Permian spicular chert from the east of Mt. Asahi-dake, Itoigawa City, Niigata Prefecture, Japan

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Abstract

This article documents siliceous spicules with radiolarians from a red-ocher chert sample in the east of Mt. Asahi-dake, Itoigawa City, Niigata Prefecture, Japan. The spicule assemblage is characterized by dominant monaxon, common critriactine and tetractine, and rare anadiaene. One radiolarian species, *Quinqueremis* sp. aff. *Q. robusta* Nazarov and Ormiston, which occurred in the Cisuralian–Guadalupian (lower–middle Permian) as mentioned in previous studies, was also extracted. Permian spicular chert is well-known from the Akiyoshi belt, and the red-ocher chert presumably comes from that belt.

Introduction

Biogenic chert, a sedimentary rock composed of siliceous organisms such as radiolarians and sponges, is one of the significant components of Permian and Jurassic accretionary complexes in the Japanese Islands. The characteristics of the chert in the accretionary complexes have been described and compared (e.g., Imoto, 1983, 1984a, b; Kakuwa, 1991; Imoto and Saijyo, 1993).

Isolated radiolarians and spicules also have been investigated; however, there is a

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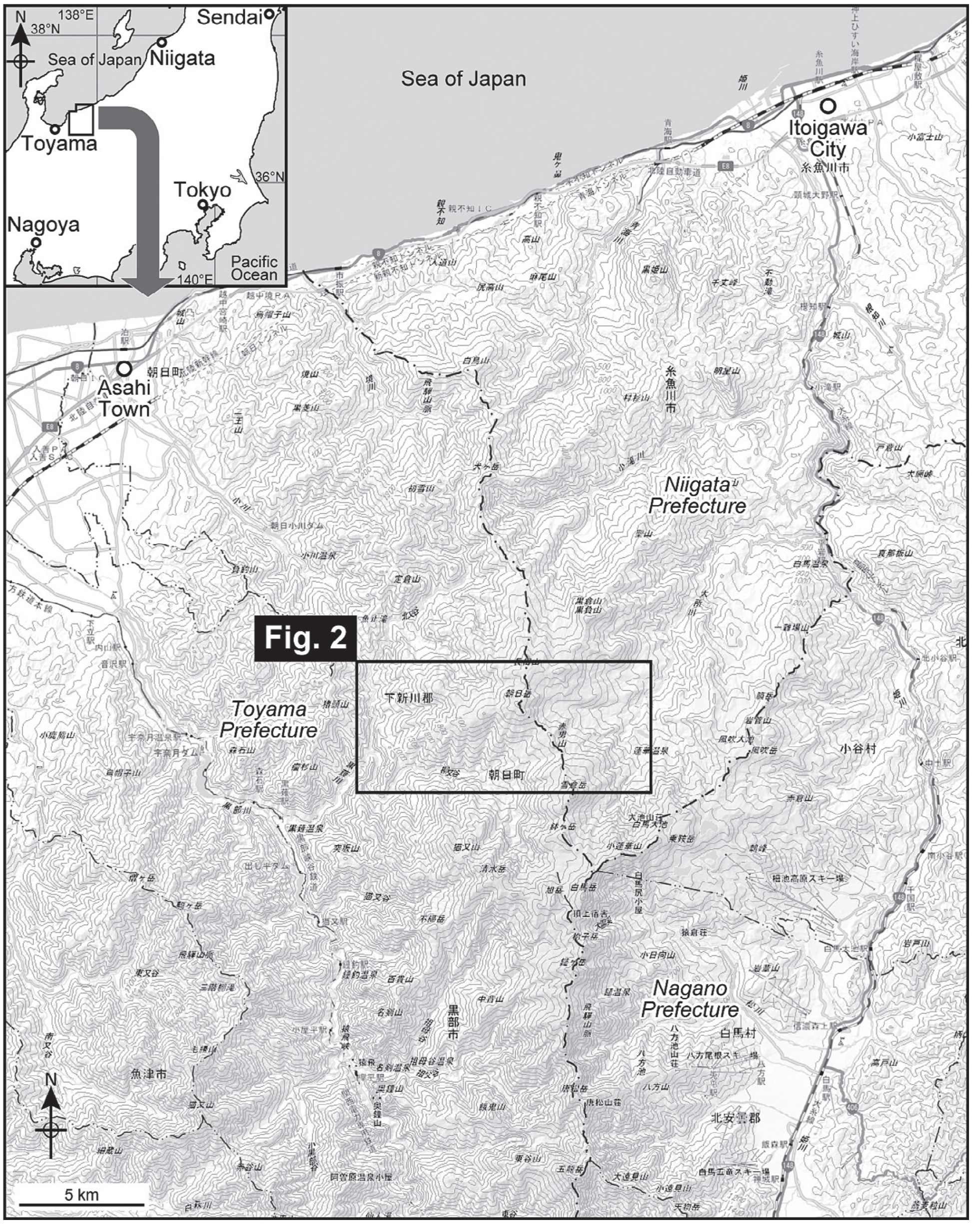

Fig. 1. Index map of sample locality. Modified from a topographic map published by Geospatial Information Authority of Japan (https://maps.gsi.go.jp/).

substantial difference in the accumulation of the research on the isolated fossils. Numerous studies have described isolated radiolarians from the Permian and Jurassic accretionary complexes in the Japanese Islands since around 1980 (e.g., Nakaseko and Nishimura, 1979; Yao, 1979, 1982; Ishiga and Imoto, 1980; Yao et al., 1982; Matsuoka, 1983). On this basis, Permian, Triassic, and Jurassic radiolarian biozonations have been constructed (e.g., Ishiga, 1986, 1990; Matsuoka, 1995; Sugiyama, 1997; Kuwahara et al., 1998; Matsuoka and Ito, 2019). In contrast, studies on spicules from the accretionary complexes are limited; even micrographs and images of isolated spicules have been rarely reported (e.g., Ishiga and Imoto, 1980; Ito and Matsuoka, 2016; Ito, 2021; Ito and Nakamura, 2021).

The collaborative research group (Niigata University, Itoigawa City, and Geological Survey of Japan, AIST) investigated the geology around Mt. Asahi-dake, bordering Niigata and Toyama prefectures, central Japan (Fig. 1) during August 3–6, 2021 (Ito et al., 2021). We discovered a spicular chert east of Mt. Asahi-dake. This article describes isolated siliceous spicules with a few radiolarians from the chert to provide the basic knowledge of spicules.

Geologic outline

Various rocks with a wide age range are exposed from Itoigawa City of Niigata Prefecture to Asahi Town of Toyama Prefecture (e.g., Nakano et al., 2002; Takeuchi et al., 2004, 2017; Nagamori et al., 2010; Ito et al., 2017). Paleozoic rocks belonging to the Renge, Akiyoshi, Maizuru, and Hida-Gaien belts are basement rocks of the area. Mesozoic–Cenozoic deposits cover them, and Mesozoic–Cenozoic volcanic rocks are intruded.

Around Mt. Asahi-dake, serpentinite mélange with metamorphic rock blocks belonging to the Renge belt are distributed (e.g., Ito, 1966; Nakamizu et al., 1989). The isotopic ages of 323 Ma and 311 Ma were determined from muscovite in the metamorphic rock (Shibata and Ito, 1978). The amphibolite of the Renge belt and Permian sedimentary rocks of the Hida-Gaien belt are distributed in the surrounding areas of Mt. Asahi-dake (Nakano et al., 2002; Nagamori et al., 2010; Takeuchi et al., 2017). Devonian–Carboniferous fossils, such as corals, crinoids, and bryozoans, have been reported from limestone around Mt. Asahi-dake (Minato, 1975; Takano and Komatsu, 1984; Ibaraki and Niko, 2012). Mudstone and siliceous tuff to the south and east of Mt. Asahi-dake yielded Permian radiolarians (Takizawa et al., 1995; Takeuchi et al., 2004).

Outcrop distribution based on our fieldwork

Figure 2 shows outcrop distribution mainly along mountain climbing trails based on our fieldwork. Granitic rocks and contact metamorphosed sedimentary rocks are exposed around the Kitamata Dam. Serpentinite is widely distributed in the traverse map and is well exposed around Mt. Asahi-dake and along a southern climbing trail of Mt. Yukikura-dake. Sedimentary rocks also exist in outcropping at several points along the climbing trails in the traverse map.

The sample locality (IT21080602b) in this study was a climbing trail between the Shirakochizawa and Seto rivers (eastern end of Fig. 2). The chert was exposed along the climbing trail. The chert was red-ocher-colored. The outcrops of the chert were small, and

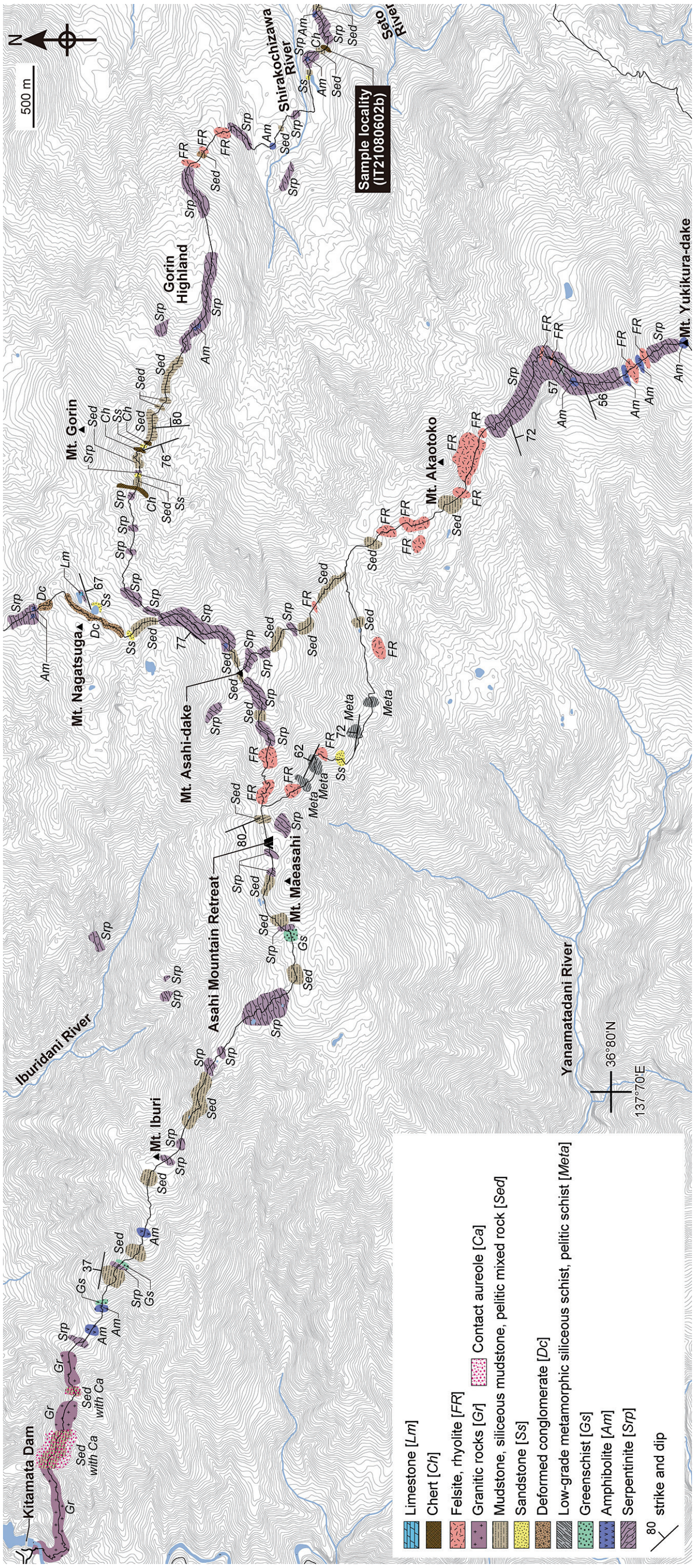

Fig. 2. Travers map around Mt. Asahi-dake based on the authors' fieldwork during August 3–6, 2021.

the chert appeared massive. The chert was exposed in the distributional area of the serpentinite.

Materials and method

The sample was soaked in a hydrofluoric acid (HF) solution (ca. 5%) at room temperature (ca. 20–30 °C) for approximately 24 h. Adequate residues were collected using a sieve (mesh diameter: 54 μm). Some of the sieved residues were enclosed within a prepared slide with a photocrosslinkable mounting medium (GJ-4006, Gluelabo Ltd., Kuwana, Japan). The slide was observed under a transmitted light microscope and imaged. Fossil tests within the dried residues were conducted using binocular microscopy and mounted on a stub. The fossil tests mounted on the stub were coated with gold using a sputter-coater and imaged using a scanning electron microscope (SEM). The HF-etched rock sample was also coated using gold and imaged with SEM in a low-vacuum state.

Fossil occurrence and age assignment

The HF-etched surfaces are shown in Fig. 3. The micrographs of the transmitted microscopy and SEM images of the isolated fossils are shown in Fig. 4.

Spicules, especially monaxon, dominate both the HF-etched surface and residues. Monaxon included the style, strongyloxea, oxea, and strongyle. Anadiaene is present, but it is scarce. Most spicules on the etched surfaces are parallel to the bedding planes of the chert (Fig. 3). A clear preferred orientation was not observed in the bedding planes. As with other spicules, tetractine and critriactine are common in these residues.

The radiolarians *Quinqueremis* sp. aff. *Q. robusta* Nazarov and Ormiston sensu Blome and Reed (1992) were extracted from the residues. *Quinqueremis* sp. aff. *Q. robusta* co-occurred with the Cisuralian–Guadalupian (early–middle Permian) species (Sosson et al., 1984; Blome and Reed, 1992; Basir Jasin and Ali, 1997; Ito and Matsuoka, 2015). Similar specimens possibly identified as *Q. robusta* also occurred in the Cisuralian–Guadalupian (e.g., Wang, 1993a, b, 1995; Nakagawa and Wakita, 2016). Consequently, the sample is likely Cisuralian–Guadalupian in age.

Paleontological note

All specimens shown in this section were extracted from sample IT21080602b. The stub, prepared slide, and HF-etched rock are deposited in the Fossa Magna Museum, Itoigawa City, Niigata Prefecture, Japan. The depository numbers of the HF-etched rock, stub, and prepared slide are FMM06445, FMM06446, and FMM06447, respectively.

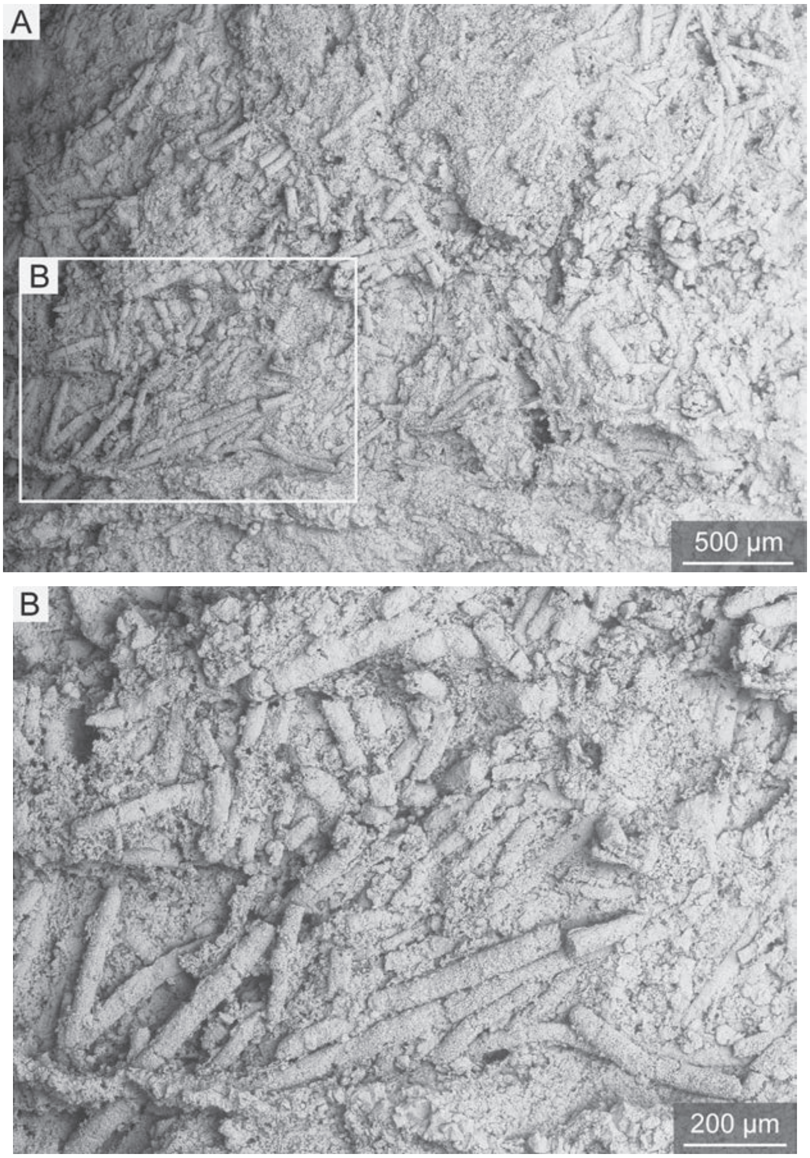

Fig. 3. Etched surface of red-ocher chert (sample IT21080602b). The surface is parallel to the bedding planes. Depository number: FMM06445.

Spicules

Morphological terminology and descriptive classification are preferred to classify isolated spicules from sponges, and Linnaean taxonomy is generally not used. This is because an individual sponge possesses a wide variety of spicule types; different sponge taxa have approximately the same form of spicules (e.g., Boury-Esnault and Rützler, 1997).

Siliceous spicules obtained from Permian siliceous rocks are generally considered to originate from sponges. Previous studies (e.g., Liu et al., 2008; Ito et al., 2016) generally employ the terminology coined by Boury-Esnault and Rützler (1997) for sponge spicules; thus, we used the same terminology in the present study.

Style (monaxon)

Fig. 4.1

Description: This form has a cylindrical spicule of a single axis, with rounded and blunt ends. The shape of the spicule is straight. The blunt end is symmetrical. The surface is generally smooth and has no spine or ornament. The total length is approximately 800 μm, and the maximum thickness (diameter) is approximately 50 μm.

Strongyloxea (monaxon)

Fig. 4.2

Description: This form has a cylindrical spicule of a single axis, with fusiform and blunt ends. The shape of the spicule is slightly flexuous. The blunt end is asymmetrical. The surface is generally smooth and has no spine or ornament. The total length is approximately 800 μm, and the maximum thickness (diameter) is approximately 50 μm.

Oxea (monaxon)

Fig. 4.3

Description: This form has a cylindrical spicule of a single axis with blunt ends. The shape of the spicule is slightly curved. The blunt ends are asymmetrical. The surface is generally smooth and has no spine or ornament. The total length is approximately 700 μm, and the maximum thickness (diameter) is approximately 50 μm.

Strongyle (monaxon)

Figs. 4.4–4.8, 4.12

Description: This form has a cylindrical spicule of a single axis with rounded ends. The shape of the spicule is straight (Figs. 4.6, 4.7), slightly curved (Figs. 4.4, 4.5), or curved (Figs. 4.8, 4.12). The surface is generally smooth and has no spine or ornament. The total length is approximately 200–700 μm, and the maximum thickness (diameter) is approximately 10–50 μm.

Possible monaxon

Figs. 4.9, 4.10

Description: The specimens have a cylindrical spicule of a single axis. The shape of the spicule is flexuous. The end of the spicules was lost, and these specimens might not be derived from monaxons but other forms, such as tetractines. The surface is generally

Fig. 4. Spicules (1–17) and radiolarians (18, 19) from red-ocher chert (sample IT21080602b). (1) Style (monaxon). (2) Strongyloxea (monaxon). (3) Oxea (monaxon). (4–8, 12) Strongyle (monaxon). (9–10) Possible monaxon. (11) Anadiaene. (13, 15) Tetractine. (16, 17) Critriactine. (18, 19) *Quinqueremis* sp. aff. *Q. robusta* Nazarov and Ormiston sensu Blome and Reed (1992). Depository numbers: stub (2, 3, 7–10, 13–17): FMM06446; prepared slide (1, 4–6, 11, 12, 18, 19): FMM06447.

smooth and has no spine or ornament. The minimum length is approximately 800 μm, and the maximum thickness (diameter) is approximately 50 μm.

Anadiaene

Fig. 4.11

Description: This form has a cylindrical spicule of a single axis with two clads curved backward. One end of the spicule (another side of clads) is blunt. The surface is generally smooth and has no spine or ornament. The total length is approximately 300 μm, and the maximum thickness (diameter) is approximately 20 μm.

Critriactine

Fig. 4.16, 4.17

Description: This form has three co-planar spines with a spiral ornament. The end of the spines is hastate. The ornaments are dextrally spiral ribs. The length of each spine is approximately 200 μm, and the maximum thickness (diameter) is approximately 50 μm.

Tetractine

Figs. 4.13, 4.15

Description: This form has four possible co-planar spines. The end of the spine is unclear because it was lost. The spines taper. The surface is generally smooth and has no spine or ornament. The length of each spine is approximately 100–300 μm or more, and the maximum thickness (diameter) is approximately 50 μm.

Radiolarians

The specimens described here are possibly spicules of sponges and not radiolarians. However, the surfaces of sponge spicules are generally smooth or spinous, and grooves on sponge spicules are less commonly present. Instead, grooved arms are the general characteristics of the radiolarian family Ormistonellidae De Wever and Caridroit. Therefore, we regarded the specimens as radiolarians.

Assuming that the specimens are radiolarians, they resemble *Quinqueremis* sp. aff. *Q. robusta* sensu Blome and Reed (1992). The higher taxonomic classification of this species employs the scheme described by Noble et al. (2017).

Order LATENTIFISTULARIA Caridroit, De Wever and Dumitrica, 1999

Family ORMISTONELLIDAE De Wever and Caridroit, 1984

Genus *Quinqueremis* Nazarov and Ormiston, 1983

Type species: *Quinqueremis arundinea* Nazarov and Ormiston, 1983

Quinqueremis sp. aff. *Q. robusta* Nazarov and Ormiston, 1985 sensu Blome and Reed (1992)

Figs. 4.18, 4.19

Quinqueremis sp.: Sosson et al., 1984, pl. I, fig. 6.

Quinqueremis sp. aff. *Q. robusta* Nazarov and Ormiston: Blome and Reed, 1992, figs. 11.17, 11.18, 12.1.

Quinqueremis robusta Nazarov and Ormiston: Basir Jasin and Ali, 1997, pl. 2, fig. 7.
Sponge spicule: Ito and Matsuoka, 2015, fig. 7.21.
?*Quadriremis flata* Wang: Wang, 1993a, pl. IV, figs. 5–9; Wang, 1993b, pl. II, figs. 3, 4. Wang, 1995, pl. II, figs. 3, 6.
?*Ormistonella robusta* De Wever and Caridroit: Nakagawa and Wakita, 2016, pl. 9, figs. 8, 9.
?*Quinqueremis robusta* Nazarov and Ormiston: Wang, 1995, pl. II, fig. 3; Wang et al., 2012, pl. 17, figs. 17, 21.

Description: The specimens have four co-planar arms originating from a trapezoidal part. The arms are elongated and three-bladed. Although the arms were broken, the longest one is 200 μm in length, and the width is approximately 50 μm. The arms seem to taper, and each base of the arms is thicker than each confirmable end. The trapezoidal part seems to be unperforated.

Remarks: The specimens are closely similar to *Quinqueremis* sp. aff. *Q. robusta* sensu Blome and Reed (1992). The specimens resemble *Q. robusta* in outline; however, the arms of the species possess small pores in a single row (Nazarov and Ormiston, 1985). In contrast, the arms of *Q.* sp. aff. *Q. robusta* are characterized by deep grooves, similar to the specimens examined in this study.

Furthermore, both *Q. robusta* and *Q.* sp. aff. *Q. robusta* have a trapezoidal part with many small pores and one short vertical spine. The trapezoidal part of our examined specimens seems to be unperforated and to have no spine, although the preservation was poor.

Occurrences: The Cisuralian–Guadalupian (early–middle Permian) from North America (Sosson et al., 1984; Blome and Reed, 1992) and the Cisuralian from Malaysia (Basir Jasin and Ali, 1997) and Southwest Japan (Ito and Matsuoka, 2015).

Implications

Spicule assemblage based on recent sponges

Siliceous spicules from the Phanerozoic are generally considered to originate from sponges. Siliceous sponges are composed of two groups, i.e., demosponges and hexactinellids. The former group generally inhabits shallow seas and the latter deep seas. According to Murchey (2004), rhax, calthrops, desma, and protriaene are isolated from demosponges, whereas hexactine, birotula, and anadiaene from hexactinellids. Monaxon, including the strongyle, is common in both groups.

Our chert sample yielded dominant monaxon, common critriactine and tetractine, and rare anadiaene. Based on the classification of Murchey (2004), its origin was undetermined.

Siliceous spicule assemblages have been reported in some Permian strata (Ishiga and

Imoto, 1980; Kozur and Mostler, 1989; Liu et al., 2008; Ito et al., 2013, 2016). However, the spicules from our examined sample differ from those by having critriactine and lacking oxyaster or polyaxon. Further research in several areas and comparisons are necessary.

Significance of the spicular chert

In this study, we discovered a Permian spicular chert. This type of chert is well-known in the Permian, especially the Permian accretionary complex of the Akiyoshi belt (e.g., Uchiyama et al., 1986; Sano et al., 1987; Sano and Kanmera, 1988; Naka, 1995; Ito and Matsuoka, 2015). The Permian chert in the Akiyoshi belt is generally reddish in the author's observation (Ito and Matsuoka, 2015, 2016) and the previous studies. The present spicular chert presumably belongs to the Akiyoshi belt based on the current knowledge. Although Harayama et al. (1995) showed the distribution of Permian chert in the area, they considered it to belong to the Hida-Gaien belt.

The present results imply the presence of Permian spicular chert of the Akiyoshi belt to the east of Mt. Asahi-dake. An eastern extension of the Akiyoshi belt is distributed in the Itoigawa area, and Permian chert has been reported there (Hasegawa, 1985; Hasegawa et al., 2001; Kawai and Takeuchi, 2001; Kurihara et al., 2020). However, confirmable rock exposures of the Akiyoshi belt are located more than 10 km northeast from the sample locality (Nagamori et al., 2010), and some previous geological maps have shown no distribution of the Akiyoshi belt around Mt. Asahi-dake (e.g., Ito, 1966; Nakano et al., 2002; Takeuchi et al., 2004, 2017; Nagamori et al., 2010). Takizawa et al. (1995) also reported red chert with a possible Permian-type conodont from an area adjacent to our sample locality. Consequently, a certain amount of Permian chert is probably distributed in the area. As mentioned previously, the chert is exposed in the distributional area of the serpentinite; however, the detailed occurrence has not yet been determined. Further fieldwork should be conducted to update the geological map of the area.

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