Memoir of the Fukui Prefectural Dinosaur Museum 14: 11–18 (2015)

ARTICLE

MIDDLE JURASSIC RADIOLARIANS FROM CALCAREOUS NODULES WITHIN SILTY SANDSTONE FLOAT BOULDER DERIVED FROM THE KAIZARA FORMATION OF THE TETORI GROUP IN CENTRAL JAPAN

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ABSTRACT

This is the first report on radiolarians present in the Kaizara Formation of the Kuzuryu Subgroup, Tetori Group, located in the Shimoyama–Kaizara area, in central Japan. Previous works based on ammonoid biostratigraphy date the Kaizara Formation in the late Bathonian to early Callovian. The radiolarian fossils were extracted from two calcareous nodules included in silty sandstone that was collected as a float boulder on a river bed draining into the Taniyama River, a tributary of the Kuzuryu River. Although its precise stratigraphic horizon is unknown, the location of collection and characteristic features, namely the presence of calcareous nodules, make it a probable derivate of the Kaizara Formation. Several other microfossils and bioclasts were also retrieved from the same radiolarian-bearing nodules: benthic foraminifers, sponge spicules, prodissoconchs of pelecypods, and echinoderm fragments. According to the Unitary Associations Zones (UAZ.) of Baumgartner et al. (1995), the presence of *Dictyomitrella* ? *kamoensis*, *Striatojaponocapsa conexa*, *Stichocapsa naradaniensis* and *Williriedellum carpathicum* places the radiolarian age between the late Bathonian and early Callovian (Middle Jurassic) of UAZ. 7. In addition, the radiolarian zonation for Japan and the western Pacific proposed by Matsuoka (1995a) suggests the age to fall in the interval ranging from the Callovian to Oxfordian (Middle–Late Jurassic) based on the co-occurrence of *Stichocapsa naradaniensis* and *Striatojaponocapsa conexa*. According to the UAZ. of Baumgartner et al. (1995), the radiolarian age of the Kaizara Formation is shown to range from the late Bathonian to early Callovian, based on the consistency between the radiolarian age and the ammonoid age.

Key words : Tetori Group, Kuzuryu Subgroup, Kaizara Formation, Middle Jurassic, radiolaria, calcareous nodule

柏木健司・平澤　聡（2015）手取層群貝皿層に由来するシルト質砂岩転石中の石灰質団塊から産したジュラ紀中世放散虫化石．福井県立恐竜博物館紀要 14：11–18.

下山－貝皿地域に分布する手取層群九頭竜亜層群の貝皿層から，放散虫化石の産出を初めて報告する．貝皿層は，アンモナイト化石の生層序に基づき，既にBathonian後期～Callovian前期の時代を示すことが知られている．放散虫化石は，下山－貝皿地域の九頭竜川支流の谷山川に流れ込む河床から採取したシルト質砂岩の転石中に含まれる石灰質団塊２試料から得られた．採取試料は，その正確な層序位置は不明であるものの，その採取地点と石灰質団塊を含む岩相的特徴から，貝皿層に由来すると判断される．また，底生有孔虫，海綿骨針，二枚貝原殻，および棘皮動物片を含む微化石と生砕片が，同じ含放散虫化石団塊試料から得られた．放散虫化石の示す時代は，Baumgartner et al. (1995)のUnitary Association Zones（UAZ.）に基づくと，*Dictyomitrella* ? *kamoensis*, *Stichocapsa naradaniensis*, *Striatojaponocapsa conexa*, および*Williriedellum carpathicum*の共産するUAZ. 7のBathonian後期～Callovian前期（ジュラ紀中世）に，Matsuoka (1995a)による日本－西太平洋の放散虫化石帯に従うと*Stichocapsa naradaniensis*と*Striatojaponocapsa conexa*の共産よりジュラ紀中世Callovian～ジュラ紀新世Oxfordianを示す．貝皿層の放散虫化石時代は，アンモナイト時代と一致することが期待されることから，Baumgartner et al. (1995)のUAZ.に基づくBathonian後期～Callovian前期である．

Received November 4, 2014. Accepted September 17, 2015.
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編集注）:「古世」「中世」「新世」は，それぞれ「前期」「中期」「後期」と同義.
(The asterisk should be replaced by @)

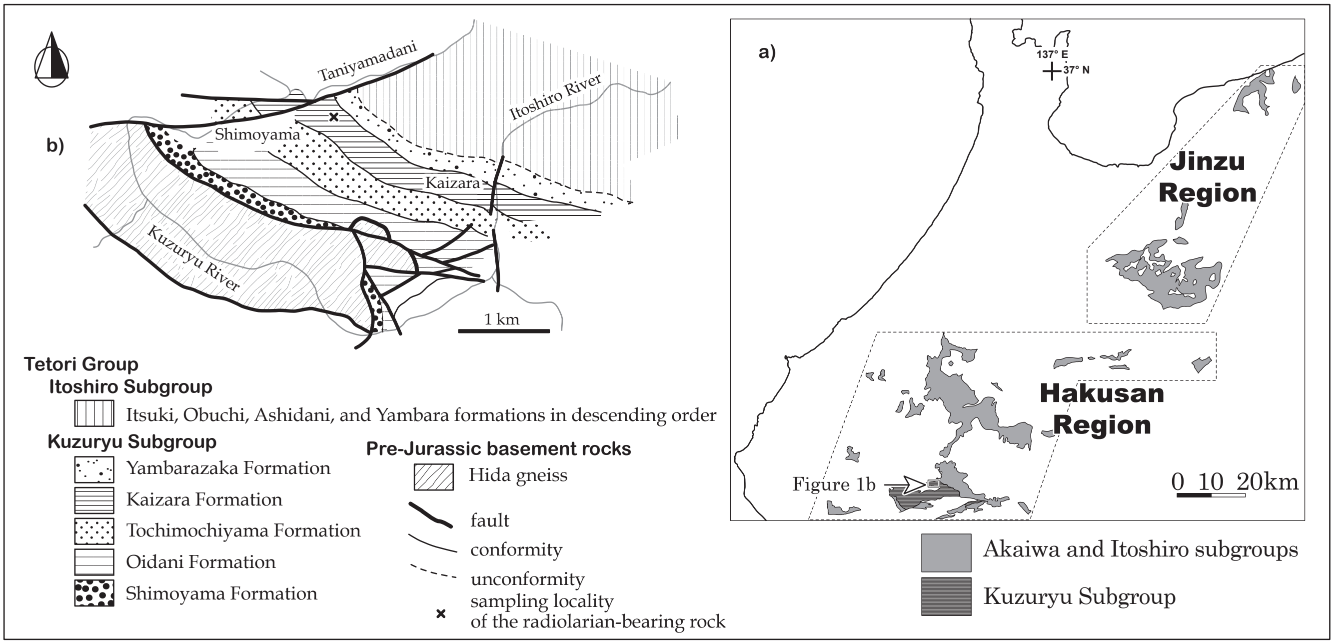

FIGURE 1. Geological map in the Shimoyama–Kaizara area in central Japan, featuring the sampling locality of the float boulder used for radiolarian analyses. Modified from Maeda (1952).

INTRODUCTION

The Tetori Group in northern central Japan predominantly comprises non-marine deposits along with some intercalations of marine sediments. It also includes high diversified zoo- and phyto-assemblages (e.g., Maeda, 1961b; Sato, 1962, 2008; Sato and Westermann, 1991; Fujita, 2003; Matsukawa et al., 2003a; Yabe et al., 2003; Yamada and Uemura, 2008; Sato et al., 2012; Goto and Handa, 2014; Handa et al., 2014; Sato and Yamada, 2014). The marine strata have been divided into three intervals dated mainly by ammonoid fossils: from the Bathonian to Oxfordian, the Tithonian to Berriasian, and the Hauterivian to Barremian (Sato et al., 2003, 2008; Sato and Yamada, 2005; Goto, 2007; Matsukawa et al., 2007; Matsukawa and Fukui, 2009). Although ammonoid fossils have been used all over the world as an index for the diagnosis of fossil age through the Paleozoic to Mesozoic strata, ammonoid ages of the Tetori Group still remains to be confirmed through the use of other fossil taxa, or better preserved and more abundant ammonoid fossils. The Mitarai Formation of the Tetori Group, in the Shokawa area, for example, have originally been dated in the Callovian by the reason of the presence of an ammonoid *Lilloetia* sp. described by Sato and Kanie (1963). Its age had been widely accepted by many geologists in the following four decades (e.g., Fujita, 2003). In the last over ten years, however, the Mitarai Formation has been dated in the Berriasian, on the basis of the abundant, well-preserved collection of ammonoid on that location (Sato et al., 2003, 2008).

Radiolarians are generally considered as one of the most useful fossil indexes for dating, owing to their widespread and abundant occurrence, even on small-size piece rock samples. From this point of view, the authors have reported radiolarians from several marine strata of the Tetori Group, and dated them in order to verify the age previously reported on ammonoid fossils (e.g., Hirasawa and Kashiwagi, 2008; Kashiwagi and Hirasawa, 2010; Kashiwagi et al., 2011; Kashiwagi, 2014). The present paper serves the purpose of reporting first on the Middle Jurassic radiolarian assemblage from the Kaizara Formation, exposed in the Shimoyama–Kaizara area, and to discuss its age determination based on the two radiolarian zonations of the Middle to Late Jurassic interval.

GEOLOGICAL OUTLINE

The Middle Jurassic to Lower Cretaceous Tetori Group is sporadically distributed in the Hakusan and Jinzu regions (Fig. 1). It has been stratigraphically divided into the Kuzuryu, Itoshiro and Akaiwa subgroups, in ascending order (e.g., Maeda, 1952, 1961b; Maeda and Takenami, 1957; Fujita, 2003). Recently, Matsukawa et al. (2014) revised the widely accepted stratigraphy of the Tetori Group in the Jinzu Region, by defferentiating the Jinzu Group in the upper horizon from the Tetori Group in the lower one. The Jinzu Group, which is mainly composed of non-marine deposits, includes the Ioridanitoge, Inotani, and Shiroiwagawa formations, in ascending order. Furthermore, the Group is assigned to the Aptian–Albian based on zircon fission track dating of tuffaceous sandstones in the Inotani Formation (Matsukawa et al., 2014). Although Matsukawa et al. (2014) emphasized the discrepancy between the Tetori and Jinzu Groups' depositional ages, the

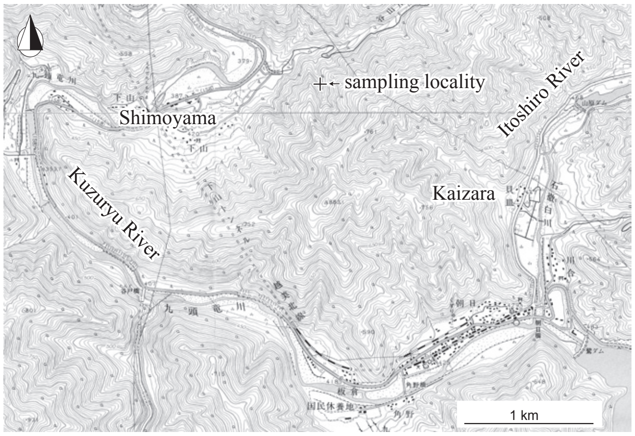

FIGURE 2. Sampling locality of the silty sandstone float boulder in the Shimoyama–Kaizara area. Based maps are 1:25,000 maps of Shimoyama and Echizen-asahi of the Geographical Survey Institute of Japan.

lowermost and uppermost horizons of the Jinzu Group have not been dated so far. In this paper, we adopt the division in three subgroups proposed by Maeda (1961b) for the lithostratigraphy of the Tetori Group in the Jinzu Region.

The Kuzuryu Subgroup is widely distributed in the upper reaches of the Kuzuryu River on the southern margin of the Hakusan Region (Fig. 1). Its lithostratigraphy has been the object of extensive research (e.g., Oishi, 1933; Maeda, 1952, 1961a; Kawai et al., 1957; Yamada et al., 1989; Fujita, 2002; Matsukawa et al., 2003b). In this paper, we follow the stratigraphic scheme described by Maeda (1952, 1961b) and Fujita (2003) for the Kuzuryu Subgroup, which consists of the Shimoyama, Oidani, Tochimochiyama, Kaizara, and Yambarazaka formations in ascending order, and they conformably pile up in turn. In the Shimoyama–Kaizara area, where the type locality of the Kaizara Formation is located, these formations feature NW–SE strikes and steep N-dipping. The Yambara Formation, the lowermost formation of the Itoshiro Subgroup, unconformably overlies the Yambarazaka Formation.

The Kaizara Formation, the object for the present study, mainly consists of black massive and/or laminated sandy siltstone with some intercalations of fine- to coarse-grained sandstones. Spherical to ellipsoidal calcareous nodules can be found at a few specific horizons in sandy siltstone. The formation features abundant marine invertebrate fossils: ammonoids, belemnites, pelecypods and so on (e.g., Yokoyama, 1904; Kobayashi, 1947; Maeda, 1952, 1961b; Hayami, 1960; Sato, 1962; Sano et al., 2010; Handa et al., 2014), as well as fewer plant fossils (Yamada and Uemura, 2008). According to the ammonoid biostratigraphy, the Kaizara Formation is dated as the late Bathonian–early Callovian (Maeda, 1961b; Sato, 1962, 1992; Sato and Westermann, 1991; Handa et al., 2014).

MATERIALS AND METHODS FOR EXTRACTING RADIOLARIANS

We examined radiolarians from two calcareous nodule samples (KAI and KAN) collected from a single float boulder of a silty sandstone on a river bed draining into the Taniyama River, a tributary of the Kuzuryu River, in the Shimoyama–Kaizara area (Fig. 2). The Kaizara Formation crops out in and around the sampling locality (Figs. 1, 2). The calcareous nodules are one of the distinguishable lithological characteristics for the Kaizara Formation, because they have not been observed in the underlying Tochimochiyama and overlying Yambarazaka formations, in both of which lithofacies are dominated by sandstone facies (Maeda, 1952; Maeda, 1977; Yamada et al., 1989). Although the precise reconstruction of the stratigraphic horizon of the float boulder, where radiolarian-bearing calcareous nodules occur, is difficult, above-mentioned lithological features and sampling locality support the argument that the studied samples probably derive from the Kaizara Formation.

The float of ca. 40 cm in length features silty very fine-grained sandstone with thin intercalations of fine-grained sandstone beds and spherical to ellipsoidal calcareous nodules. Two fragments of elliptical nodules — approximately 3 cm in minor axis (sample KAI), and spherical nodule of ～3 cm in diameter (sample KAN, Fig. 3a) — are examined. Standard rock thin sections were prepared from the studied samples in order to investigate their microfacies.

Both silty sandstone part and calcareous nodules are bioturbated by abundant small burrows such as *Phycosiphon* and *Planolites*. The burrows display unbranched and simple cylindrical shape (less than 1.5 mm wide). They are filled with a massive muddy matrix containing sand-sized grains. Some burrows show obscure muddy lining or back fill structure. The inner part of calcareous nodules show a matrix-supported texture as well.

The radiolarians and some other microfossils were extracted from the calcareous nodules basically following to the method proposed by Dumitrica (1970) and Pessagno and Newport (1972). The rock samples were treated with a 5 % diluted hydrofluoric acid solution for ca. 24 hours, and rinsed under running water in order to remove radiolarians from the rock surface. The residue was collected through 425 and 63 μm meshes and subsequently boiled for up to a minute with diluted hydrogen peroxide, and then dried slowly in an oven (no more than ca. 60 degrees).

Abundant microfossils were found in two samples (KAI and KAN). Sample KAI contains abundant radiolarians with a few benthic foraminifers. Sample KAN displays a lesser quantity of radiolarians compared to sample KAI, as well as various other microfossils, including benthic foraminifers, sponge spicules and prodissoconchs of pelecypods (Fig. 3c, d). Microfossils are present only in calcareous nodules, and not in the surrounding silty sandstone matrices (Fig. 3b). Radiolarian tests and sponge spicules are partly replaced by calcite and/or pyritized overall. A few plates of echinoderm are only observed in rock thin section (Fig. 3c).

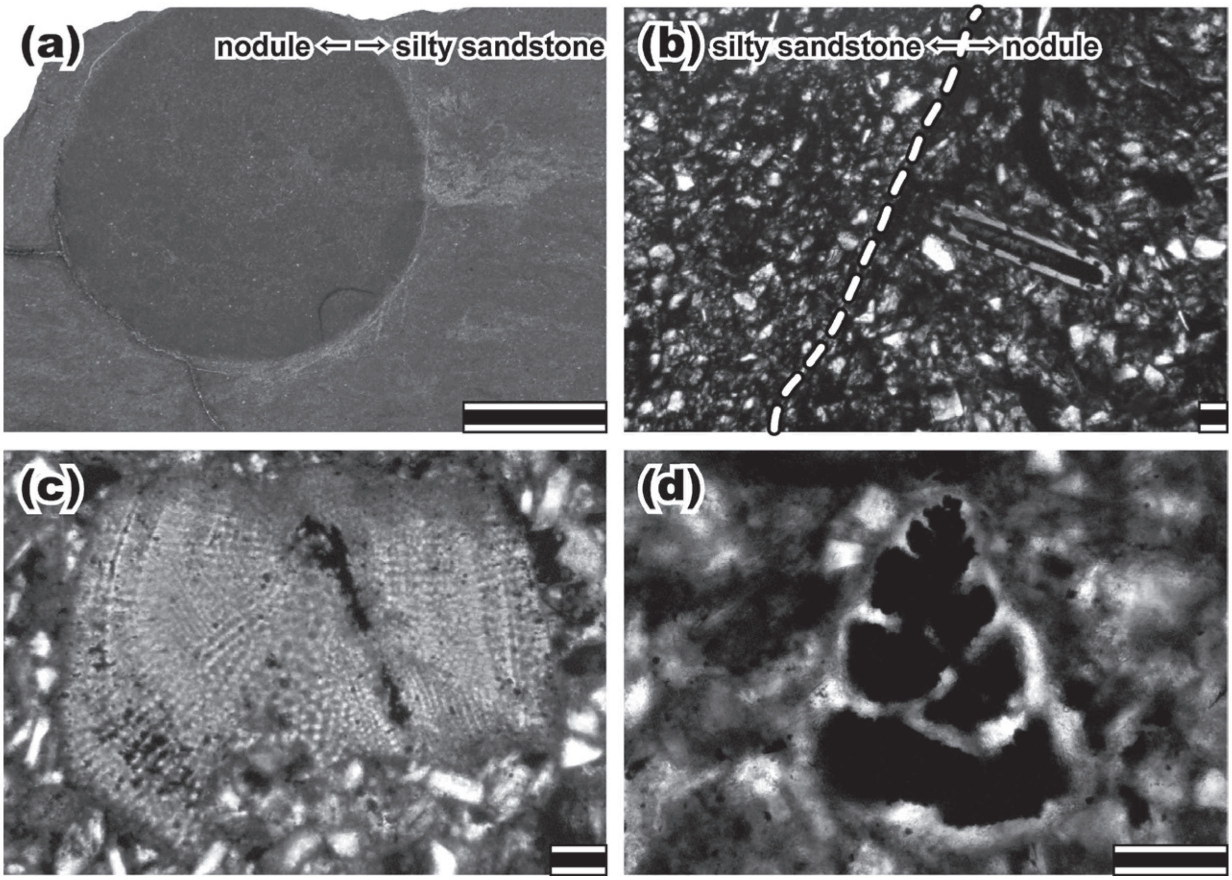

FIGURE 3. Calcareous nodule sample KAN and photographs of microfossils and bioclasts in sample KAN. **a**, Polished hand specimen of calcareous nodule with its surrounding matrix. Scale bar indicates 1 cm. **b**, Sponge spicule in calcareous nodule. Note that the silty sandstone matrix contains no fossils at all. **c**, Echinoderm fragment in calcareous nodule. **d**, Benthic foraminifer in calcareous nodule. Scale bars in b–d are 100 μm.

RADIOLARIAN AGE ASSIGNMENTS

Radiolarian ages of both samples KAI and KAN should nearly coincide on the ground that they were collected from the same float boulder. We can adopt two biostratigraphic schemes for the Middle–Late Jurassic biostratigraphic markers: the Unitary Association Zones (UAZ.) of Baumgartner et al. (1995) and the Middle Jurassic to Early Cretaceous radiolarian zonation for Japan and the western Pacific proposed by Matsuoka (1995a). Radiolarians from samples KAI and KAN are listed in Table 1, and are illustrated with other microfossils in Fig. 4.

Among the listed species in Table 1, the UAZ. of the following species are indicated according to Baumgartner et al. (1995): *Dictyomitrella* ? *kamoensis* (UAZ. 3–7); *Parvicingula dhimenaensis* s.l. (UAZ. 3–11); *Parvicingula* ? *spinata* (UAZ. 3–10); *Podobursahelvetica* (UAZ. 3–10); *Ristola altissima* (UAZ. 5–12); *Stichocapsa naradaniensis* (UAZ. 6–7); *Striatojaponocapsa conexa* (UAZ. 4–7); and *Williriedellum carpathicum* (UAZ. 7–11) for nassellarians, and *Triactoma blakei* (UAZ. 4–11); *Triactoma mexicana* (UAZ. 5–9); and *Tritrabs ewingi* (UAZ. 4–22) for spumellarians. Their co-occurrence is restricted to UAZ. 7, which corresponds to the late Bathonian–early Callovian following the UAZ. of Baumgartner et al. (1995) (Fig. 5).

The radiolarian zonation of Matsuoka (1995a) has been commonly aligned to Jurassic to Early Cretaceous radiolarian assemblages reported from the Japanese Islands and East Asian Continent by many Japanese researchers. Among the listed species, *Stichocapsa naradaniensis* and *Striatojaponocapsa conexa* are the age indicative species for the biochronology of Matsuoka (1995a). *Stichocapsa naradaniensis* points out to a Middle–Late Oxfordian age in the upper *Kilinora spiralis* zone (Matsuoka, 1986; Matsuoka and Yao, 1986). However, this species has been also reported to be from the upper half of the *Striatojaponocapsa conexa* zone (Ishida, 2011), as well as from the upper half of the *Striatojaponocapsa conexa* to *Kilinora spiralis* zones (Nishizono, 1996). Consequently, the age range of *Stichocapsa naradaniensis* could be from the upper half of the *Striatojaponocapsa conexa* zone to the *Kilinora spiralis* zone, corresponding to Callovian–Oxfordian age. *Striatojaponocapsa conexa*, which is a taxon for age diagnosis from the *Striatojaponocapsa conexa* zone to the

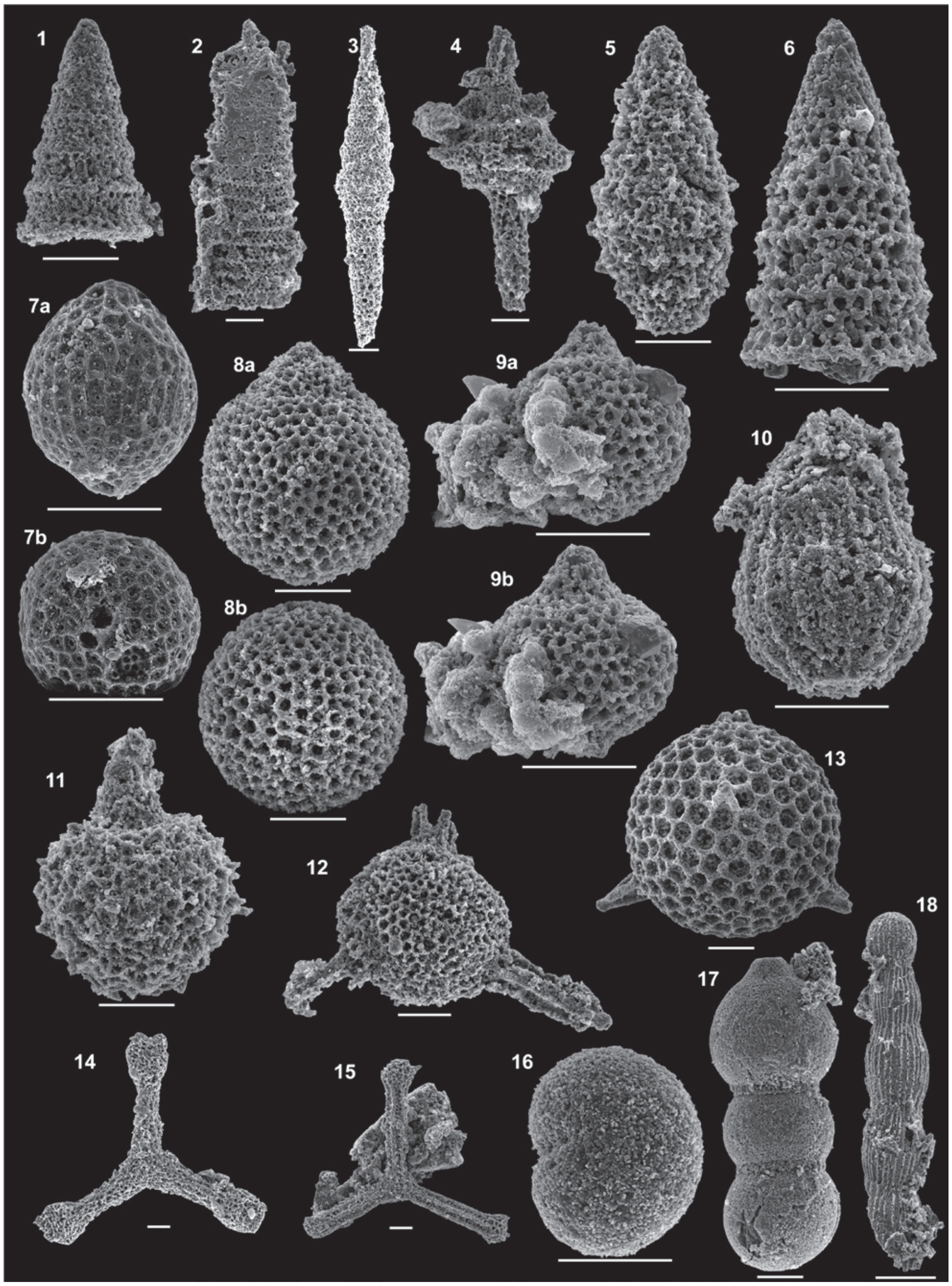

FIGURE 4. Radiolarians and other microfossils from the calcareous nodules from silty sandstone float boulder probably derived from the Kaizara Formation of the Tetori Group. **1**, *Dictyomitrella* ? *kamoeisis*, KAI; **2**, *Ristola altissima*, KAI; **3**, *Pseudoeucyrtis* sp., KAI; **4**, *Podobursa helvetica*, KAI; **5**, *Parvicingula dhimenaensis* s.l., KAI; **6**, *Parvicingula* ? *spinata*, KAN; **7a, b**, *Striatojaponocapsa conexa*, KAI; **8a, b**, *Zhamoidellum* sp., KAN; **9a, b**, *Williriedellum carpathicum*, KAN; **10**, *Stichocapsa naradaniensis*, KAI; **11**, *Sethocapsa* sp., KAI; **12**, *Triactoma blakei*, KAI; **13**, *Triactoma mexicana*, KAN; **14**, *Paronaella* sp., KAI; **15**, *Tritrabs exotica*, KAI; **16**, Sponge spicule, KAN; **17, 18**. Benthic foraminifers, KAI, KAN, respectively. Scale bars = 50 μm.

Kilinora spiralis zone, indicates an age interval ranging from the middle Bathonian to Oxfordian (Matsuoka, 1995a). The co-occurrence of *Stichocapsa naradaniensis* and *Striatojaponocapsa conexa* shows that the radiolarian age of the Kaizara Formation is Callovian–Oxfordian based on the radiolarian zonation of Matsuoka (1995a).

Comparing age of radiolarians determined using the UAZ. of Baumgartner et al. (1995) and the radiolarian zonation of Matsuoka (1995a), it is evident that the former is almost concordant with the ammonoid age (late Bathonian–early Callovian) as reported by Sato (1962) and Sato and Westermann (1991), whereas the latter points out to a younger age than the one suggested by

TABLE 1. Middle Jurassic radiolarians from the calcareous nodules collected from silty sandstone float boulder probably derived from the Kaizara Formation of the Tetori Group.

radiolarian species / studied samples	KAI	KAN	radiolarian species / studied samples	KAI	KAN
Spumellaria			**Nassellaria**		
Cenosphaera ? sp.	○		*Dictyomitrella* ? *kamoensis* Mizutani and Kido	○	
Crucella sp.	○		*Hsuum* sp.	○	
Emiluvia ? sp.	○		*Parvicingula dhimenaensis* s.l. Baumgartner	○	
Orbiculiforma sp.	○	○	*Parvicingula* ? *spinata* (Vinassa)		○
Paronaella sp.	○		*Podoversa helvetica* (Rüst)	○	
Parvivacca ? sp.		○	*Protunuma* sp.	○	
Phaseliforma sp.	○		*Pseudoeucyrtis* sp.	○	
Praeconocaryomma sp.	○		*Ristola altissima* (Rüst)	○	
Suna sp.		○	*Sethocapsa* spp.	○	
Triactoma blakei (Pessagno)	○		*Stichocapsa naradaniensis* Matsuoka	○	
Triactoma mexicana Pessagno and Yang		○	*Stichocapsa tuscanica* (Chiari et al.)	○	
Tripocyclia sp.	○		*Striatojaponocapsa conexa* (Matsuoka)	○	○
Tritrabs ewingi (Pessagno)	○		*Striatojaponocapsa* spp.	○	
Tritrabs sp.	○		*Unuma* sp.	○	
			Zhamoidellum sp.		○
			Williriedellum carpathicum Dumitrica		○

radiolarian species	KAI	KAN	UAZ. 1—22 by Baumgartner et al. (1995)
Dictyomitrella ? *kamoensis* Mizutani and Kido	○		3—7
Parvicingula ? *spinata* (Vinassa)		○	3—10
Podoversa helvetica (Rüst)	○		3—10
Parvicingula dhimenaensis s.l. Baumgartner	○		3—11
Striatojaponocapsa conexa (Matsuoka)	○	○	4—7
Triactoma blakei (Pessagno)	○		4—11
Tritrabs ewingi (Pessagno)	○		4—22
Triactoma mexicana Pessagno and Yang		○	5—9
Ristola altissima (Rüst)	○		5—12
Stichocapsa naradaniensis Matsuoka	○		6—7
Williriedellum carpathicum Dumitrica		○	7—11

FIGURE 5. Selected radiolarians species from the Kaizara Formation relevant for the age assignment. The Unitary Association Zones (UAZ.) is based on Baumgartner et al. (1995).

ammonoid biochronology. The age of the Kaizara Formation has been assigned to the late Bathonian–early Callovian in the light of precise ammonoid biochronology by Sato (1962), and further confirmed by more recent research on ammonoids provided by Handa et al. (2014). In consequence, the radiolarian age of the Kaizara Formation falls more probably in the late Bathonian–early Callovian according on Baumgartner's et al. (1995) method. Additionally, some researchers (Matsuoka, 1995b; Suzuki et al., 2004) have pointed a discrepancy in the age assignment of Middle–Late Jurassic radiolarian assemblages reported by Baumgartner et al. (1995) and Matsuoka (1995a). This result shows the urgent necessity to further study the correlation between the Middle–Late Jurassic radiolarian zonations of Baumgartner et al. (1995) and Matsuoka (1995a), as Matsuoka (1995b) has pointed out.

SUMMARY

This is the first report on radiolarians from the Kaizara Formation of the Tetori Group. It has been dated as the late Bathonian–early Callovian based on ammonoid biochronology. The sampling locality and occurrence of calcareous nodules suggest that the float boulder, from which radiolarian-bearing calcareous nodules were collected, probably derive from the Kaizara Formation. Its radiolarian age is late Bathonian–early Callovian according to the UAZ. of Baumgartner et al. (1995),

and Callovian–Oxfordian based on the radiolarian zonation of Matsuoka (1995a). Based on the already well-known age of the ammonoid, we can infer that the radiolarian age of the Kaizara Formation is likely to fall in the late Bathonian–early Callovian.

ACKNOWLEDGMENTS

We give our thanks to Dr. Shin-ichi SANO (Fukui Prefectural Dinosaur Museum) for reading an early version of the manuscript, for his valuable suggestions, as well as for his support and supervision of the work performed on the SEM at the Fukui Prefectural Dinosaur Museum. Special thanks to Dr. Shugo OHI and Mr. Masaki TAKAYA (Dept. Geol. Mineral., Kyoto Univ.) for discussing the petrography of the rock samples. We also thank Prof. Atsushi MATSUOKA (Niigata Univ.) and an anonymous reviewer for helpful comments and recommendations for the improvement of the manuscript. The study was financially supported in part by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (Kashiwagi, K., No. 23540547, 2011–2013).

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*** : in Japanese with German and English abstracts
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