Middle Jurassic radiolarians from chert clasts within conglomerates of the Itsuki Formation of the Itoshiro Subgroup (Tetori Group) in the Taniyamadani Valley, Fukui Prefecture, central Japan

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Abstract

This paper reports Middle Jurassic radiolarians observed in etched surfaces of chert clasts within conglomerates of the Itsuki Formation of the Itoshiro Subgroup (Tetori Group) in the Taniyamadani Valley, Fukui Prefecture, central Japan. This is the first report of Middle Jurassic chert clasts within the Tetori Group. Middle Jurassic cherts were included in late Middle Jurassic and younger accretionary complexes in East Asia on the basis of previous studies. This study indicates that late Middle or younger accretionary complexes had been exposed and denuded in the provenance of the Tetori Group by the depositional time of the Itsuki Formation.

Key words: conglomerate, etched surface, Triassic, Jurassic, radiolaria, conodont, Tetori Group, accretionary complex.

Introduction

The Tetori Group, distributed over the Hokuriku District in Japan, has yielded radiolarian-bearing clasts within conglomerates (e.g., Ito et al., 2012). These clasts were presumably derived from mid-Mesozoic accretionary complexes (ACs) that are widely exposed in East Asia. The initiation of denudation of the mid-Mesozoic ACs in the provenance of the Tetori Group has been discussed on the basis of the age of microfossil-

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bearing clasts. Takeuchi et al. (1991) discovered Triassic and Jurassic radiolarians from clasts within conglomerates of the Akaiwa Subgroup in Toyama Prefecture. They concluded that the mid-Mesozoic ACs were already uplifted and denuded in the late Neocomian (Early Cretaceous). Matsukawa and Takahashi (1999) reported Permian and Triassic radiolarians from chert clasts in the Otaniyama Formation of the Itoshiro Subgroup in Gifu Prefecture. On the basis of the stratigraphic relationship to the ammonoid-bearing Mitarai Formation, the Otaniyama Formation had corresponded to the Upper Jurassic–lowest Cretaceous. They highlighted that the mid-Mesozoic ACs had been exposed earlier than the age presumed by Takeuchi et al. (1991). Sato et al. (2008) discovered Berriasian ammonoids from the Mitarai Formation, indicating that the Otaniyama Formation corresponds to the Lower Cretaceous.

The mid-Mesozoic ACs are characterized by long-term accretions, suggesting that their uplifts and denudations did not occur all at once but in stages. However, few studies have considered the denudational change of the mid-Mesozoic ACs in the provenance of the Tetori Group using microfossils from clasts. We observed microfossils on etched surfaces of siliceous rock clasts in conglomerates of the Itsuki Formation of the Itoshiro Subgroup of the Tetori Group in the Taniyamadani Valley, Fukui Prefecture, central Japan. Some chert clasts yielded Middle Jurassic radiolarians, which were presumably derived from late Middle Jurassic or younger ACs. There are a few reports of Middle Jurassic radiolarians from the clasts within the Tetori Group (Saida, 1987; Ito et al., 2014). However, Saida (1987) extracted Middle Jurassic radiolaria from residues of conglomerate; therefore, the derivation is undetermined. Ito et al. (2014) obtained Middle Jurassic radiolarians from a siliceous mudstone clast within conglomerates of the Mizukamidani Formation in the Itoigawa area, Niigata Prefecture. This study presents the occurrences of Middle Jurassic chert clasts within the Tetori Group for the first time, indicating the denudation of the latest Middle Jurassic or younger ACs in the provenance of the Tetori Group.

Geologic setting

The Kuzuryu area is located in southeastern Fukui Prefecture (Fig. 1). The Tetori Group of this area is composed of three subgroups, Kuzuryu, Itoshiro, and Akaiwa, in the ascending order (Maeda, 1961) (Fig. 2). The Kaizara and Yambarazaka formations yielded Bathonian–Callovian and Oxfordian ammonoids, respectively (Maeda, 1952; Sato and Westermann, 1991; Handa et al., 2014). Tithonian ammonoids occurred in the Kamihambara Formation (Sato and Yamada, 2005). Based on zircon U–Pb dating, the youngest zircon grain from the sandstone of the lower Itsuki Formation has a concordant age of 127.2 ± 2.5 Ma (Kawagoe et al., 2012), which corresponds to the Barremian (126.3–130.8 Ma: Gradstein et al., 2012).

In the route along the Taniyamadani Valley shown in Fig. 1, the Obuchi, Itsuki, and

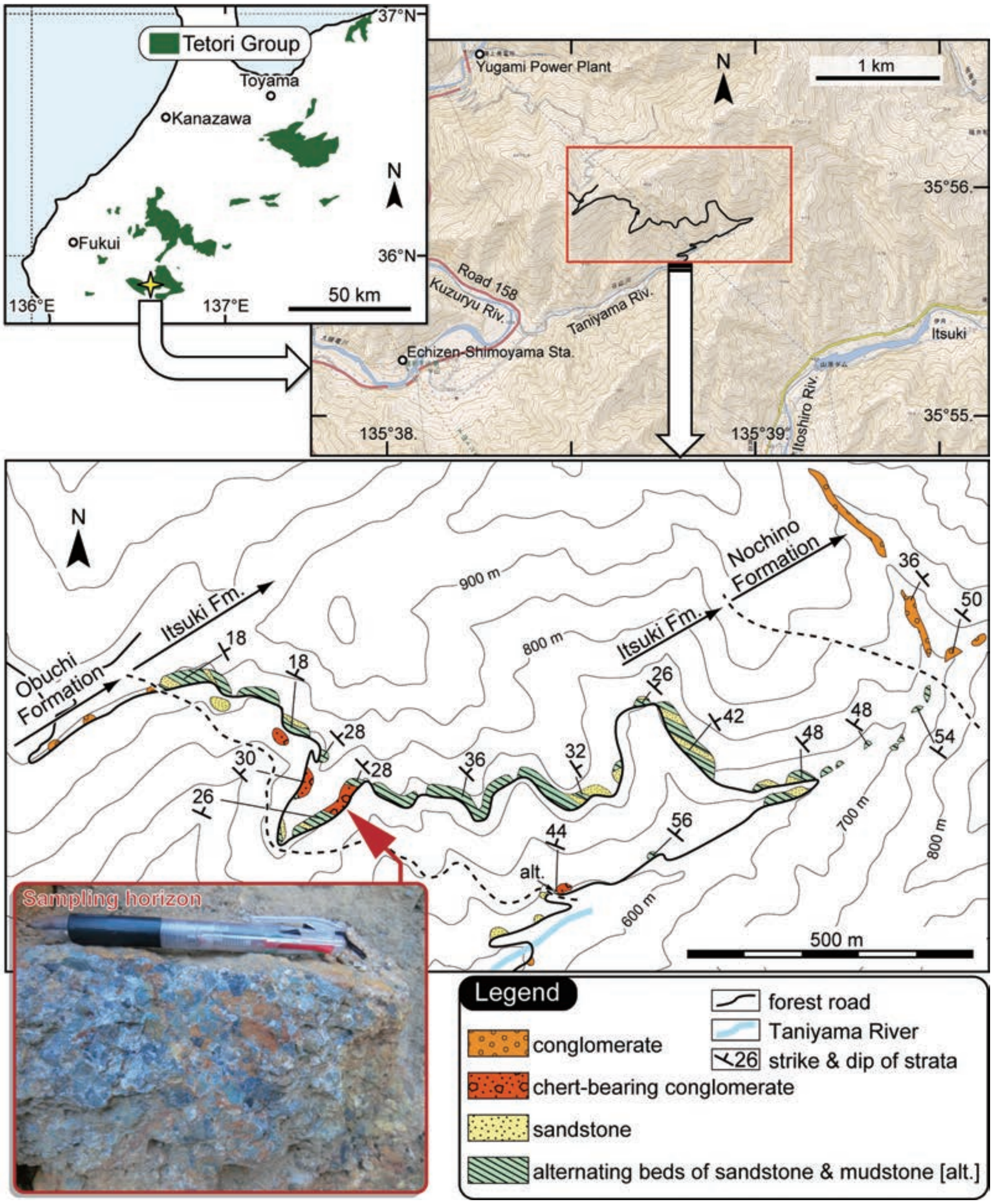

Fig. 1. Index map of the sampling site and a route map through the Taniyamadani Valley, Fukui Prefecture, central Japan. Distributions of the Tetori Group are after Maeda (1961). The map of the Kuzuryu area is modified from topographic map published by Geospatial Information Authority of Japan.

Nochino formations are exposed. These strata strike approximately N40° W and dip approximately 30° NE. A few unmappable small faults and dykes are also present.

The Obuchi Formation in the route is composed mainly of massive conglomerates. The conglomerate is poorly sorted and matrix supported. Clasts are subrounded to rounded and are typically 2–4 cm in diameter. The largest clasts are approximately 10 cm in diameter. The clasts are characterized by noticeable orthoquartzite. Clasts of sandstone and granitic rocks are common, whereas no chert clast is observable. The matrix is bright-gray very-coarse-grained sandstones.

The Itsuki Formation in the route is composed mainly of alternating beds of sandstones and mudstones. Plant and bivalve fossils occur commonly in the alternating beds. Chert-bearing conglomerate layers are present in the lower part of the Itsuki Formation. The conglomerate is well sorted and clast supported. Clasts are subangular to subrounded and are typically 1–2 cm in diameter. The matrix is bright-gray very-coarse-grained sandstone. The clasts are dominantly chert (greenish gray, gray, and black) and minor black siliceous mudstone. There are some quartz pebbles and granules. A few volcanic rock clasts, which seem to be weathered basalt, are present. Meanwhile, some horizons, which are characterized by being matrix supported, include orthoquartzite clasts. Lateral continuity of the conglomerate layers is not distinct. The Obuchi and Nochino formations in the route consist mainly of conglomerates characterized by noticeable orthoquartzite. However, the conglomerates of the Itsuki Formation in the route clearly differ from the conglomerates of these formations in the presence of chert clasts.

The Nochino Formation in the route is composed of conglomerates, which are poorly sorted and clast supported. Most clasts are rounded and are typically 3–5 cm in diameter. The largest clasts exceed 12 cm in diameter. The clasts are characterized by noticeable orthoquartzite. Clasts of granite and andesite are rare. The matrix consists of very coarse sandstone.

Materials and method

We collected conglomerate samples from a horizon of the lower part of a thick conglomerate (ca. 7 m in thickness) at a sampling site in the lower Itsuki Formation (Fig. 1).

The collected samples underwent the following processes for observation of etched surfaces (Fig. 2). The samples were sliced to a chip, a few centimeters on a side, with a rock cutter. About 100 chips were observed using a loupe to identify siliceous and muddy rock clasts. Clasts were found on 37 chips, and these chips were soaked in a solution of approximately 5% hydrofluoric acid (HF) for one day at room temperature. The HF solution was removed, and the etched chips were resoaked in fresh water. The water was then removed, and the etched chips were dried naturally. The etched chips were then observed

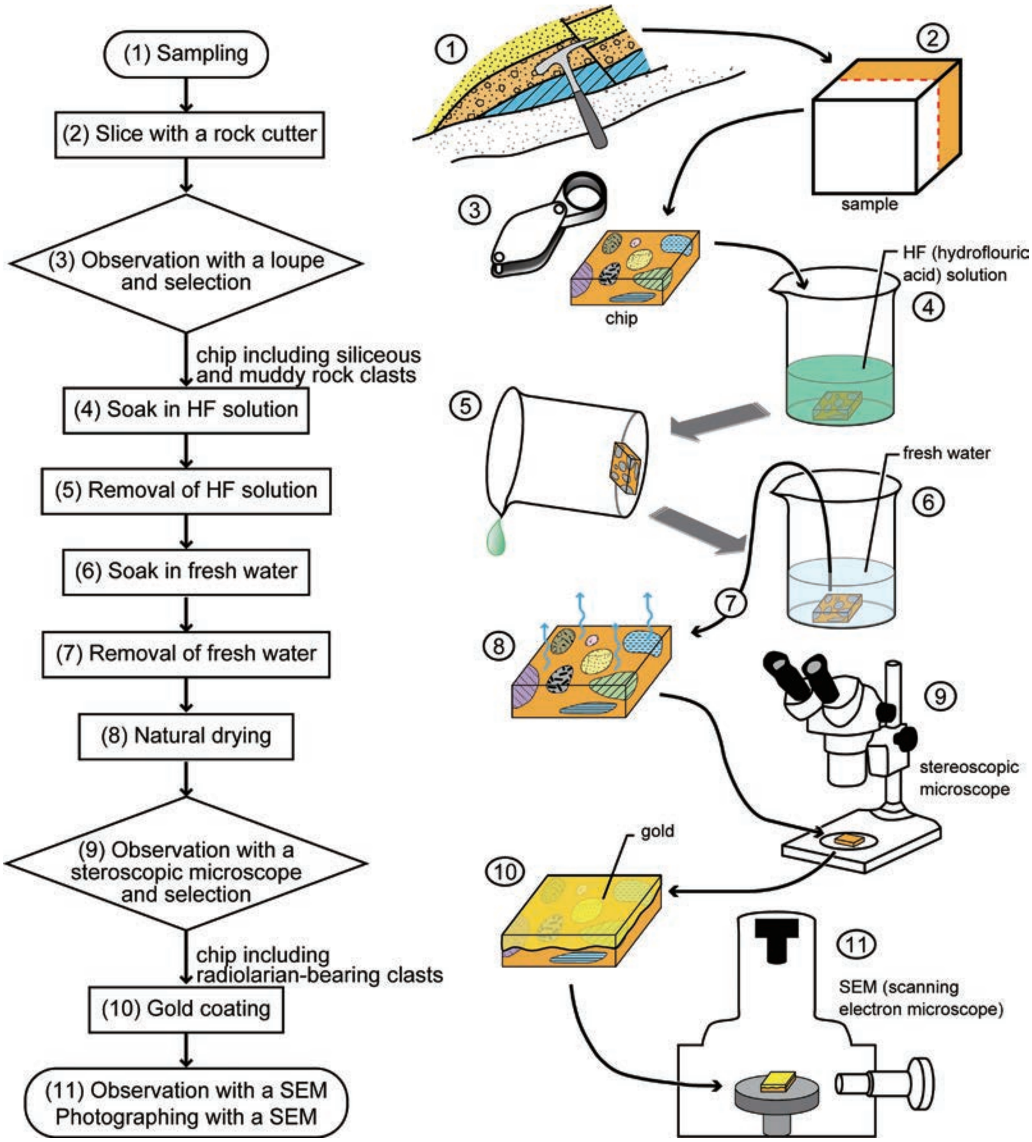

Fig. 2. Flowchart illustrating sample treatment for observation of etched surfaces.

under a stereoscopic microscope. Under the microscope, microfossils were found on the etched surfaces of 15 chips. The surfaces of the etched chips with gold coating were observed and photographed using a scanning electron microscope (SEM).

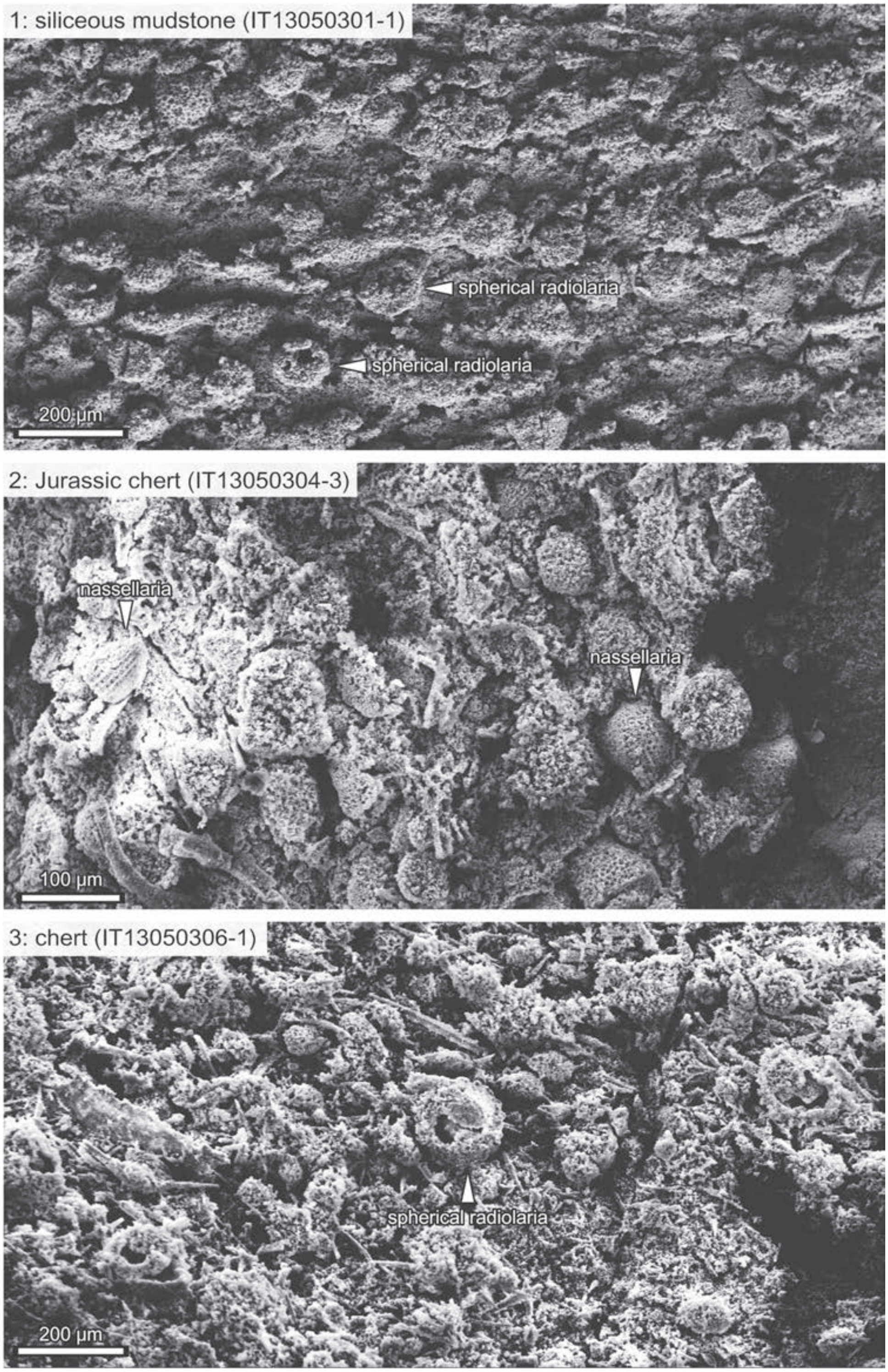

Fig. 3. Photomicrographs of etched surfaces of a siliceous mudstone and chert clasts.

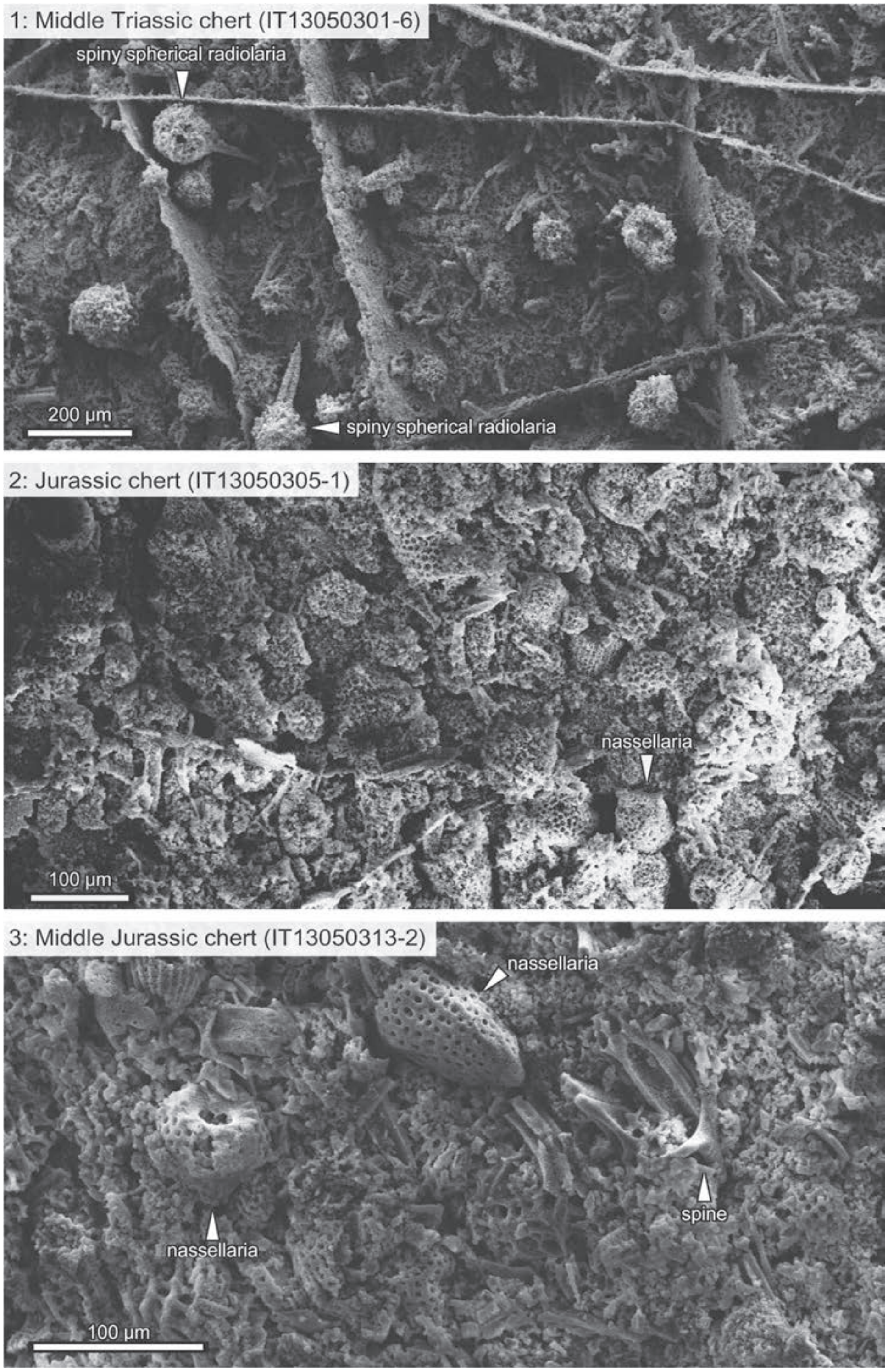

Fig. 4. Photomicrographs of etched surfaces of chert clasts.

Fossil occurrence

The etched surfaces of siliceous mudstone clasts are characterized by dominant mudstone matrices with bioclasts (Fig. 3.1). The bioclasts are scattered on the mudstone matrices and are not sorted. Although some spherical radiolarians and a few spines are present, their preservation is generally poor. In addition, no fossil that proved to be valuable for age assignment was identified in the siliceous mudstone clasts.

The etched surfaces of chert clasts are characterized by dominant bioclasts and by being bioclast supported (Figs. 3.2, 3.3, 4.1–4.3). Bioclasts are composed mainly of spines, spherical radiolarian shells, and nassellarians and these are not sorted. Their components differ by clasts. Figures 3.2 and 4.2 show the dominance of nassellarians; Fig. 3.3 shows dominant spines with minor spherical radiolarian shells; Fig. 4.1 shows the dominance of spines and spiny spherical radiolarian shells, with a few nassellarians; and Fig. 4.3 shows the dominance of nassellarians and spines. Six chert clasts yielded better preserved microfossils (Table 1). SEM images of representative microfossils are shown in Fig. 5.

A chert pebble (IT13050301-6) yielded *Triassocampe* sp. and *Pseudostylosphaera*? sp. These genera occur commonly in the Middle Triassic (e.g., Sugiyama, 1997; O' Dogherty et al., 2009b). Therefore, this chert pebble is probably Middle Triassic.

Neogondolella sp. was obtained from a chert granule (IT13050301-2). In Addition, spines of *Pseudostylosphaera*? sp. occurred in the chert granule. These occurrences indicate the possibility that this chert granule is Triassic.

Hexasaturnalis? sp., *Pantanellium* sp., *Parvicingula*? sp., *Parahsuum* sp., and *Hsuum*? sp. occurred in a chert granule (IT13050304-3). *Pantanellium* sp. and *Parvicingula*? sp. were obtained from a chert granule (IT13050305-1). These genera are common in the Jurassic (e.g., O' Dogherty et al., 2009a), suggesting that these chert granules are Jurassic.

The following radiolarians were extracted from a chert granule (IT13050311-2): *Unuma* sp. cf. *U. typicus* Ichikawa and Yao, *Eucyrtidiellum*? sp., and *Pantanellium* sp. *Unuma typicus* is characterized by 14 to 20 longitudinal plicae and two to four longitudinal rows of small circular pores between adjacent longitudinal plicae. Yao et al. (1982) and Yao (1997) reported that *Unuma typicus* occurs in the *Unuma echinatus* Assemblage-zone or the chronologically equivalent *Striatojaponocapsa plicarum* Zone (JR4: Bajocian–lower Bathonian) of Matsuoka (1995). Consequently, this assemblage can correspond to that of the *S. plicarum* Zone.

A chert pebble (IT13050313-2) yielded *Stichocapsa japonica* Yao, *Parahsuum*? sp., *Archaeodictyomitra* sp., and *Eucyrtidiellum disparile* (Nagai and Mizutani). Nagai and Mizutani (1990) demonstrated that *E. disparile* occurs mainly in the *Laxtorum*(?) *jurassicum* Zone (JR3: Aalenian) of Matsuoka (1995). *Stichocapsa japonica*, characterized by a flattened-spherical fourth segment with basal flat, occurs commonly in the *Laxtorum*(?) *jurassicum*

Table 1. Microfossil occurrences from clasts within conglomerates of the Itsuki Formation in the study section.

Sample number	IT13050301-2	IT13050301-6	IT13050304-3	IT13050305-1	IT13050311-2	IT13050313-2
Lithology of clast	chert granule	chert pebble	chert granule	chert granule	chert granule	chert pebble
age	Triassic	Middle Triassic	Jurassic	Jurassic	Bajocian–lower Bathonian (JR4)	Aalenian (JR3)
Nassellaria					+	
Closed-end Nassellaria				+	+	+
Archaeodictyomitra sp.						+
Eucyrtidiellum sp.					?	
E. disparile (Nagai & Mizutani)						+
Hexasaturnalis sp.			?			
Hsuum sp.			?			
Pantanellium sp.			+	+	+	
Parahsuum sp.			+			?
Parvincingula sp.			?	?		
Pseudostylosphaera sp.		?				
Spine of *Pseudostylosphaera* sp.	?					
Stichocapsa japonica Yao						+
Triassocampe sp.		+				
Unuma typicus Ichikawa & Yao					cf.	
Neogondolella sp.	+					

and *S. plicarum* zones (JR3 and JR4: Aalenian–lower Bathonian) of Matsuoka (1995). On the basis of these radiolarian occurrences, it is found that this chert pebble probably corresponds to the *Laxtorum*(?) *jurassicum* Zone.

Middle Jurassic chert clasts within the Tetori Group

This study recognizes the Middle Jurassic (Aalenian and Bajocian–lower Bathonian) chert clasts from the Itsuki Formation. The youngest zircon grain from the sandstone of the lower Itsuki Formation has a concordant age of 127.2 ± 2.5 Ma on the basis of a zircon U–Pb dating (Kawagoe et al., 2012). Occurrences of Permian, Triassic, and Early Jurassic radiolarians, derived from clasts within conglomerates of the Tetori Group, have been reported by some researchers (Saida, 1987; Takeuchi et al., 1991; Matsukawa and Takahashi, 1999; Tomita et al., 2007; Ito et al., 2012). However, a few Middle Jurassic radiolarians occurred in clasts within conglomerates of the Tetori Group. Saida (1987) reported *Japonocapsa* sp. cf. *J. fusiformis* (Yao) (described as *Tricolocapsa* (?) cf. *fusiformis* Yao) from the Kamihambara Formation in the Tamodani Valley. *Japonocapsa fusiformis* occurred in the Aalenian–lower Bajocian (Matsuoka, 1995). However, the radiolaria was obtained from residues of conglomerate. Consequently, it is unclear whether the radiolaria was derived

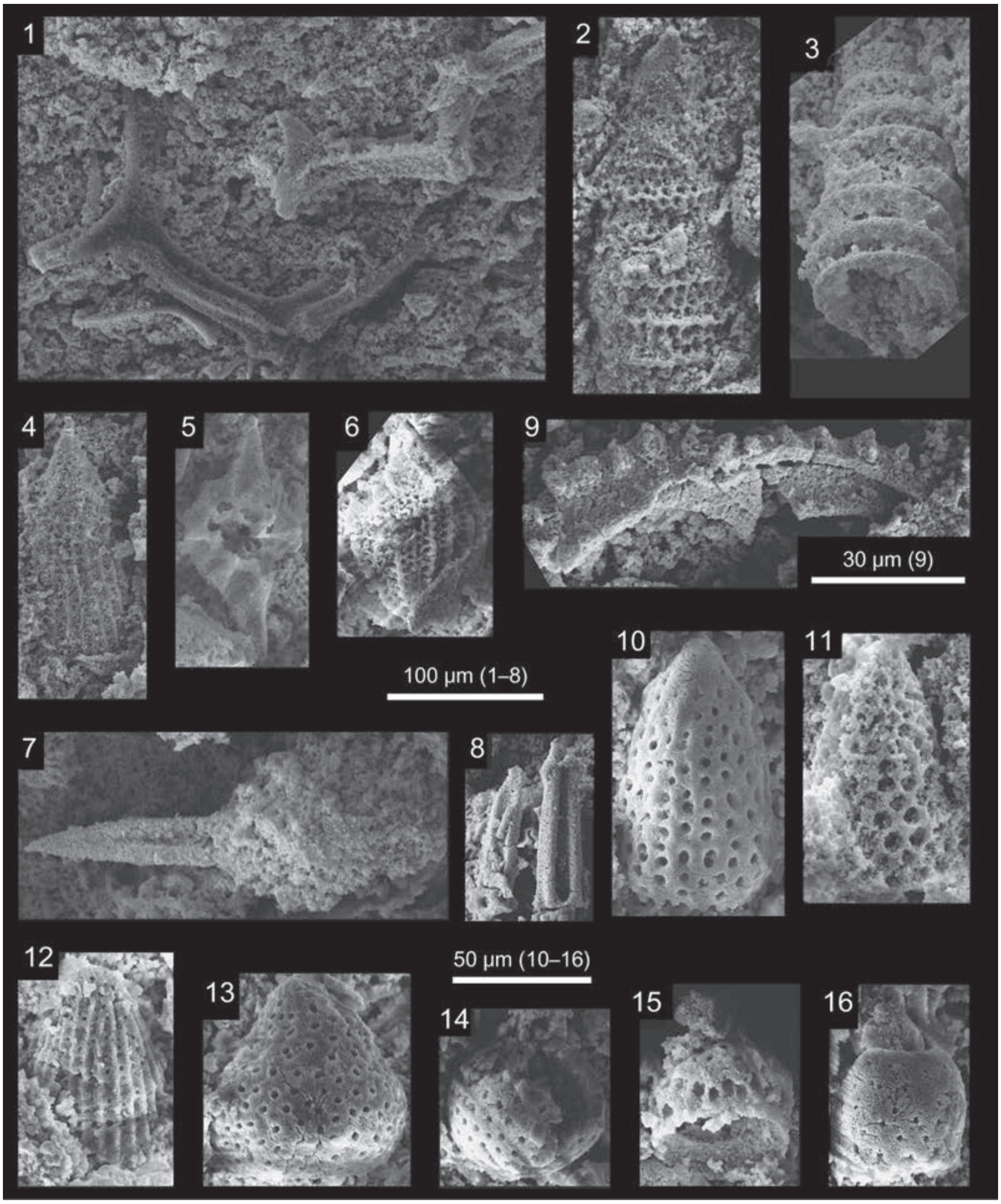

Fig. 5. Photomicrographs of microfossils from chert clasts within conglomerates of the Itsuki Formation in the study section. 1: *Hexasaturnalis*? sp.; 2: *Parvicingula*? sp.; 3: *Triassocampe* sp.; 4: *Parahsuum* sp.; 5: *Pantanellium* sp.; 6: *Unuma* sp. cf. *U. typicus* Ichikawa and Yao; 7: *Pseudostylosphaera*? sp.; 8: spines of *Pseudostylosphaera*? sp.; 9: *Neogondolella* sp.; 10: *Parahsuum*? sp.; 11: *Parvicingula*? sp.; 12: *Archaeodictyomitra* sp.; 13: *Stichocapsa japonica* Yao; 14: Closed-end Nassellaria; 15: *Eucyrtidiellum*? sp.; 16: *Eucyrtidiellum disparile* (Nagai and Mizutani). Sample numbers: 1, 2, 4: IT13050304-3; 3, 7: IT13050301-6; 8, 9: IT13050301-2; 5, 6, 15: IT13050311-2; 10, 12–14, 16: IT13050313-2; 11: IT13050305-1.

from siliceous mudstone or chert clast, or matrix. Ito et al. (2014) reported Middle Jurassic (JR4) radiolarians from conglomerates of the Mizukamidani Formation in the Itoigawa area; however, the radiolarians were derived from a siliceous mudstone clast. This study shows the Middle Jurassic radiolarians from the chert clasts, indicating the first reports of Middle Jurassic chert clasts within the Tetori Group. As shown in Figs. 3 and 4, observations of etched surfaces permit determination of the lithology of the microfossil-bearing clasts. However, this method is not necessarily suitable for detailed identification because a fossil on an etched surface is partially buried. Observations of both etched surfaces and residues are important for the study of microfossil-bearing clasts.

The mid-Mesozoic ACs, widely exposed in East Asia (Kojima and Kametaka, 2000; Wakita and Metcalfe, 2005), are composed mainly of ocean plate deposits and further-overlying terrigenous clastics. These deposits are chert-clastic sequences composed of chert, siliceous mudstone, mudstone, and sandstone (in ascending order). Microfossil dating has clarified the relationships between lithostratigraphy and biostratigraphy of chert-clastic sequences in the mid-Mesozoic ACs (e.g., Nakae, 2000). Middle Jurassic cherts are included in the latest Middle Jurassic and younger ACs, such as the Togano Group (Matsuoka, 1983) and the Tsurugaoka Complex (Nakae, 1990). On the basis of previous studies of the mid-Mesozoic ACs (e.g., Nakae, 2000), it was found that the latest Middle Jurassic AC is younger in the mid-Mesozoic ACs. Consequently, the recognition of Middle Jurassic chert clasts indicates that some younger geological bodies in the mid-Mesozoic ACs had been exposed and denuded in the provenance of the Tetori Group by the depositional time of the Itsuki Formation. In addition, the previous studies of the mid-Mesozoic ACs revealed that the latest Middle Jurassic AC had been structurally located in a lower position in the mid-Mesozoic ACs. This indicates that some geological bodies, which were structurally located in a lower position, had been exposed and denuded by the depositional time. The chert clasts are subangular to subrounded, and lateral continuity of the conglomerate layers is not distinct. These facts suggest that the supply of the chert clast was local.

Further studies based on the aforementioned observational methods will provide information for reconstruction of the denudation history in detail.

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