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**Middle Jurassic radiolarians from a siliceous mudstone clast within  
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**Abstract**

Well-preserved radiolarians were extracted from a siliceous mudstone pebble within conglomerate of the Mizukamidani Formation of the Tetori Group in the Itoigawa area, Niigata Prefecture, central Japan. These radiolarians correspond to the assemblage of the Middle Jurassic (*Striatojaponocapsa plicarum* Zone (JR4); Bajocian to early Bathonian). Based on general features of an accretionary complex and previous knowledge of the surrounding geological units in East Asia, the Middle Jurassic (JR4) siliceous mudstone was derived from the latest Middle or Late Jurassic accretionary complexes. This result indicates that the latest Middle or Late Jurassic accretionary complexes had been exposed and denudated in the depositional time of the Mizukamidani Formation.

*Key words:* conglomerate, etched surface, Jurassic radiolaria, Mizukamidani Formation, Tetori Group, accretionary complexes.

**Introduction**

The Middle Jurassic to Lower Cretaceous Tetori Group is distributed in the Hokuriku District, central Japan (Fig. 1.2). Some radiolarian fossils have occurred from siliceous rock clasts within conglomerates of the Tetori Group (Kojima, 1986; Saida, 1987; Takeuchi et al., 1991; Matsukawa and Takahashi, 1999; Tomita et al., 2007; Ito et al., 2012). Based on these

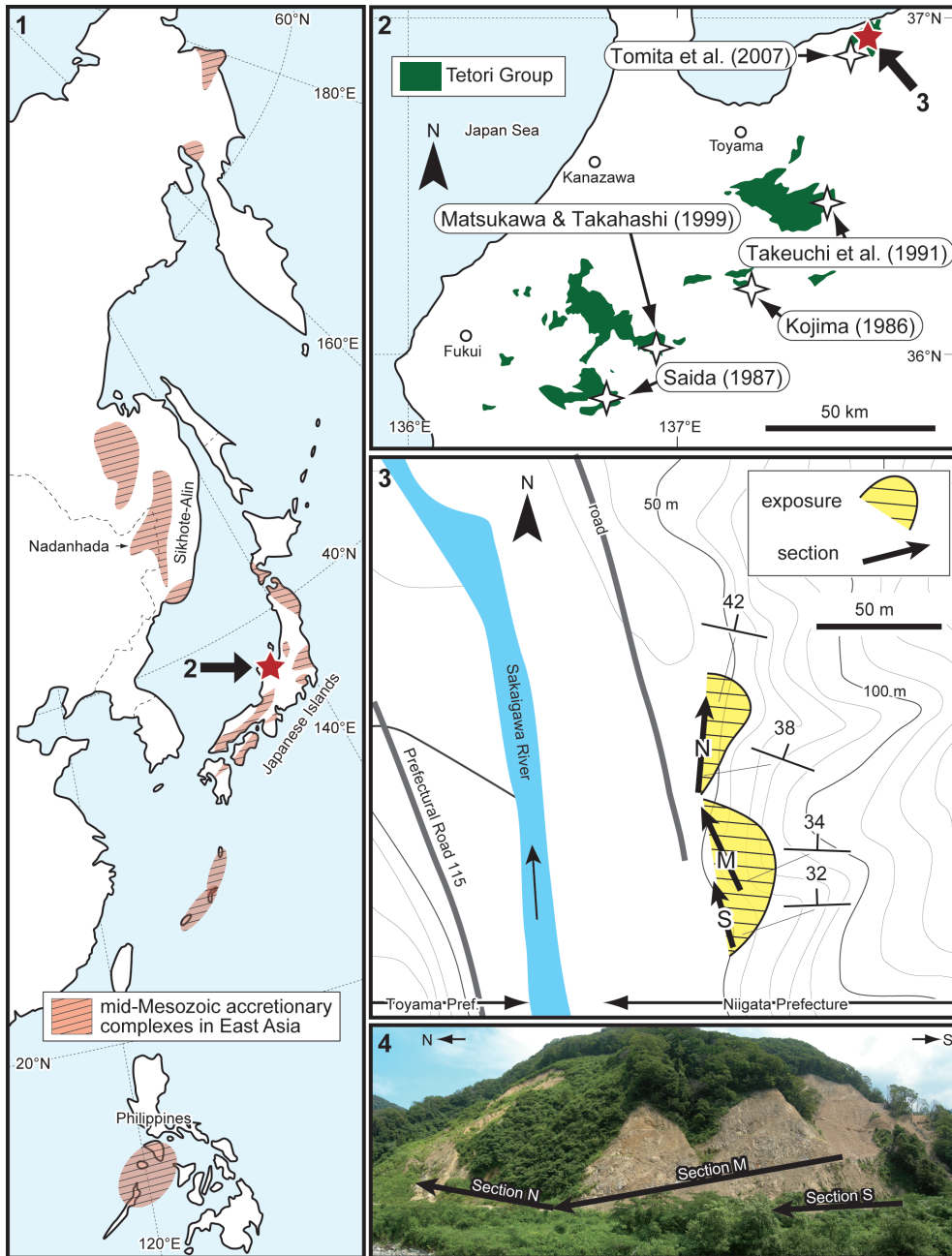
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**Fig. 1.** 1: Distributions of mid-Mesozoic accretionary complexes in East Asia modified from Kojima and Kametaka (2000). 2: Distributions of the Tetori Group (after Maeda, 1961) and radiolarian localities from clasts in previous studies. 3: The studied successions which outcrop along the right bank of the Sakaigawa River. 4: Panoramic view of the study sections from the left bank of the Sakaigawa River.

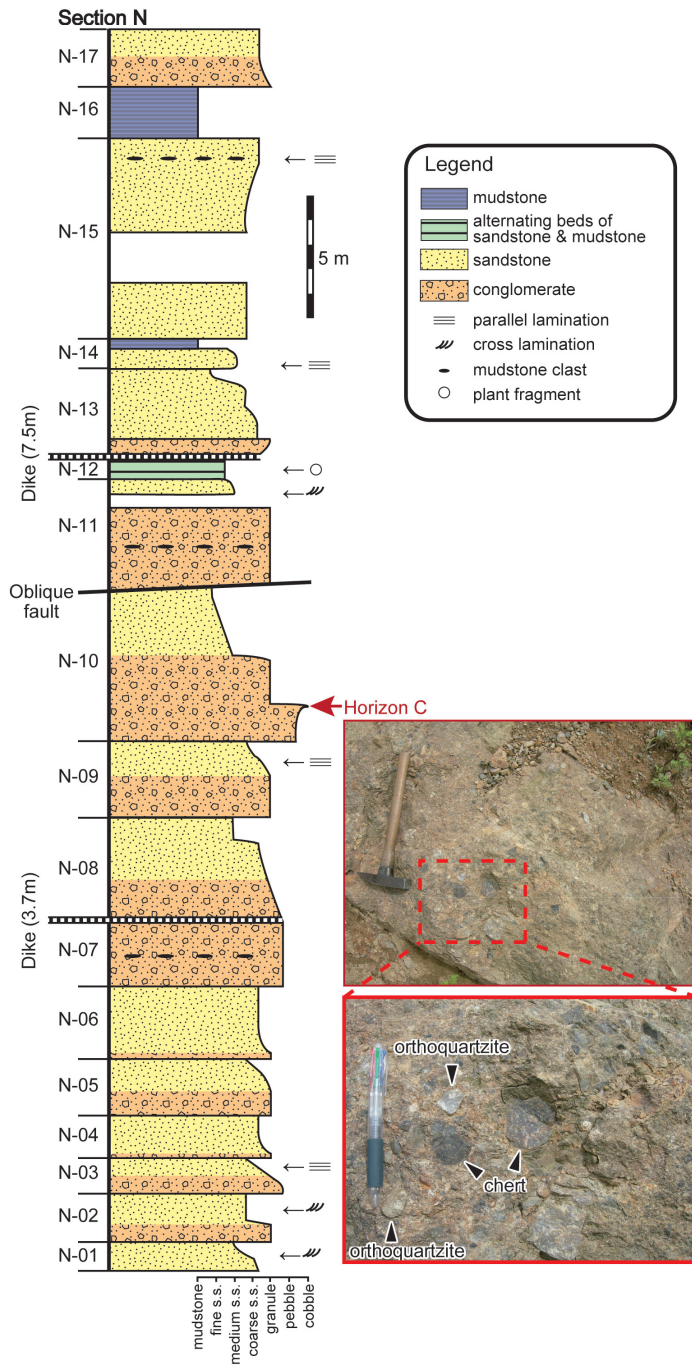
occurrences, some researchers have discussed the provenances of the Tetori Group. Takeuchi et al. (1991) concluded that the Mino terrane in a broad sense, mid-Mesozoic accretionary complex (AC), was already uplifted and eroded in the late Neocomian (Early Cretaceous) on the basis of the presences of Triassic and Jurassic clasts within conglomerates of the Yakushizawa-migimata Conglomerate Member of the Tetori Group. Matsukawa and Takahashi (1999) found Permian or Triassic chert clasts from the Otaniyama Formation of the Tetori Group in the upper reaches of the Shokawa River. It had been presumed that the Otaniyama Formation corresponds partially to the Upper Jurassic to lowest Cretaceous based on the stratigraphic relationship to the underlying Mitarai Formation, ammonoid-bearing marine deposits. They highlighted the Mino terrane sensu Takeuchi et al. (1991) had been exposed earlier than the age presumed by Takeuchi et al. (1991). However, a Berriasian ammonoid (*Neocosmoceras*) was found from the Mitarai Formation (Sato et al., 2008), indicating that the Otaniyama Formation corresponds to the Lower Cretaceous. In previous studies, valuable radiolarians for detailed age assignments had not occurred from siliceous mudstone clasts of the Tetori Group.

The Itoigawa Mesozoic Research Team has investigated the Mizukamidani Formation of the Tetori Group in the Itoigawa area, Niigata Prefecture, central Japan (Ito et al., 2010, 2012; Sakai et al., 2012, 2013). We obtained Middle Jurassic radiolarian fossils from a siliceous mudstone pebble within conglomerate of the Mizukamidani Formation. In this paper, we report this radiolarian assemblage and speculate the origin of the siliceous mudstone clast.

### Geological setting

The Tetori Group is representative sediments from the Middle Jurassic to Early Cretaceous in the Inner Zone of Southwest Japan. The Tetori Group is characterized by marine-terrestrial deposits consisting mainly of clastics and subdivided into the following three subgroups: the Kuzuryu, Itoshiro, and Akaiwa subgroups in ascending order (Maeda, 1961). The Kuzuryu Subgroup consists of marine-brackish strata yielding ammonoids; the Itoshiro Subgroup is composed mainly of brackish-terrestrial strata and characterized by flood plain deposits; the Akaiwa Subgroup consists mainly of brackish-terrestrial strata and is characterized by coarse-grained sandstone formed on braided stream (Isaji, 2010).

The Itoigawa area is located at the west-end of Niigata Prefecture (Fig. 1). The Mesozoic sequences in this area are composed of the Kuruma Group (Lower Jurassic) and the Tetori Group. The Tetori Group in this area consists of the Kurobishiyama Conglomerate, and the Mizukamidani and Shiridakayama formations (e.g., Tomita et al., 2006). The Mizukamidani Formation (Kobayashi et al., 1957) consists mainly of poorly-sorted conglomerates and sandstone. Coaly matters and plant-fossil-fragments occur commonly from the Mizukamidani Formation, while other fossils have barely occurred. Although the Mizukamidani Formation



**Fig. 2.** Stratigraphic column for Section N of the Mizukamidani Formation and the occurrence of conglomerate at Horizon C.

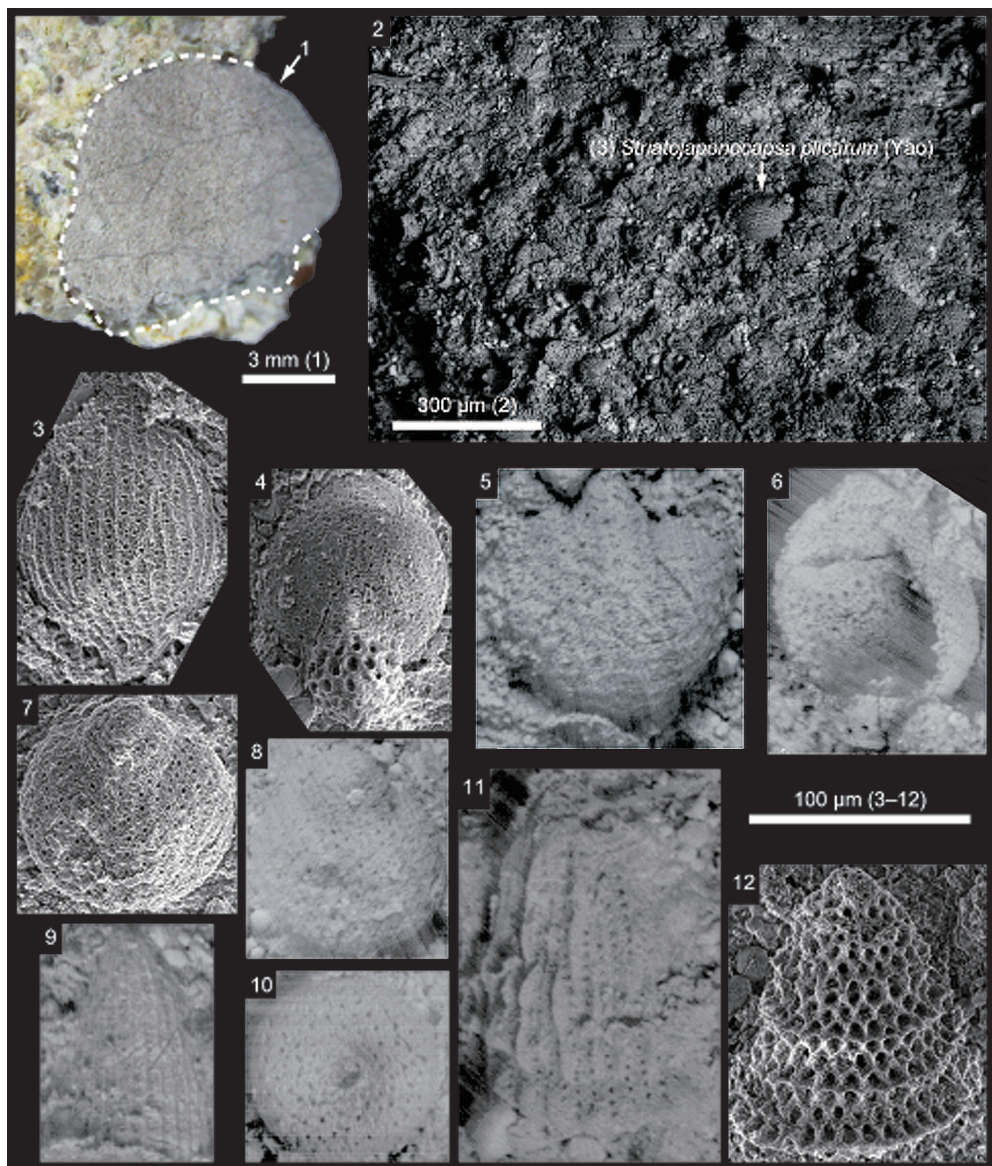
had been formerly considered as the uppermost part of the Kuruma Group (e.g., Kobayashi et al., 1957; Goto, 1983), it has been corresponded to the Akaiwa Subgroup in recent decades (e.g., Takizawa, 1984; Shiraishi 1992; Tomita et al., 2006; Sakai et al., 2012). Based on a zircon U–Pb dating, the youngest zircon grain from the sandstone of the Mizukamidani Formation has the concordant age of 128 Ma (Takeuchi et al., 2013).

The study sections (36° 57.556′ N, 137° 39.152′ E) outcrop along the right bank of the Sakaigawa River (Figs. 1.3, 1.4). We sectioned three columns, northward-namely S, M, and N (Sakai et al., 2012). These sections are subdivided into 43 subsections. The uppermost part of Section S (S-11 to S-13) and the lowermost part of Section M (M-01 to M-03) are the same horizons. Section M and Section N are successive. These strata approximately strike N80° W and dip 35° N. There are some high-angled oblique faults in the sections. Some bedding faults are recognized in subsection boundaries. The sections are composed mainly of feldspathic-arenite and conglomerates with minor mudstones. The conglomerates are characterized by abundances of chert and orthoquartzite clasts. Fining-upward cycles are repeated in the sections. Coaly matters occur commonly from the sections; plant-fossil-fragments occurred from several horizons; trace fossils are observed. Sakai et al. (2012) reported molluscan fossils from mudstone clasts in the lower S-06 as a first report of mollusks from the Mizukamidani Formation. In this study, we deal with Section N (Fig. 2).

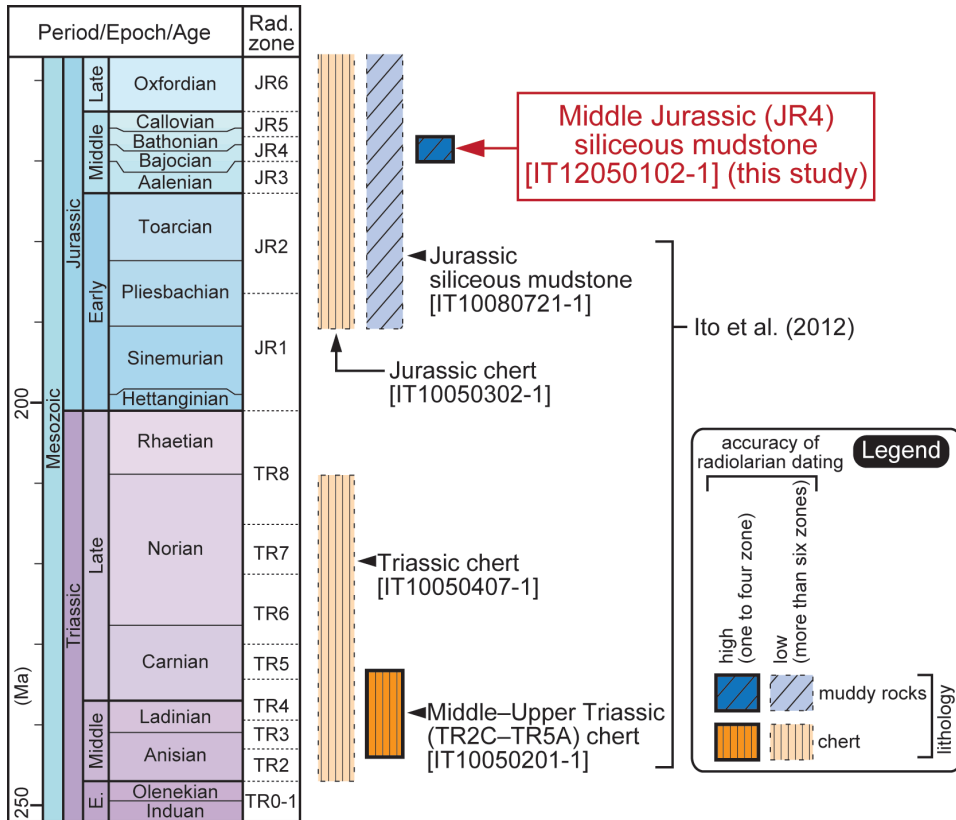
### Materials and methods

Ito et al. (2012) collected conglomerate samples from five horizons of Section M and three horizons of Section N. A black siliceous mudstone pebble (IT12050102-1) (Fig. 3.1), dealt in this paper, was collected from Horizon C in Ito et al. (2012). Horizon C is situated in a brown conglomerate layer (3.4 m) in lower N-10 (Fig. 2). Clasts are typically 2 cm in diameter; the largest clasts are approximately 10 cm in diameter. Clasts are sub-rounded to rounded, poorly-sorted, and clast-supported. Chert (black, dark-gray, and gray) and orthoquartzite clasts are dominant; black siliceous mudstone, fine-grained sandstone, and granite clasts are minor; bright-gray very-coarse-grained sandstones are matrices.

The conglomerate sample was cut in hand-size with rock cutter and then soaked in an approximately 5% hydrofluoric acid (HF) solution for one day at room temperature. The HF solution was removed and the etched sample was subsequently refilled with fresh water. The water was removed and the etched sample was dried naturally. Surface of the etched siliceous mudstone without gold coating was photographed with a scanning electron microscope (SEM). A SEM image of the etched surface is shown in Fig. 3.2; SEM images of selected radiolarians are shown in Figs. 3.3–3.12.



**Fig. 3.** Photograph of a siliceous mudstone pebble (IT12050102-1) (1), SEM images of enlarged HF-etched surface (2), and radiolarians scattered at the surface (3–12); 3: *Striatojaponocapsa plicatum* (Yao); 4: *Cyrtocapsa mastoidea* Yao; 5–8, 10: closed-end nassellarians; 9: *Archaeodictyomitra* sp.; 11: *Hsuum* sp.; 12: *Parvicingula* sp.



**Fig. 4.** Relations between the lithology of radiolarian-bearing clasts and their age assignments within conglomerates in the Mizukamidani Formation. Radiolarian zones and their age assignments are after Sugiyama (1997) and Matsuoka (1995).

### Radiolarian occurrence

An etched surface of the siliceous mudstone pebble (IT12050102-1) is characterized by dominance of closed-end and multi-segmented nassellarians, and being slightly-matrix-supported (Fig. 3.2). The bioclasts are distributed uniformly in the surface. The preferred orientation of bioclasts is not observed.

The following radiolarians occurred from the siliceous mudstone pebble: *Striatojaponocapsa plicarum* (Yao) (Fig. 3.3), *Cyrtocapsa mastoidea* Yao (Fig. 3.4), closed-end nassellarians (Figs. 3.5–3.8, 3.10), *Archaeodictyomitra* sp. (Fig. 3.9), *Hsuum* sp. (Fig. 3.11), and *Parvincingula* sp. (Fig. 3.12).

*Striatojaponocapsa* is a key genus of Middle Jurassic and its lineage has been investigated in detail (e.g., Matsuoka, 1983, 1986, 1988; O'Dogherty et al., 2005; Hatakeda et



al., 2007). *Striatojaponocapsa plicarum* is a diagnostic species of the *Striatojaponocapsa plicarum* Zone (JR4) of Matsuoka (1995) and occurs from the *S. plicarum* and *Striatojaponocapsa conexa* zones (JR4 and JR5). *Striatojaponocapsa plicarum* evolved from the *Stichocapsa tegiminis* Yao group (Matsuoka and Yao, 1986; Matsuoka, 1995). The first evolutionary appearance of *S. plicarum* defines the base of the JR4 Zone. The occurrence of *Cyrtocapsa mastoidea* is limited to only the JR4 Zone (Matsuoka, 1983, 1995). Therefore, the siliceous mudstone pebble corresponds to the JR4 Zone (Bajocian to lower Bathonian).

## Discussion

This study recognized the Middle Jurassic (JR4) siliceous mudstone clast from the study section, in addition to the Middle to Upper Triassic (TR2C to TR5A zones of Sugiyama, 1997: middle Anisian to middle Carnian) chert, Jurassic chert, Triassic chert, and Jurassic siliceous mudstone clasts of Ito et al. (2012). Based on the previous knowledge of the surrounding geological units in East Asia, these clasts are probably derived from the mid-Mesozoic ACs. Figure 4 shows relations between the lithology of the radiolarian-bearing clasts and their age assignments. The mid-Mesozoic ACs are widely distributed in southwest Japan (Kojima and Kametaka, 2000; Nakae, 2000) and other countries in East Asia (e.g., Russian, China, and the Philippines) (Wakita and Metcalfe, 2005) (Fig. 1.1). Middle Jurassic (JR4) siliceous mudstones have occurred from some geologic bodies of the mid-Mesozoic ACs, such as the Kamiaso Complex of the Mino terrane (Matsuoka, 1988), the Togano Unit of the Southern Chichibu terrane (Matsuoka, 1983), the Otori Formation of the North Kitakami terrane (Suzuki et al., 2007), the Khabarovsk Complex in Russian (Kojima et al., 1991), and the Northern Busuanga Belt in the Philippines (Zamoras and Matsuoka, 2001). Based on the general feature of an AC and the previous occurrences as mentioned above, the Middle Jurassic (JR4) siliceous mudstone clast was derived from the latest Middle or Late Jurassic ACs. In other words, the middle Middle Jurassic and older ACs should not include Middle Jurassic (JR4) siliceous mudstones. Hence the siliceous mudstone clast from this study should not be originated from the middle Middle Jurassic and older ACs but some of the latest Middle or Late Jurassic ACs such as the above geological bodies or corresponding ones.

Although some researchers have reported radiolarian occurrences from clasts within the Tetori Group, there has no occurrence of valuable Mesozoic radiolarians for age assignment from siliceous mudstone clasts. The result of this study, the first report of Middle Jurassic siliceous mudstone clast, indicates that the latest Middle or Late Jurassic accretionary complexes had been exposed and denudated in the depositional time of the Mizukamidani Formation.

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