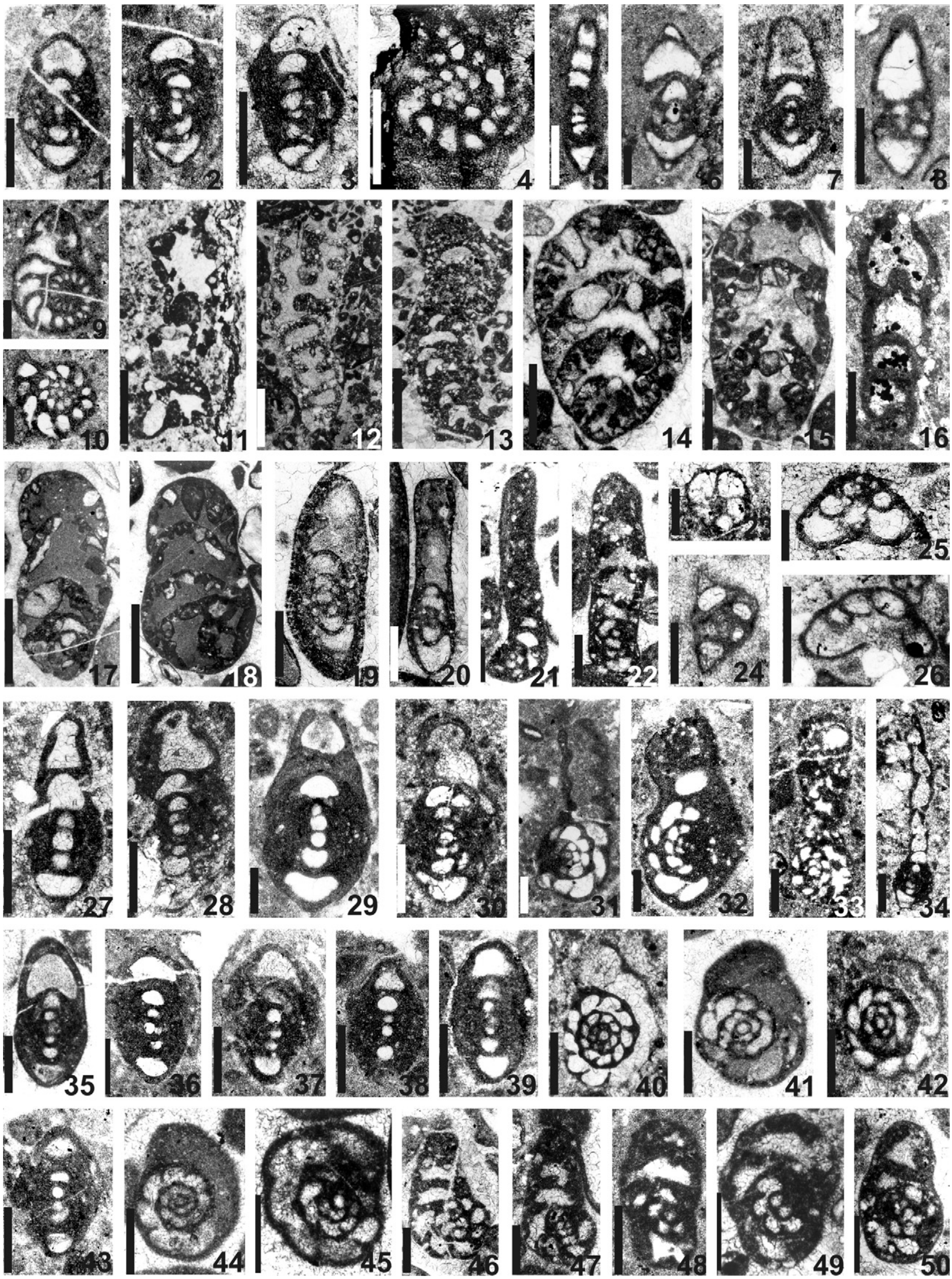

Fig. 4. **1–4**. *Nautiloculina oolithica* Mohler. 1: D2-028212, Loc. 300; 2: D2-028069a, Loc. 205; 3: D2-028186, Loc. 34; 4: D2-028101, Loc. 205. **5–10**. *Freixialina planispiralis* Ramalho. 5: D2-028080a; 6: D2-028070a; 7: D2-028082; 8: D2-028086a; 9: D2-028106; 10: D2-028070b, all from Loc. 205. **11–13**. *Acruliammina* cf. *neocomica* Bartenstein. 11: D2-014260a, Loc. 34; 12: D2-028258a, Loc. 309; 13: D2-014124, Loc. 309. **14**, **15**. *Haplophragmium lutzei* Hanzlikova. 14: D2-014230; 15: D2-028149, both from Loc. 31. **16**. *Reophax* sp. D2-027853, Loc. 5. **17**, **18**. *Haplophragmium*? sp. 17: D2-014223a; 18: D2-

Although it is very rare, *Torinosuella*? sp. (Fig. 5(32–34)) occurs in ooid grainstones of the Kamiyozwa Formation at Loc. 31 and bioclastic packstones of the Ogouchi Group at Loc. 205. The diagnosis of this genus is based on the specimens described by Yabe and Hanzawa (1926) from the type locality of the Torinosu limestones in Sakawa, and the type species, *Torinosuella peneropliformis*, occurs in the Kimmeridgian of Japan, Portugal, Switzerland and Algeria, and also in the Lower Cretaceous of Yugoslavia (Maync, 1959). Stratigraphic range of this genus is restricted to Oxfordian to Lower Cretaceous interval in Europe, west Asia and Algeria according to subsequent workers (Banner, 1966; Ramalho, 1971; Thodria, 1977; Gorbachik and Kuznetzova, 1994; Kuznetzova et al., 1996).

An occurrence of Involutinidae is restricted to *Trocholina molesta* (Fig. 5(41, 42)) from Locs. 31 and 32 in the Kamiyozawa Formation. This species is known in the upper Tithonian–Valanginian interval of Crimea and northwestern Caucasus, the Valanginian of France, the Berriasian of Switzerland, the upper Valanginian to lower Barremian of Romania and Lower Cretaceous of Ukraine (Kuznetzova and Gorbachik, 1985).

In addition to these species and genera, the present microfauna contains many taxa and is important in having three forms of *Lenticulina* (Fig. 5(43) and Fig. 6(23, 24, 27)), *Astacolus*? sp. (Fig. 6(25)) and Polymorphinidae gen. and sp. indet. (Fig. 6(26)) with their transparent hyaline wall, and *Epistomina*? sp. (Fig. 6(6–9)) with a similar perforate wall. Spirillinidae gen. and sp. indet. (Fig. 5(35–37)) from the Kamiyozawa Formation at Locs. 307 and 309 may be a new genus, though well-oriented specimens have not been obtained.

The Tithonian age is suggestive for Torinosu-type limestones of Kamiyozawa and Hikawa Formations and of the Ogouchi Group based on the concurrent range of representative and important species whose ranges are well-determined in Europe, west Asia, and North Africa. On the other hand, detailed foraminiferal biostratigraphic zonation available for international correlation has not been established and stratigraphic ranges of species and genera are more or less variable in places. About some of algae mentioned above, *A. podolica* is typical for the Upper Jurassic of Europe (e.g. Bassoullet et al., 1978; Ramalho, 1971; Soták, 1987), whereas *P. deceneii* occurs in the Cretaceous of Romania (Bucur, 1994) and probably in the Tithonian of Portugal (Ramalho, 1971). Most of other algae are long-ranging and inferior in their biostratigraphic value.

It is more reasonably concluded, accordingly, that all the Torinosu-type limestones in the southern Kanto Mountains were deposited in a time interval within Tithonian to Berriasian rather than restricted to the Tithonian.

5. Allochtonous origin and emplacement of Torinosu-type limestones

Lithologies and fossils of the Torinosu-type limestones clearly showing their reefal deposition environment on the shallow shelf are quite different from those of seamount limestones accompanied by basaltic rocks which are abundantly contained in the Kamiyozawa and Gozenyama Formations and more rarely in the Ogouchi Group. Against the Tithonian to Berriasian of Torinosu-type limestones, based on foraminifera and conodonts, oceanic-affinity rocks are early Carboniferous (Serpukhovian) to latest Permian (Changhsingian) and late Triassic (?) in the Kamiyozawa Formation, middle Permian (Capitanian) to late Triassic (Carnian) in the Gozenyama Formation, and Late Triassic (?) in the Ogouchi Group. They are totally absent in the Hikawa Formation.

The ages of the mudstones are Bajocian to Bathonian in the Kamiyozawa Fm, Kimmeridgian in the Hikawa Formation, Tithonian to Barremian in the Gozenyama Formation, and late Albian to middle Maastrichtian in the Ogouchi Group (Takahashi and Ishii, 1995; Takahashi, 1999). Nearly successive accretion from the northeastward Kamiyozawa Formation to the southwestward Ogouchi Group is suggested by their reconstructed lithostratigraphy beginning with basalt and seamount limestone and ending with terrigenous rocks through pelagic bedded cherts and hemipelagic acidic tuffs and variegated siliceous mudstones, and their ages becoming regularly younger southwestward (Takashima and Koike, 1984; Ozawa and Kobayashi, 1985; Takahashi and Ishii, 1995; Matsuoka et al., 1998; Takahashi, 1999).

Depositional age of the Torinosu-type limestones is roughly penecontemporaneous with the age of the mudstones in the Hikawa (?) and Gozenyama Formations and older than that in the Ogouchi Group. On the other hand, the ages of the mudstone determined in the Kamiyozawa Formation are limited to middle to early late Jurassic (Takashima and Koike, 1984; Ozawa and Kobayashi, 1985; Sakai, 1987) or middle Jurassic (Bajocian to Bathonian) (Takahashi and Ishii, 1995; Takahashi, 1999). These ages of the mudstones are available for the determination of the timing of accretion and their younger age than

028147, both from Loc. 31. **19**, **20**. *Charentia* sp. 19: D2-028153a, Loc. 31; 20: D2-014229, Loc. 32. **21**, **22**. *Ecougella* sp. B. 21: D2-028255; 22: D2-028240, both from Loc. 309. **23**, **25**, **26**. *Trochammina* sp. B. 23: D2-002368a, Loc. 21; 25: D2-002368b, Loc. 21; 26: D2-027856, Loc. 5. **27**–**32**. *Charentia evoluta* (Gorbatchik). 27: D2-028175; 28: D2-028196; 29: D2-014178a; 30: D2-002413a; 31: D2-028069b; 32: D2-028075; 27, 28: Loc. 34; 29, 31, 32: Loc. 205; 30: Loc. 81. **33**, **34**. *Ecougella* sp. A. 33: D2-014183, Loc. 205; 34: D2-014260b, Loc. 34. **35**–**45**. *Melathrokerion spirialis* Gorbatchik. 35: D2-028122; 36: D2-028073; 37: D2-014186; 38: D2-014175a; 39: D2-014172; 40: D2-028181; 41: D2-028148, 42: D2-028206; 43: D2-014178b; 44: D2-028123; 45: D2-028140a; 42: D2-027869; 43: D2-014175a; 44: D2-014172; 45: D2-028160; 35, 41, 44, 45: Loc. 31; 36–39, 43: Loc. 205; 40: Loc. 34; 42: Loc. 300. **46**–**50**. *Everticyclammina* cf. *virguliana* (Koechlin). 46: D2-028251; 47: D2-028272a; 48: D2-028079; 49: D2-028264; 50:D2-028249, 48: Loc. 205; others: Loc. 309. Scale bars equal 0.1 mm in 6, 7, 10, 23–25; 0.5 mm in 11–15; 1 mm in 17, 18; 0.2 mm in others.

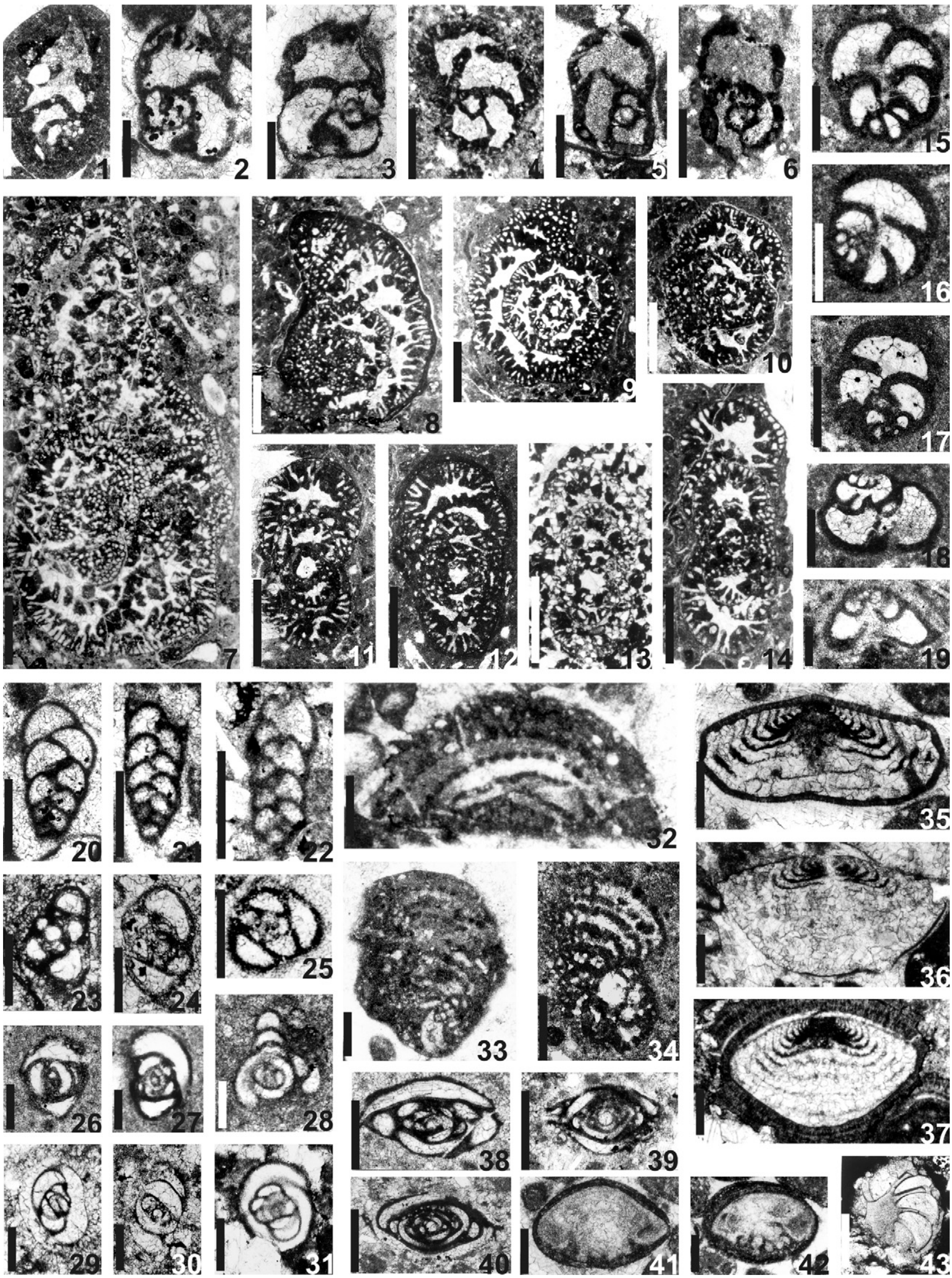

Fig. 5. **1**. *Everticyclammina* cf. *virguliana* (Koechlin). D2-028272b, Loc. 309. **2**–**6**. *Everticyclammina*? sp. 2: D2-028278; 3: D2-028252; 4: D2-028179; 5: D2-028256b; 6: D2-027851; 2, 3, 5: Loc. 309; 4: Loc. 34; 6: Loc. 5. **7**–**14**. *Pseudocyclammina lituus* (Yokoyama). 7: D2-028086b; 8: D2-028074a; 9: D2-028091a; 10: D2-028093; 11: D2-028083; 12: D2-028087; 13: D2-028057a; 14: D2-014176a, all from Loc. 205. **15**–**19**. *Trochammina* sp. A. 15: D2-028098; 16: D2-028095; 17: D2-028089; 18: D2-028101; 19: D2-028081, all from Loc. 205. **20**–**22**. *Textularia* sp. A. 20: D2-028140b, Loc. 31; 21: D2-014118, Loc. 307; 22: D2-027860, Loc.

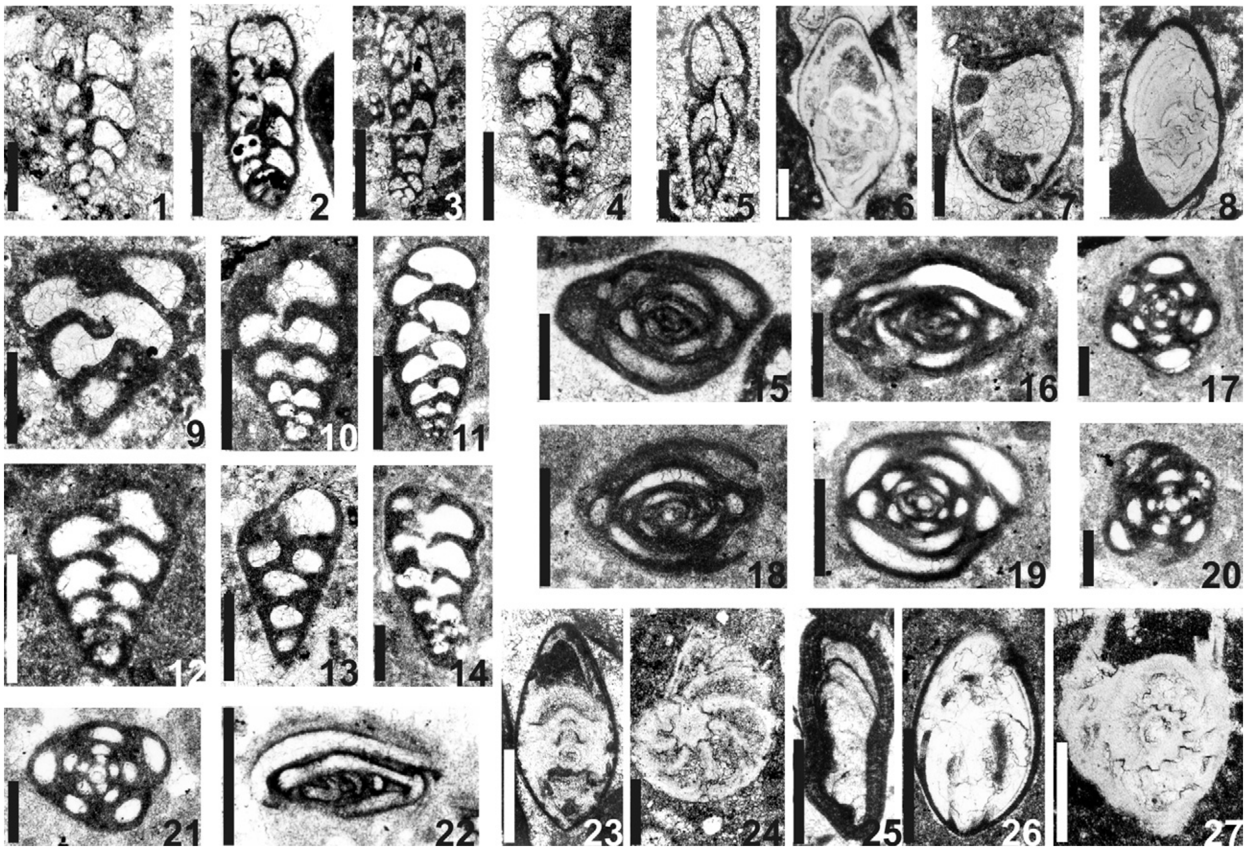

Fig. 6. **1**–**5**. *Siphovalvulina* sp. 1: D2-028191b; 2: D2-028274; 3: D2-014261; 4: D2-014096; 5: D2-028193; 1, 3, 5: Loc. 34; 2: Loc. 309; 4: Loc. 305. **6**–**8**. *Epistomina*? sp. 6: D2-028254; 7: D2-028281a; 8: D2-028281b, all from Loc. 309; **9?**, **10**–**14**. *Valvulina* spp. 9: D2-028195b. 10: D2-028102; 11: D2-028084b; 12: D2-028080b; 13: D2-028195a; 14: D2-028074b; 9, 13: Loc. 34; others: Loc. 205, 38. **15**, **16?**, **17**–**21**. *Quinqueloculina podlubiensis* Terestschuk. 15: D2-028124; 16: D2-028069c; 17: D2-028070c; 18: D2-028103; 19: D2-014176b; 20: D2-028070d; 21: D2-028076a, 15: Loc. 31; others: Loc. 205. **22**. *Ophthalmidium* sp. D2-014072, Loc. 301. **23**, **24**. *Lenticulina* sp. A. 23: D2-028152; 24: D2-028151, both from Loc. 31. **25**. *Astacolus*? sp. D2-028276b, Loc. 309. **26**. Polymorphinidae gen. and sp. indet. D2-028076b, Loc. 205. **27**. *Lenticulina* sp. C. D2-028091b, Loc. 205. Scale bars equal 0.1 mm in 1, 17, 20, 21, 24; 0.5 mm in 25; 0.2 mm in others.

the age of the Torinosu-type limestone have not been recorded in the Kamiyozawa Formation. Based on occurrences, lithologies and ages, allochthonous origin of Torinosu-type limestones in the southern Kanto Mountains is easily suggested.

Possible interpretation concerning the emplacement of Torinosu-type limestones are: (1) roughly penecontemporaneous, sedimentary or tectonic mixing with siliciclastic rocks in the Hikawa (?) and Gozenyama Formations; (2) post-Berriasian redeposition unconformably on the accreted Bajocian to Bathonian complexes together with early Carboniferous to Triassic oceanic blocks after the uplift of accretionary complexes in the Kamiyozawa Formation; (3) transport into depositional site of siliciclastic rocks during late Albian to middle Maastrichtian in the Ogouchi Group.

Torinosu-type limestones are thought to have been unexceptionally redeposited intermittently during latest Jurassic to late Cretaceous times. Their redepositional ages by formations and group, however, have been remained uncertain. Trigger of redeposition is still in mystery. Younger depositional age of the Torinosu-type limestones than accretion age as old as Bajocian to Bathonian in the Kamiyozawa Formation is very important in southern Kanto Mountains as well as other Jurassic to Cretaceous terranes of Japan as to the post-accretionary tectonics in these terranes.

5. **23**–**25**. *Ophthalmidium*? sp. 23: D2-002368d, Loc. 21; 24: D2-002368c, Loc. 21; 25: D2-002374, Loc. 25. **26**, **27**. *Istriloculina*? sp. A. 26: D2-028084a; 27: D2-014182, both from Loc. 205. **28**. *Glomospirella* sp. D2-014251, Loc. 33. **29**–**31**. *Istriloculina*? sp. B. 29: D2-028197; 30: D2-028191a; 31: D2-014161a; 29, 30: Loc. 34; 31: Loc. 203. **32**–**34**. *Torinosuella*? sp. 32: D2-028153b; 33: D2-028156; 34: D2-028077; 32, 33: Loc.31; 34: Loc. 205. **35**–**37**. Spirillinidae gen. and sp. indet. 35: D2-028250, Loc. 309; 36: D2-028258b, Loc. 309; 37: D2-014115, Loc. 307. **38**, **39?**, **40?**. *Quinqueloculina* sp. 38: 26: D2-002413b; 39: D2-028195c; 40: D2-028184; 38: Loc. 81; 39, 40: Loc. 34. **41**, **42**. *Trocholina molesta* Gorbachik. 41: D2-014240; 42: D2-014239, both from Loc. 32. **43**. *Lenticulina* sp. B. D2-028057b, Loc. 203. Scale bars equal 0.5 mm in 4; 1 mm in 7–14; 0.1 mm in 19, 23–31, 38; 0.2 mm in others.

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