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ARTICLE

AN EXOTIC BODY OF THE MIDDLE JURASSIC TORINOSU-TYPE LIMESTONE IN THE HIKAWA FORMATION, SOUTHEASTERN KANTO MOUNTAINS, JAPAN

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ABSTRACT

An exotic body of the Middle Jurassic Torinosu-type limestone was found in the Upper Jurassic Hikawa Formation, southeastern Kanto Mountains, Japan. A radiolarian assemblage containing *Kilinora tecta* (Matsuoka), *Striatojaponocapsa conexa* (Matsuoka), *Sj. plicarum* (Yao) sensu Hatakeda et al. (2007), *Japonocapsa fusiformis* (Yao), *Stichocapsa japonica* Yao, *Stc. naradaniensis* Matsuoka, *Zhamoidellum ovum* Dumitrica, *Praewilliriedellum spinosum* Kozur, *Tethysetta dhimenaensis* (Baumgartner), and *Dictyomitrella* (?) *kamoensis* Mizutani and Kido was recovered from the limestone body and is equivalent to that from the upper part of the *Sj. conexa* Zone (Bathonian to middle Callovian). The limestone body occurred in an Upper Jurassic (Kimmeridgian to lower Tithonian) gravelly mudstone of the lower member of the Hikawa Formation as a boulder-sized clast.

An exotic body of the Middle Jurassic Torinosu-type limestone has also been reported from the Upper Jurassic Ebirase Formation, western Kyushu. The Hikawa and Ebirase formations are two of the Upper Jurassic trench-slope basin deposits formed simultaneously in the Southern Chichibu Belt. The occurrences of the exotic Middle Jurassic limestone bodies in these Upper Jurassic formations indicate that Middle Jurassic shallow-marine strata containing carbonate sediments were eroded on the accretionary complexes in widespread areas of the Southern Chichibu Belt and rock debris originating from these strata was transported into trench-slope basins during the Late Jurassic.

Key words: Torinosu-type limestone, radiolaria, Jurassic, Hikawa Formation, Southern Chichibu Belt, Kanto Mountains

石田直人（2011）関東山地南東部，上部ジュラ系氷川層に産する異地性岩体としてのジュラ紀中世鳥巣式石灰岩．福井県立恐竜博物館紀要 10：103 – 112.

関東山地南東部の秩父累帯南帯に分布する上部ジュラ系氷川層において，異地性の産状を示すジュラ紀中世鳥巣式石灰岩体が確認された．この石灰岩体から産する放散虫化石群集は *Striatojaponocapsa conexa* 帯上部から産するものに一致し，ジュラ紀中世後期（Bathonian期〜Callovian期中期）を示す．この岩体は，上部ジュラ系Kimmeridgian階とTithonian階の境界付近の層準の含礫泥岩に礫として含まれており，周囲の砕屑岩との年代差に加え，堆積環境の相違からも異地性岩体と結論できる．異地性のジュラ紀中世鳥巣式石灰岩は，九州西部に分布する上部ジュラ系篚瀬層にも知られている．氷川層と篚瀬層は共に，同時に形成された海溝斜面海盆堆積物とされる．両層に産する異地性の鳥巣式石灰岩は，付加体上にあるジュラ紀中世の炭酸塩岩を含む浅海成層がジュラ紀新世に浸食され，その岩屑が海溝斜面海盆へと流入した現象が広域に生じたことを示唆する．

INTRODUCTION

The distribution of upper Mesozoic strata containing the Torinosu-type limestone in the Japanese Islands is well known (e.g., Tamura, 1960). “Torinosu-type limestone” is a generic name for Japanese Jurassic and Lower Cretaceous shallow-marine limestone that commonly contains ooids and reef components along with terrigenous siliciclastic grains and

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(The asterisk should be replaced by @.)
編集注）「中世」「新世」は、それぞれ「中期」「後期」と同義.

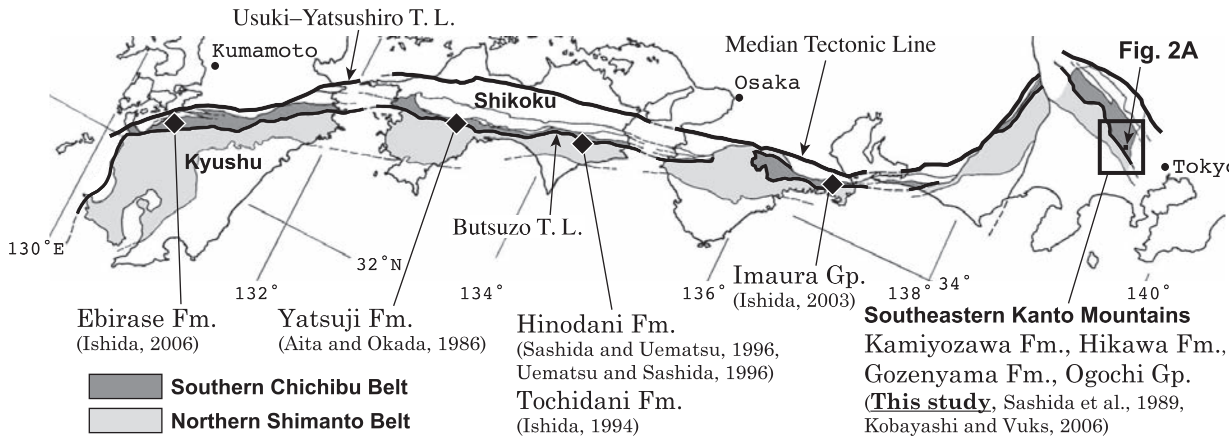

FIGURE 1. Distribution of the Southern Chichibu and Northern Shimanto belts in the Outer Zone of Southwest Japan (referenced from the Geological Survey of Japan, 1992). Median Tectonic Line, Usuki–Yatsushro Tectonic Line, and Butsuzo Tectonic Line are indicated by heavy lines. Locations of the microfossil age-ascertained Torinosu-type limestone bodies (diamonds), the southeastern Kanto Mountains (black frame), and study area (black square) are also shown.

organic matter.

Occurrences of the shallow-marine Torinosu-type limestone bodies are known from the Southern Chichibu and Northern Shimanto belts of the Outer Zone of Southwest Japan. However, deep-marine siliciclastic sediments of Jurassic to Cretaceous accretionary complexes are widely distributed in these belts. Ages of the Torinosu-type limestone and limestone-bearing strata in these belts have been determined over the last two decades using microfossils (Fig. 1). In addition, studies of sedimentary facies (Kano, 1988; Kano and Jiju, 1995), strontium isotopic ages (Shiraishi et al., 2005), carbon isotope stratigraphy of this type of limestone (Kakizaki and Kano, 2009), and rudist bivalve fauna (Sano et al., 2007; Sano and Skelton, 2010) have also been performed. Nevertheless, the reason so many Torinosu-type limestone bodies are found in and around the deep-marine siliciclastics of the accretionary complexes remains unexplained.

A previous study of an exotic body of the Middle Jurassic Torinosu-type limestone found in the Upper Jurassic Ebirase Formation in the Southern Chichibu Belt, western Kyushu, elucidated the formative and redepositional processes relevant to the sedimentary and tectonic evolution of accretionary complexes (Ishida, 2006). A Middle Jurassic radiolarian age was newly obtained from a Torinosu-type limestone body in the Upper Jurassic Hikawa Formation in the Southern Chichibu Belt in the southeastern Kanto Mountains (Fig. 1) and it turned out that the limestone body is an exotic clast contained in deep-marine siliciclastics. This paper describes faunal composition of the radiolarian assemblage and mode of occurrence of the limestone body, and provides insight into the tectono-sedimentary implication of the limestone body in the context of the Late Jurassic evolution of the accretionary complexes in the Southern Chichibu Belt.

HIKAWA FORMATION

The Hikawa Formation, established by Fujimoto (1939), is an Upper Jurassic siliciclastic formation in the Southern Chichibu Belt in the southeastern Kanto Mountains (e.g., Yasuda, 1989; Ishida, 2004). The formation conformably overlies the lower to middle Upper Jurassic Mitsugo Formation (Ishida, 2004). These Upper Jurassic formations are distributed among accretionary complexes and are in fault contact with the Middle to early Late Jurassic thrust pile of the Unazawa Formation in the northeast and with the Early Cretaceous limestone−mafic volcanic rock complexes (Kanoto and Gozenyama formations) in the southwest (Takaoka, 1954; Takashima and Koike, 1984; Sakai, 1987; Yasuda, 1989; Takahashi, 2000; Ishida, 2004) (Fig. 2A).

The approximately 700 m thick Mitsugo Formation is mainly composed of muddy turbidites with massive sandstone beds and exotic bodies of chert (Ishida, 2004). The Hikawa Formation, approximately 1,100 m in thickness, is subdivided into lower and upper members (Yasuda, 1989). The lower member consists of thick coarse-grained turbiditic sandstone in conjunction with muddy turbidites and gravelly mudstone beds. The upper member is mainly composed of muddy turbidites, gravelly mudstone, and turbiditic sandstone. Torinosu-type limestone bodies mainly occur in four stratigraphic horizons of the Hikawa Formation: one is in the lower member and the others are in the upper member (Ishida, 2004). In ascending order, the Upper Jurassic radiolarian zones of the Hikawa Formation (Ishida, 2004) are the *Hsuum maxwelli* Zone, *Loopus primitivus* Zone, and the *Pseudodictyomitra carpatica* Zone of Matsuoka (1995).

Hexacorals and other reefal biota have been reported from the Torinosu-type limestone bodies in the Hikawa Formation (e.g., Fujimoto, 1939). Additionally, fossil corals were recovered from

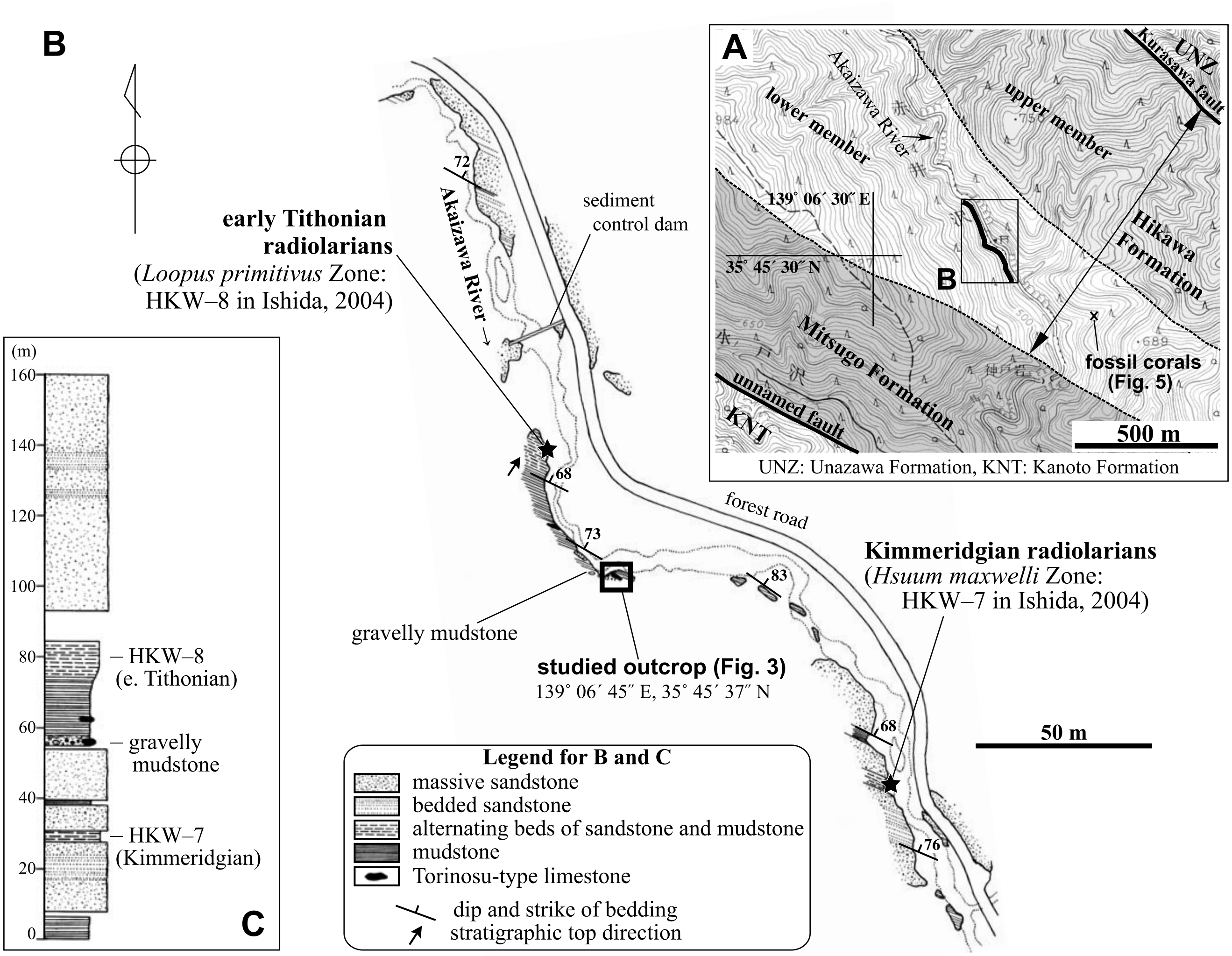

FIGURE 2. **A**, Map showing the location of studied route. The simplified geologic map is after Ishida (2004). The map is based on the 1:25,000 "Okutamako" topographic sheet (Geographical Survey Institute of Japan). **B**, Route map along the Akaizawa River. A black frame indicates the location of studied outcrop shown in Fig. 3. Stars show the locations of radiolarians by Ishida (2004). The World Geodetic System was used to designate the longitudes and latitudes. **C**, Stratigraphic column of the lower member of the Hikawa Formation exposed in the study route..

a limestone body in the lower member during this study (Fig. 2 A).

Radiolarian fossils have also been recovered from two limestone bodies (Sashida et al., 1989): one is certainly from the lower member, whereas the stratigraphic horizon of the other is unknown. The presence of radiolarians such as *Tricolocapsa plicarum* Yao, *T. conexa* Matsuoka, *Protunuma turbo* Matsuoka, and *Eucyrtidiellum unumaense* (Yao) indicates an age around the late Middle Jurassic. Two species referred to as the genus *Tricolocapsa* in this study were reassigned to the genus *Striatojaponocapsa* by Hull (1997).

Recently, foraminifers have been reported from four limestone bodies in the formation (Kobayashi and Vuks, 2006) and have been identified to species level in one body in the lower part of the upper member. The foraminiferal assemblage, containing *Nautiloculina oolithica* Mohler, *Haplophragmium lutzei* Hanzlikova, *Melathrokerion spiralis* Gorbachik, and *Everticyclammina* cf. *virguliana* (Koechlin), is considered to be Tithonian in age.

Thus, Middle Jurassic ages have been reported for the limestone bodies in the lower member, whereas, the Tithonian limestone body occurred in the upper member. This study focused on Middle Jurassic limestone in the lower member and reassessed the age because scanning electron microscope (SEM) images of radiolarians and the mode of occurrence of the limestone bodies were not included in the previous study. A Middle Jurassic radiolarian age was newly obtained for another limestone body in the lower member during this study, confirming the results of Sashida et al. (1989).

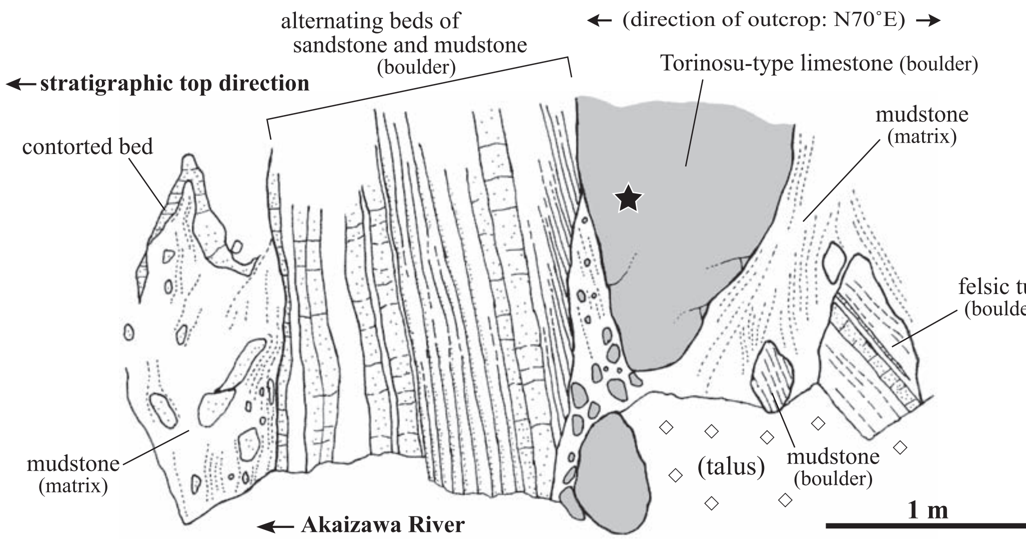

FIGURE 3. Mode of occurrence of the Torinosu-type limestone bodies in the Hikawa Formation on the right bank of the Akaizawa River. Boulders of Torinosu-type limestone, mudstone, acidic tuff, and alternating beds of sandstone and mudstone occur in a mudstone matrix. The radiolarian location is indicated by a star.

EXAMINED TORINOSU-TYPE LIMESTONE BODY

The examined Torinosu-type limestone body crops out on the right bank of the Akaizawa River in Hinohara Village, western Tokyo Metropolis (Fig. 2A). A 160 m thick succession of the middle part of the lower member of the Hikawa Formation is exposed in the studied route along the river, with a WNW−ESE strike and a 68°–83° northward dip (Fig. 2B). This succession is mainly dominated by coarse-grained sandstone, with a 35 m thick muddy intercalation in the middle part (Fig. 2C). A ~3.2 m thick gravelly mudstone bed containing clasts of the Torinosu-type limestone is found in the lowermost part of this intercalation.

The gravelly mudstone bed has a matrix-supported framework and is overlain by a contorted bed. The examined limestone body occurs in the gravelly mudstone bed with cobble- to boulder-sized clasts of felsic tuff, alternating beds of mudstone and sandstone, and mudstone (Fig. 3). The apparent major axis of the limestone boulder is ~1.5 m in length. This limestone is grayish-black and no internal structure was visible during field observation.

A radiolarian assemblage equivalent to that in the *H. maxwelli* Zone has been recovered from the horizon of 26 m below the gravelly mudstone bed (HKW-7 in Ishida, 2004), whereas the horizon 25 m above the bed (HKW-8 in Ishida, 2004) yielded radiolarians equivalent to those in the *L. primitivus* Zone (Fig. 2 B). The gravelly mudstone bed horizon is biostratigraphically in the transition between the *H. maxwelli* Zone and *L. primitivus* Zone, which is equivalent to the middle to upper Upper Jurassic (Kimmeridgian to lower Tithonian).

Petrographic examination under a polarizing microscope revealed that the examined body is an arenaceous limestone (Fig. 4A) composed of poorly-sorted fine to very fine sand-sized quartz, organic matter, indeterminate carbonate grains, and opaque minerals in a clayey matrix with calcite cement (Fig. 4 B). A small amount of altered mica and altered plagioclase grains are also present. Radiolarian tests are contained rarely (Fig. 4B). Other fossils such as those of cnidarians, bivalves, and foraminifers, were not recognized in this limestone.

Although the typical fossils of Torinosu-type limestone are not present in this radiolarian-bearing limestone, fossil corals were recovered from another limestone body in the same gravelly mudstone bed, exposed 450 m southeast of the radiolarian-bearing limestone (Fig. 5A). This limestone body, with an apparent major axis is ~5 m in length, is an arenaceous limestone having a very similar lithofacies to the radiolarian-bearing limestone. Bioclastic layers are sometimes observed in this limestone (Fig. 5B).

RADIOLARIANS

A rock sample, approximately 800 g in weight, was collected from the limestone (Fig. 3). The sample was crushed into pieces 1–2 cm in diameter and soaked in a dilute hydrochloric acid (10%) for several hours. After soaking, the pieces were washed through a 63 micron mesh sieve. To remove calcite and extraneous matters from radiolarians, sieved residue was rinsed by a concentrated hydrochloric acid for several minutes and boiled by a hydrogen peroxide solution. Radiolarian tests were picked from the dried residue under an optical stereomicroscope and photographed under a SEM.

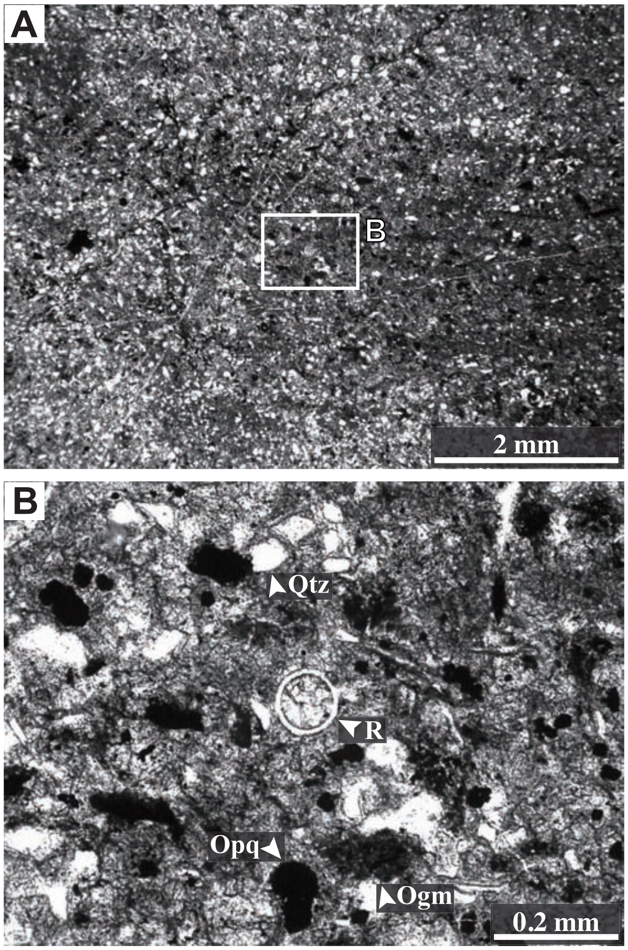

FIGURE 4. Thin-section photomicrographs of the studied Torinosu-type limestone (plane polarized light). **A**, Overview of the limestone. A white frame indicates the area of photo B. **B**, Close-up view of the central part of photo A. Grains of fine to very fine sand-sized quartz (Qtz), organic matter (Ogm), and opaque minerals (Opq) can be seen. A radiolarian test (R) is present.

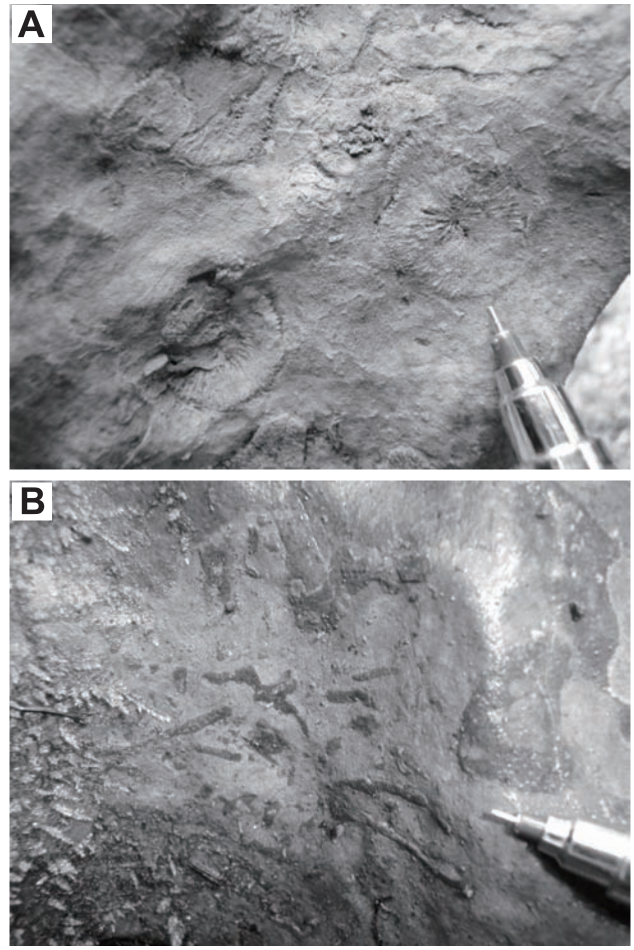

FIGURE 5. Fossil corals (**A**) and indeterminate bioclasts (**B**) found from a limestone body in the gravelly mudstone.

Radiolarian fossils were rare in this sample. Although all of the radiolarians were recrystallized, the surface ornamentation of some tests was moderately to well preserved. From 259 radiolarian specimens examined under the SEM, 18 genera and 13 species were identified (Fig. 6). The assemblage was mainly composed of nassellarians such as *Kilinora tecta* (Matsuoka), *Striatojaponocapsa conexa* (Matsuoka), *Sj. plicarum* (Yao) sensu Hatakeda et al. (2007), *Japonocapsa fusiformis* (Yao), *Stichocapsa japonica* Yao, *Stc. naradaniensis* Matsuoka, *Williriedellum* cf. *dierschei* Suzuki and Gawlick, *Praewilliriedellum spinosum* Kozur, *Zhamoidellum ovum* Dumitrica, *Protunuma* cf. *ochiensis* Matsuoka, *Eucyrtidiellum nodosum* Wakita, *Hsuum* cf. *maxwelli* Pessagno, *H.* cf. *brevicostatum* (Ozvoldova), *Tethysetta dhimenaensis* (Baumgartner), and *Dictyomitrella* (?) *kamoensis* Mizutani and Kido.

The assemblage contained several age-diagnostic species. The stratigraphic range of *Sj. conexa* extends from the base of the *Sj. conexa* Zone to the top of the *Kilinora spiralis* Zone (Matsuoka, 1995). The first appearance of *K. tecta* is located in the upper part of the *Sj. conexa* Zone (Matsuoka, 1983; Aita, 1987; Nishizono, 1996). Although the genus *Kilinora* is abundant in the lower part of the *K. spiralis* Zone (Matsuoka, 1983; Aita, 1987; Nishizono, 1996), the assemblage did not contain species of the genus *Kilinora* with the exception of *K. tecta*. The occurrence of *J. fusiformis* in the *Sj. plicarum* and *Sj. conexa* zones is generally common (e.g., Matsuoka, 1983; Yao, 1997), even though it has not been reported from the *K. spiralis* Zone. The specific co-occurrence in the assemblage is correlative with that in the upper part of the *Sj. conexa* Zone, which Matsuoka (1995) considered late Middle Jurassic (Bathonian to middle Callovian) in age.

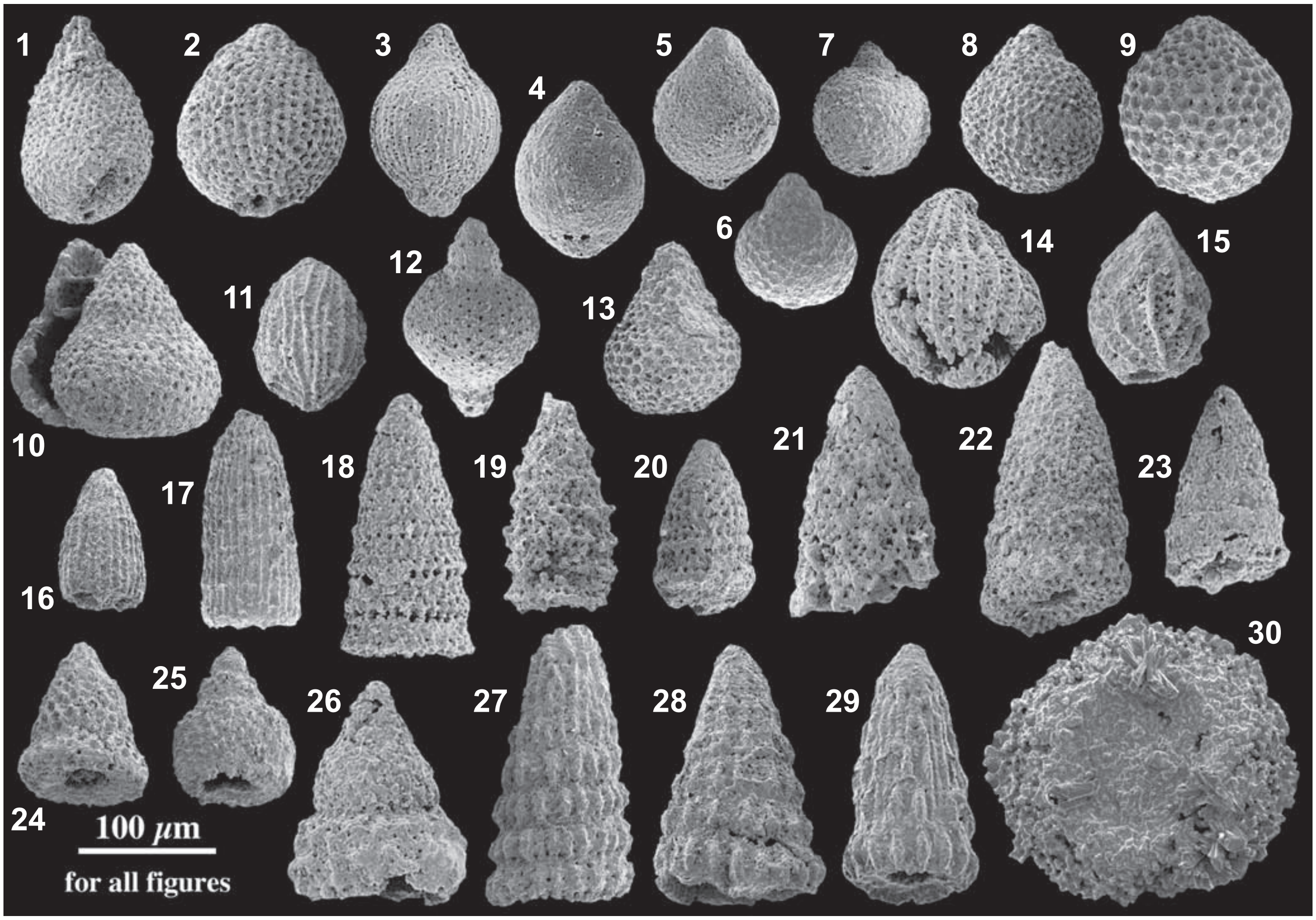

FIGURE 6. Scanning electron micrographs of radiolarians from the Torinosu-type limestone body in the Hikawa Formation. **1**, *Kilinora tecta* (Matsuoka); **2**, *Striatojaponocapsa conexa* (Matsuoka); **3**, *Striatojaponocapsa plicarum* (Yao) sensu Hatakeda et al. (2007); **4**, *Japonocapsa fusiformis* (Yao); **5**, *Japonocapsa* aff. *fusiformis* (Yao); **6**, *Williriedellum* cf. *dierschei* Suzuiki and Gawlick; **7**, *Praewilliriedellum spinosum* Kozur; **8**, *Zhamoidellum ovum* Dumitrica; **9**, *Zhamoidellum* (?) sp.; **10**, *Stichocapsa japonica* Yao; **11**, *Stichocapsa naradaniensis* Matsuoka; **12**, *Stichocapsa* sp. E sensu Baumgartner et al. (1995); **13**, *Stichocapsa* (?) sp.; **14**, *Protunuma* cf. *ochiensis* Matsuoka; **15**, *Protunuma* sp. E sensu Yao (1997); **16**, *Archaeodictyomitra* sp. 1; **17**, *Archaeodictyomitra* sp. 2; **18**, *Dictyomitrella* (?) *kamoensis* Mizutani and Kido; **19**, *Tethysetta dhimenaensis* (Baumgartner); **20**, *Parvicingula* sp.; **21**, *Stichomitra annibille* Kocher sensu Suzuki and Gawlick (2003); **22**, *Spongocapsula* sp.; **23**, *Spongocapsula* cf. *krahsteinensis* Suzuki and Gawlick; **24**, *Quarticella hunzikeri* O'Dogherty, Gorican and Dumitrica; **25**, *Eucyrtidiellum nodosum* Wakita; **26**, *Eucyrtidiellum* sp.; **27**, *Hsuum* cf. *brevicostatum* (Ozvoldova); **28**, *Hsuum* cf. *maxwelli* Pessagno; **29**, *Hsuum* sp.; **30**, *Orbiculiforma* sp.

DISCUSSION

Torinosu-type limestone as exotic bodies

The gravelly mudstone characterized by a matrix-supported framework with the contorted bed can be compared with a debrite. The Torinosu-type limestone and various kinds of clasts in the gravelly mudstone were obviously transported from their initial site of deposition.

Cnidarian fossils have been recovered from limestone bodies in the Hikawa Formation (e.g., Fujimoto, 1939). In addition, fossil corals and other bioclasts were discovered from a limestone body in the gravelly mudstone (Fig. 5). The limestone bodies in the Hikawa Formation, notably the limestone clasts in the gravelly mudstone, seem to have initially been deposited in a shallow-marine environment. In contrast, the facies association of the Hikawa Formation, dominated by turbiditic siliciclastics with gravelly mudstone beds, represents a deep-marine depositional environment (e.g., Walker, 1992).

The stratigraphic horizon of the gravelly mudstone bed is approximately correlative with the boundary between the Kimmeridgian and Tithonian (Fig. 2C), whereas the examined radiolarian-bearing Torinosu-type limestone body is of late Middle Jurassic age. An age difference between the limestone body and the surrounding siliciclastic sediments is present. Considering the age difference, the mode of occurrence of the

TABLE 1. Microfossil age-ascertained Torinosu-type limestone bodies in and around the accretionary complexes in the Southern Chichibu and Northern Shimanto belts. Location of each body is shown in Fig. 1. The ages of siliciclastics of the Hikawa Formation were revised according to Ishida (2004).

	Belt	Formation, Group	Fossil	Age of surrounding siliciclastics	Age of limestone	Age difference	Reference
upper Middle Jura. limestone	SC	Hikawa Fm.	R	Kimmeridgian–Tithonian	Bathonian–mid. Callovian	present	This study
	SC	Hikawa Fm.	R	middle–upper Upper Jurassic	up. Mid.–low. Up. Jurassic	present	Sashida et al. (1989)
	SC	Hikawa Fm.	R	middle–upper Upper Jurassic	up. Mid.–low. Up. Jurassic?	present	Sashida et al. (1989)
	SC	Gozenyama Fm.	R	mid. Lower Cretaceous	up. Mid.–low. Up. Jurassic	present	Sashida et al. (1989)
	SC	Gozenyama Fm.	R	mid. Lower Cretaceous	up. Mid.–low. Up. Jurassic	present	Sashida et al. (1989)
	SC	Gozenyama Fm.	R	mid. Lower Cretaceous	up. Mid.–low. Up. Jurassic	present	Sashida et al. (1989)
	SC	Ebirase Fm.	R	lower Tithonian	mid.–up. Middle Jurassic	present	Ishida (2006)
	NS	Tochidani Fm.	R	upper Lower Cretaceous	Callovian–Oxfordian	present	Ishida (1994)
Upper Jurassic–Lower Cretaceous limestone	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Tithonian	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Tithonian	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Upper Jurassic	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Tithonian	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Tithonian	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Up. Jurassic–Low. Cretaceous	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Upper Jurassic	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Tithonian	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Up. Jurassic–Low. Cretaceous	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Tithonian	present	Kobayashi and Vuks (2006)
	SC	Kamiyozawa Fm.	F	Middle Jurassic?	Up. Jurassic–Low. Cretaceous	present	Kobayashi and Vuks (2006)
	SC	Hikawa Fm.	F	Tithonian	Tithonian	absent?	Kobayashi and Vuks (2006)
	SC	Gozenyama Fm.	F	mid. Lower Cretaceous	Up. Jurassic–Low. Cretaceous	absent?	Kobayashi and Vuks (2006)
	SC	Imaura Group	R	Valanginian–Hauterivian	Tithonian	present	Ishida (2003)
	SC	Yatsuji Fm.	CN	Tithonian–Lower Cretaceous	up. Tithonian–low. Berriasian	absent	Aita and Okada (1986)
	SC	Yatsuji Fm.	CN	Tithonian–Lower Cretaceous	up. Tithonian–low. Berriasian	absent	Aita and Okada (1986)
	NS	Ogochi Gp.	R	Cenomanian–Campanian	lower Tithonian?	present	Sashida et al. (1989)
	NS	Ogochi Gp.	R	Cenomanian–Campanian	lower Tithonian?	present	Sashida et al. (1989)
	NS	Ogochi Gp.	F	up. Albian–mid.Maastrichtian	Up. Jurassic–Low. Cretaceous	present	Kobayashi and Vuks (2006)
	NS	Ogochi Gp.	F	up. Albian–mid.Maastrichtian	Upper Jurassic	present	Kobayashi and Vuks (2006)
	NS	Ogochi Gp.	F	up. Albian–mid.Maastrichtian	Upper Jurassic	present	Kobayashi and Vuks (2006)
	NS	Ogochi Gp.	F	up. Albian–mid.Maastrichtian	Up. Jurassic–Low. Cretaceous	present	Kobayashi and Vuks (2006)
	NS	Ogochi Gp.	F	up. Albian–mid.Maastrichtian	Tithonian	present	Kobayashi and Vuks (2006)
	NS	Ogochi Gp.	F	up. Albian–mid.Maastrichtian	Upper Jurassic	present	Kobayashi and Vuks (2006)
	NS	Hinodani Fm.	R	up. Low.–low. Up. Cretaceous	Tithonian	present	Sashida and Uematsu (1996)
	NS	Hinodani Fm.	R	up. Low.–low. Up. Cretaceous	Tithonian	present	Sashida and Uematsu (1996)

[Abbreviations] SC: Southern Chichibu NS: Northern Shimanto R: radiolaria CN: calcareous nannofossil F: foraminifer

limestone body, and the differing sedimentary environment, it is evident that the examined limestone constitutes an exotic block. Therefore, the Middle Jurassic limestone bodies examined by Sashida et al. (1989) seems to be also exotic. On the other hand, as the lower part of the upper member has been correlated with the lower Tithonian (Ishida, 2004), the Tithonian body (Kobayashi and Vuks, 2006) was probably transported to the deeper basin immediately after the deposition.

A similar occurrence of an exotic Torinosu-type limestone body was reported from the Upper Jurassic Ebirase Formation (Oxfordian to Tithonian) in the Southern Chichibu Belt, western Kyushu (Ishida, 2006), approximately 900 km west of the Kanto Mountains. In this case, a radiolarian-dated Middle Jurassic Torinosu-type limestone boulder is contained in the lower Tithonian (*Loopus primitivus* Zone) turbiditic siliciclastics. In addition, Matsuoka (1992) suggested a possible exotic origin of the limestone bodies in the Upper Jurassic Naradani Formation (Oxfordian to Tithonian) in the Southern Chichibu Belt, Sakawa, Shikoku, approximately 640 km west of the Kanto Mountains. Because the Hikawa, Ebirase, and Naradani formations are considered to be parts of the Upper Jurassic trench-slope basin deposits that were contemporaneously formed on the accretionary complexes in the Southern Chichibu Belt (Ishida, 2009), the exotic limestone bodies were probably transported from shallow-marine sources into the trench-slope basins.

Implications for Middle to Late Jurassic tectono-sedimentary evolution

The Yatsuji Formation of the Torinosu Group in Sakawa, Shikoku, contains characteristic Torinosu-type limestone. The age of the Torinosu Group ranges from Late Jurassic (Tithonian) to the Early Cretaceous (Matsuoka and Yao, 1985; Aita and Okada, 1986). The limestone bodies and adjacent sediments in this formation are considered contemporaneous (Aita and Okada, 1986; Siraishi et al., 2005). Furthermore, transitional lithofacies between the limestone and surrounding siliciclastics have been recognized (Kano, 1988; Kano and Jiju, 1995).

In contrast, the examined limestone in the Hikawa Formation is an exotic body that was transported to the deep-marine environment. Furthermore, the radiolarian-dated limestone body in the lower member of the Hikawa Formation is older than the limestone bodies in the Yatsuji Formation. The ages of Torinosu-type limestone bodies and the surrounding siliciclastics in the Southern Chichibu and Northern Shimanto belts have been determined using microfossils over the last two decades (Aita and Okada, 1986; Sashida et al., 1989; Ishida, 1994; Sashida and Uematsu, 1996; Uematsu and Sashida, 1996; Ishida, 2003, 2006; Kobayashi and Vuks, 2006) and are summarized in Table 1: eight of the limestone bodies formed around the late Middle Jurassic. Considering that these Middle Jurassic bodies are scattered across the Kanto Mountains, eastern Shikoku, and western Kyushu, Middle Jurassic shallow-marine strata containing carbonate bodies must have been deposited in widespread areas of the Southern Chichibu Belt.

The original depositional setting of the shallw-marine strata has been inferred from the stratigraphy and sedimentary features of the Torinosu Group (Ishida, 2006, 2009). Matsuoka (1992) has presented a schematic model of the deposition of the Torinosu Group on the accretionary complexes in the Southern Chichibu Belt in a shallow-marine environment. During the Middle Jurassic, the accretionary complexes grew upward rapidly (Matsuoka, 1992). Topographic peaks of the accretionary complexes, i.e., trench-slope breaks, reached close to or above sea level, and strata containing carbonate bodies appear to have formed under these shallow-marine conditions (Ishida, 2006, 2009).

During the Late Jurassic, the Middle Jurassic sedimentary bodies on the accretionary complexes were probably incised by submarine canyons and eroded subaerially. Fragmented shallow-marine rock bodies were transported into deeper depositional environments, such as trench-slope basins, by gravity flows and submarine slides. The widespread distribution of the Middle Jurassic Torinosu-type limestone bodies and the exotic bodies in the Hikawa and Ebirase formations suggest that the erosion and reworking of the shallow-marine bodies occurred over a large area of the Southern Chichibu Belt.

No Middle Jurassic formation bearing *in situ* Torinosu-type limestone bodies has been found (Table 1). It would appear that the Middle Jurassic shallow-marine strata have been completely eroded and their only remnants are exotic clasts in younger strata, such as the limestone boulder in the Hikawa Formation.

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

＜ 地名・地層名 ＞

Akaizawa …………………… 赤井沢
Ebirase Formation …………… 箙瀬層
Gozenyama Formation …… 御前山層
Hikawa Formation …………… 氷川層
Hinodani Formation ……… 日野谷層
Hinohara Village …………… 檜原村
Imaura Group …………… 今浦層群
Kanoto Formation …………… 神戸層
Kosode Formation …………… 小袖層
Kurasawa Fault …………… 倉沢断層
Mitsugo Formation ……… 三都合層
Okutamako ……………… 奥多摩湖
Oonari Formation …………… 大成層
Sakawa ………………………… 佐川
Tochidani Formation ………… 栩谷層
Torinosu Group …………… 鳥巣層群
Unazawa Formation ………… 海沢層
Yatsuji Formation …………… 谷地層