Outline and history of the Itoigawa UNESCO Global Geopark in Niigata Prefecture in central Japan, with radiolarian occurrences in Itoigawa

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Abstract

The Itoigawa UNESCO Global Geopark is located in Itoigawa City, Niigata Prefecture in central Japan. This geopark was approved as a Global Geopark in 2009, which is one of the first Global Geoparks in Japan. The Itoigawa–Shizuoka Tectonic Line, which divides the Japanese Islands into Southwest Japan and Northeast Japan in the Cenozoic tectonic framework, lies in the central part of the City of Itoigawa. Various rocks, ranging in age from the Cambrian to Quaternary, and cultural legacies can be observed in the 24 geosites in this geopark. Silurian, Permian, Triassic, and Jurassic radiolarians have been discovered from Itoigawa.

Key words: radiolaria, UNESCO Global Geopark, geosite, Fossa Magna Museum, Itoigawa, Niigata Prefecture

Introduction

According to the Global Geopark Network, "*UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development*" [URL1].

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Table 1. Timeline of the geopark work in Itoigawa since 1987.

Itoigawa	World	Event
1987		The “Fossa Magna Region Development Plan” designed
1989		"Itoigawa City Museum Plan" designed
		Construction of Itoigawa Geopark began under above policy
1990		Fossa Magana Park (Outcrop of fault) opened
1991		Geosites in the city called “Geopark”
1994		Fossa Magna Museum opened
1996		Omi Natural History Museum opened
2000		"Niigata Nippo Cultural Award" in recognition of finding two new minerals from Niigata Nippo (newspaper company)
	2000	European Geoparks Network founded
	2001	European Geoparks Network and UNESCO committed
2002		"Sakurai Award" in recognition of research on new mineral, itoigawaite, from Mineralogical Society of Japan
2003		"Geological Society of Japan Honorable Recognition" in recognition of conservation and education of important outcrops in Itoigawa
	2004	Global Geopark Network founded
2005		Itoigawa City, Nou Town, and Omi Town merged
	2007	Japanese Geopark Liaison Council founded
2007		Statement to aim to be Itoigawa Global Geopark expressed
2008		Seven areas (Itoigawa, Toya Caldera and Usu Volcano, Mt. Apoi, Minami Alps, San’in Kaigan, Muroto, Shimabara Peninsula) approved as Japanese Geopark
2009		Examination of Global Geopark
		Itoigawa Global Geopark approved
		Global Geoparks Network affiliated
		Official mascot characters “Geomaru” and “Nuna” designed
		Itoigawa and Hong Kong geoparks committed as friendship geoparks
2010		Conference of Japanese Geopark Network held at Itoigawa
2012		Re-approval of Japanese Geopark examined
2013		Itoigawa Japanese Geopark re-approved
		Re-approval of Global Geopark examined
		Itoigawa Global Geopark re-approved
2015		Itoigawa GeoStation GeoPal opened
		Fossa Magna Museum renewed
		Global Geopark program approved by UNESCO
2016		Geoparks Niigata International Forum held
2017		Re-aproval of UNESCO Global Geopark examined
		InterRad XV in Niigata held

The Global Geopark Network comprises 127 Geoparks in 35 Member States as of May 2017.

The Itoigawa UNESCO Global Geopark has been a current member of the Global Geopark Network since 2009 (Table 1), which is one of the first Global Geoparks in Japan. In fact, the Fossa Magna Park in Itoigawa was opened as a "Geopark" in 1990. The European Geopark Network was founded in 2000. Consequently, this "Geopark" in Itoigawa was the first use of the word in the world although they differed in meaning.

One of the main attractions of the Itoigawa UNESCO Global Geopark is the exposures of various rocks in a wide age range. Among them, Permian basement rocks have yielded radiolarians (e.g., Tazawa et al., 1984; Ujihara, 1985; Kawai and Takeuchi, 2001). Our research group, comprising Niigata University, Itoigawa City, and the Geological Survey of Japan, AIST, has mainly studied upper Mesozoic neritic strata and has reported the occurrences of Triassic and Jurassic radiolarians from clasts within the strata (Ito et al., 2012, 2014; Sakai et al., 2012). Recently, our research group discovered late Silurian radiolarian assemblages from a siliceous rock pebble of a float block of conglomerate (Ito et al., 2017a, 2017b).

This article introduces the geologic outline of Itoigawa and a brief history of the Itoigawa UNESCO Global Geopark, that is the first "Geopark" in the world. In addition, this article shows radiolarian occurrences in the previous studies in Itoigawa. Finally, we introduce briefly two geosites in the geopark. In the Itoigawa UNESCO Global Geopark, the word "geosite" is used to refer to a designated, thematic region of geological significance.

Geologic outline of Itoigawa

The Japanese Islands are located near the boundaries of four tectonic plates, Eurasian (Amur), North American (Okhotsk), Philippine Sea, and Pacific plates (Fig. 1). The Itoigawa–

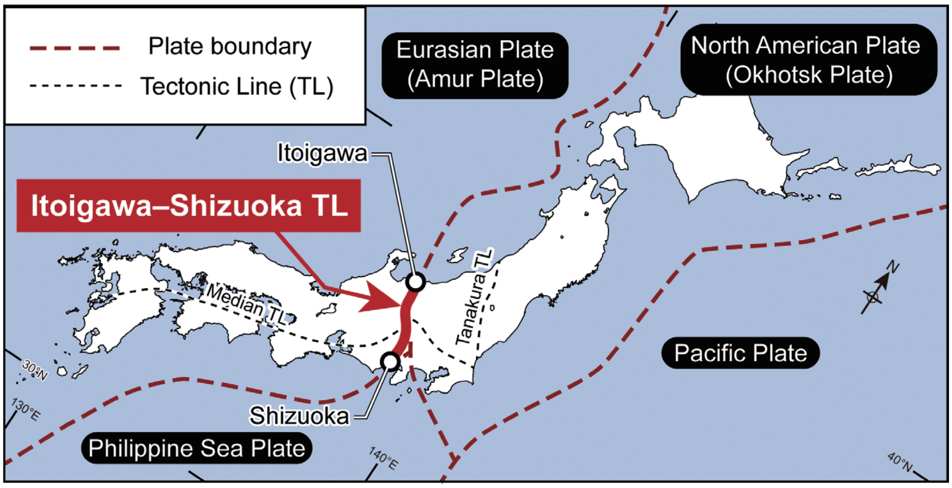

Fig. 1. Plate boundaries and major teconic lines of the Japanese Islands (based on Taira et al., 2016).

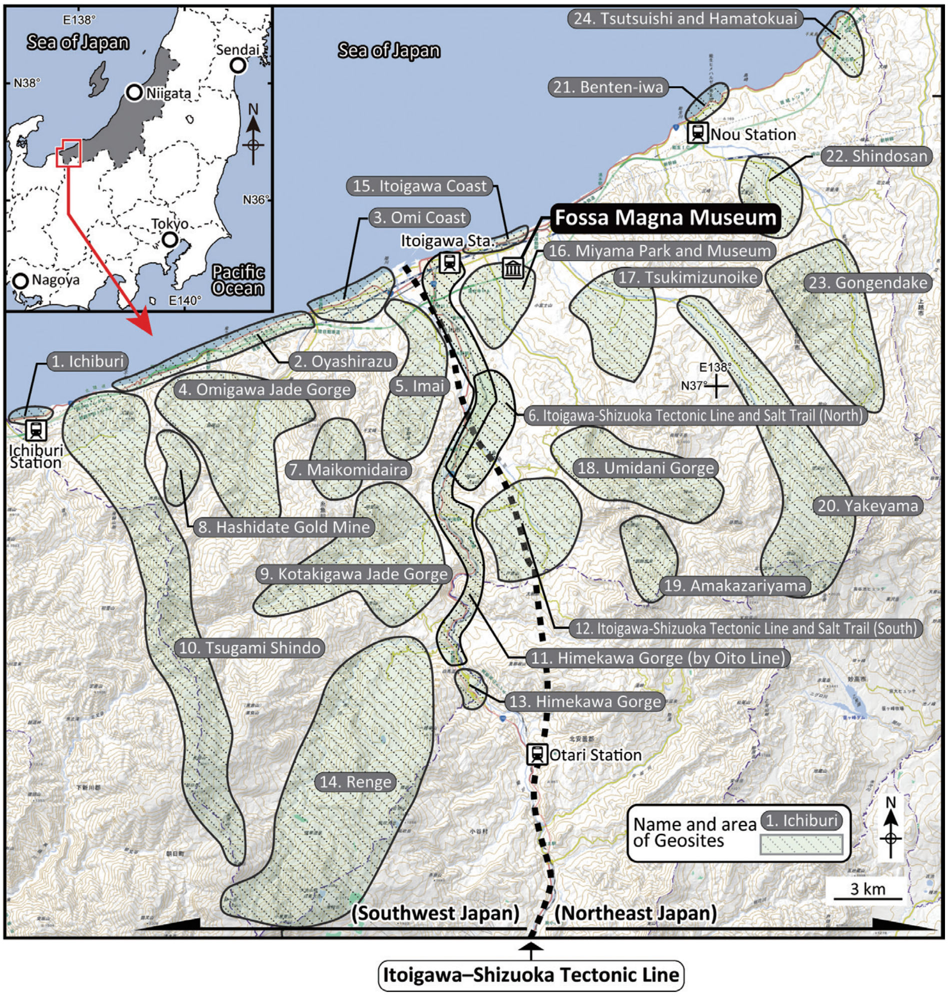

Fig. 2. Geosites in the Itoigawa UNESCO Global Geopark.

Shizuoka Tectonic Line, a massive fault line between the Eurasian and North American continental plates, lies in the central part of the City of Itoigawa. This tectonic line geologically divides the Japanese Islands into Southwest Japan and Northeast Japan in the Cenozoic tectonic framework (Fig. 2).

The City of Itoigawa, which borders the Sea of Japan, is located at the southwest end of Niigata Prefecture in central Japan. Various rocks are exposed in Itoigawa in spite of its small area (Fig. 3). This article follows the divisions of the geologic units, including their names and characters, shown by Nagamori et al. (2010) and Takeuchi et al. (2010, 2015a, 2015b). The Paleozoic and Mesozoic are mainly exposed in the west side of the Itoigawa–Shizuoka Tectonic Line whereas the Cenozoic is generally distributed over the east side of the line.

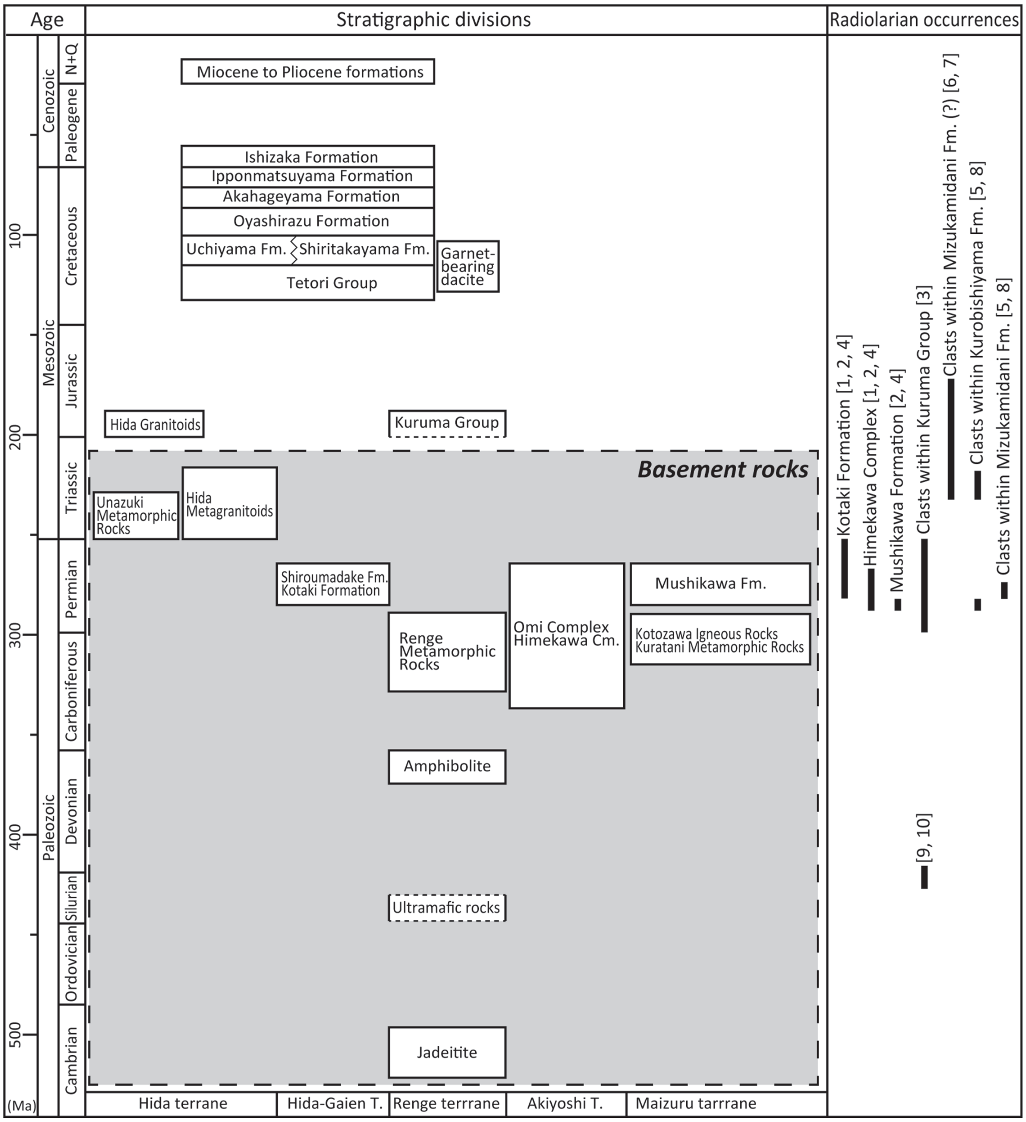

Fig. 3. Stratigraphic divisions of the Itoigawa (based on Nagamori et al., 2010; Takeuchi et al., 2010, 2015b), with previous radiolarian occurrences from tha area. Age is after Ogg et al. (2016). Quaternary deposits and the Quaternary Shirouma–Oike Volcano are omitted in this figure. Reference number: 1: Tazawa et al. (1984); 2: Ujihara (1985); 3: Kumazaki and Kojima (1996); 4: Kawai and Takeuchi (2001); 5: Tomita et al. (2007); 6: Ito et al. (2012); 7: Ito et al. (2014); 8: Takeuchi et al. (2015b); 9: Ito et al. (2017a); 10: Ito et al. (2017b).

1. Paleozoic

The Paleozoic is exposed mainly in the west part of Itoigawa. The Paleozoic in Itoigawa consists mainly of the following geologic terranes: Renge, Akiyoshi, Maizuru, and Hida-Gaien terranes.

The Renge terrane is composed mainly of the Carboniferous Renge Metamorphic Rocks, such as garnet amphibole schist, garnet biotite schist, chlorite schists, and muscovite schist, and Ordovician–Carboniferous amphibolite. Ultramafic rocks, of which age is unknown, consist of serpentinite and peridotite. In some areas, serpentinite mélanges include exotic blocks of amphibolite, jadeitite, and the Renge Metamorphic Rocks.

The Akiyoshi terrane in Itoigawa comprises the Carboniferous–Permian Omi Complex (Nagamori et al., 2010) and the Permian Himekawa Complex (Kawai and Takeuchi, 2001; redefined by Nagamori et al., 2010). The former complex consists of limestones and basalts, while the latter complex shows the repetition of chert–clastic sequences.

The Permian Maizuru terrane is composed of the Kuratani Metamorphic Rocks (Nagamori et al., 2010), the Kotozawa Igneous Rocks (Nagamori et al., 2010), and the Mushikawa Formation (Ujihara, 1985; redefined by Nagamori et al., 2010). The Mushikawa Formation consists of clastics, such as mudstones, sandstones, and breccias.

The Hida-Gaien terrane is composed of the Permian Shiroumadake and Kotaki formations. The Shiroumadake Formation (Takeuchi et al., 2001; redefined by Takeuchi et al., 2004) in Itoigawa consists of felsic tuffs and felsic tuff breccias whereas the Kotaki Formation (Nagamori et al., 2010) is characterized by greenstones, sandstones, mudstones, felsic tuffs, and cherts.

2. Mesozoic

The Mesozoic is exposed mainly in the west part of Itoigawa and comprises mainly Lower Jurassic marine–terrestrial deposits, Cretaceous terrestrial deposits, and Upper Cretaceous volcanic and intrusive rocks.

The Lower Jurassic Kuruma Group (Kobayashi et al., 1957) in Itoigawa, which overlies the Renge Metamorphic Rocks and the ultramafic rocks, comprises the Gamaharazawa, Odokorogawa and Yoshinazawa formations (Shiraishi, 1992), in ascending order. This group consists mainly of clastic rocks, such as mudstones, sandstones, and conglomerates, with tuffs.

The Lower Cretaceous Tetori Group (Oishi, 1933) in Itoigawa comprises the Mizukamidani Formation (Kobayashi et al., 1957; redefined by Takeuchi et al., 2015a) and the Kurobishiyama Formation (Takeuchi et al., 2015a), in ascending order. The former consists mainly of conglomerates, sandstones, and mudstones, while the latter is composed of sandstones and conglomerates. The Mizukamidani Formation had been considered to belong to the Kuruma Group (Kobayashi et al., 1957); however, recent studies considered that it belongs to the Tetori Group (Chihara et al., 1979; Sakai et al., 2012; Takeuchi et al., 2015a, 2015b).

The middle Cretaceous Uchiyama Formation (Takeuchi et al., 2015a) consists of conglomerates and sandstones including andesite, rhyolitic pyroclastic rock, and lava. The middle Cretaceous Shiritakayama Formation (Yoshimura and Adachi, 1976; redefined by Takeuchi et al., 2015a) consists mainly of coarser sandstones including granules and pebbles.

The Uchiyama and Shiritakayama formations are contemporaneous heterotopic facies (Takeuchi et al., 2015a). The Cretaceous Oyashirazu Formation (Chihara, 1955; redefined by Takeuchi et al., 2015a) consists mainly of andesitic tuff breccia. This formation overlies conformably the Uchiyama and Shiritakayama formations. The Cretaceous Akahageyama Formation (Chihara et al., 1979), which covers the Mushikawa Formation, consists mainly of clastic rocks and tuffs. The Upper Cretaceous Ipponmatsuyama Formation (Chihara et al., 1979; redefined by Shiraishi, 1992) consists of andesitic and dacitic tuff breccias.

3. Cenozoic

The Cenozoic is exposed mainly in the east part of Itoigawa. The Cenozoic in Itoigawa consists mainly of Neogene marine-terrestrial deposits and Pleistocene intrusive rocks. As mentioned previously, the Itoigawa-Shizuoka Tectonic Line, geologically dividing the Japanese Islands into Southwest Japan and Northeast Japan in the Cenozoic tectonic framework, lies in central Itoigawa.

The Paleogene Ishizaka Formation (Tomizawa and Kitahara, 1967; redefined by Ishii, 1976) is composed mainly of lapilli tuffs with rhyolite lava and basal conglomerates. This formation overlies unconformably the Ipponmatsuyama Formation and the Paleozoic.

The Miocene to Pliocene formations (e.g., Tokurayama, Yamamoto, Imai, Senno-zawa, Nechi, Umikawa, Tanne, and Atosugiyama formations) are distributed over the north part of the Itoigawa area (Nagamori et al., 2010). These formations consist mainly of pyroclastics and clastics.

Quaternary stratovolcanos are present in Itoigawa. The Shirouma-Oike Volcano and the Yakeyama Volcano are located in the southwest and southeast parts in Itoigawa,

Fig. 4. Volcanic fume of the Yakeyama Volcano, photographed at January 1st 2016.

respectively. Both volcanos consist mainly of andesite and dacite lavas and pyroclastics. The Yakeyama Volcano is an active volcano and its first volcanic activity started ca. 3,000 years ago (Hayatsu, 1994). In recent years, the Yakeyama Volcano fumes constantly (Fig. 4) and the small-scale eruption was observed in July 2016. Quaternary deposits, such as terrace deposits and roams, cover the older geologic units.

Radiolarian occurrences from Itoigawa

Since Tazawa et al. (1984) discovered Permian radiolarians, some researchers have reported radiolarian occurrences from Itoigawa. Paleozoic and Mesozoic radiolarian occurrences from Itoigawa are summarized in Fig. 3 and described below.

1. Permian radiolarians from siliceous and argillaceous strata

Permian radiolarians occurred in siliceous and argillaceous strata in several geologic units in the Japanese Islands, such as the Akiyoshi terrane (e.g., Sano et al., 1987; Ito and Matsuoka, 2015a, 2016), Maizuru terrane (e.g., Nishimura and Ishiga, 1987), Hida-Gaien terrane (Niko et al., 1987; Umeda and Ezaki, 1997), Ultra-Tamba terrane (e.g., Sugamori, 2011), Tamba–Mino–Ashio terrane (e.g., Ishiga and Imoto, 1980; Kuwahara, 1997), and Chichibu composite terrane (e.g., Kuwahara, 1992; Ito and Matsuoka, 2015b). Likewise, the Kotaki Formation (Hida-Gaien terrane), Mushikawa Formation (Maizuru terrane), and Himekawa Complex (Akiyoshi terrane) in Itoigawa yielded Permian radiolarians (Tazawa et al., 1984; Ujihara, 1985; Kawai and Takeuchi, 2001).

Pseudoalbaillella sp. aff. *P. longicornis* Ishiga and Imoto occurred in mudstone of the Kotaki Formation of the Hida-Gaien terrane (Tazawa et al., 1984). The specimen shown by Tazawa et al. (1984) resembles the short form of *Pseudoalbaillella fusiformis* (Holdsworth and Jones) sensu Ito et al. (2015a). *Pseudoalbaillella fusiformis* occurred generally in the upper Cisuralian (lower Permian) to the Guadalupian (middle Permian) (e.g., Ishiga, 1990; Zhang et al., 2010; Wang and Yang, 2011; Ito et al., 2015a).

Ujihara (1985) discovered *Pseudotormentus* sp. from siliceous mudstone of the Kotaki Formation. Although Schwartzapfel and Holdsworth (1996) described *Pseudotormentus delawarensis* Schwartzapfel and Holdsworth obtained from the upper Mississippian (Lower Carboniferous), *Pseudotormentus* occurred generally in all of the Permian (Ito et al., 2016). Kawai and Takeuchi (2001) reported occurrence of *Follicucullus* sp. from chert and siliceous mudstone of the Kotaki Formation. *Follicucullus* occurred generally in the Lopingian (Upper Permian) (e.g., Ishiga, 1990; Zhang et al., 2014).

Kawai and Takeuchi (2001) discovered *Pseudotormentus* sp. from cherts of the Himekawa Complex (Akiyoshi terrane), *Pseudoalbaillella fusiformis*, *F. porrectus*, and *Pseudoalbaillella monacanthus* from siliceous mudstones of the complex, and *Albaillella asymmetrica* Ishiga and Imoto from siliceous mudstone containing manganese carbonate spherules of the complex. *Pseudoalbaillella fusiformis*, *Pseudoalbaillella* sp. cf. *P. globosa* Ishiga and Imoto, *F. porrectus* Rudenko (originally described as *F. scholasticus* Ormiston and Babcock), and *Pseudoalbaillella monacantha* (Ishiga and Imoto) occurred in siliceous mudstones of the complex (Tazawa et al., 1984). The co-occurrence range of *Pseudoalbaillella fusiformis*, *Pseudoalbaillella monacantha*, and *F. porrectus* is restricted to the *F. porrectus* Interval Zone of the lower Capitanian, Guadalupian according to Zhang et al. (2014). The range of *A. asymmetrica* is restricted to the Kungurian of the Cisuralian according to Zhang et al. (2010).

Albaillella asymmetrica, Pseudoalbaillella fusiformis, and *Pseudoalbaillella longtanensis* Sheng and Wang occurred in mudstones of the Mushikawa Formation of the Maizuru terrane (Ujihara, 1985; Kawai and Takeuchi, 2001). These species co-occurred in the *P. longtanensis* Assemblage Zone of Ishiga (1990), corresponding to the Kungurian Age of the Cisuralian Epoch.

2. Permian–Jurassic radiolarians from clasts within the Mesozoic non-marine strata

Mesozoic non-marine strata in the Japanese Islands contain radiolarian-bearing clasts within conglomerate (e.g., Ishida et al., 2003; Ito et al., 2017c). Most previous studies have reported Permian–Jurassic radiolarian-bearing clasts within the Mesozoic in the Hokuriku region in central Japan (e.g., Saida, 1987; Takeuchi et al., 1991; Ito et al., 2015b). Siliceous and argillaceous rock clasts within the Kuruma Group and Mizukamidani (?) Formation in Itoigawa yielded Permian, Triassic, and Jurassic radiolarians (Kumazaki and Kojima, 1996; Tomita et al., 2007; Ito et al., 2012, 2014).

Kumazaki and Kojima (1996) reported *Pseudoalbaillella* sp. and *Pseudotormentus*? sp. occurred in siliceous mudstone clasts within conglomerates of the lower part of the Gamaharazawa Formation of the Kuruma Group. They however did not show their images. *Pseudoalbaillella* occurred in the Upper Carboniferous (Pennsylvanian) to the lower Permian (e.g., Holdsworth and Jones, 1980; Nazarov and Ormiston, 1986); *Pseudotormentus* occurred in the Permian (Ito et al., 2016).

Tomita et al. (2007) reported the occurrences of Permian and Triassic radiolarians, such as *Pseudoalbaillella* sp. cf. *P. fusiformis* and *Pseudostylosphaera japonica* Nakaseko and Nishimura, from chert clasts within the Lower Cretaceous Kurobishiyama Formation. Although Tomita et al. (2007) showed no radiolarian images, Takeuchi et al. (2015b) provided the images.

Follicucullus porrectus and *Pseudoalbaillella* sp. cf. *P. fusiformis* were discovered from mudstone clasts within the Lower Cretaceous Mizukamidani Formation (Tomita et al., 2007; Takeuchi et al., 2015b). These species occurred in the Guadalupian to Lopingian of the Permian (Zhang et al., 2014; Ito et al., 2015a).

Ito et al. (2012) found Middle to Late Triassic (Figs. 5.2, 6.5, 6.6) and Jurassic radiolarians

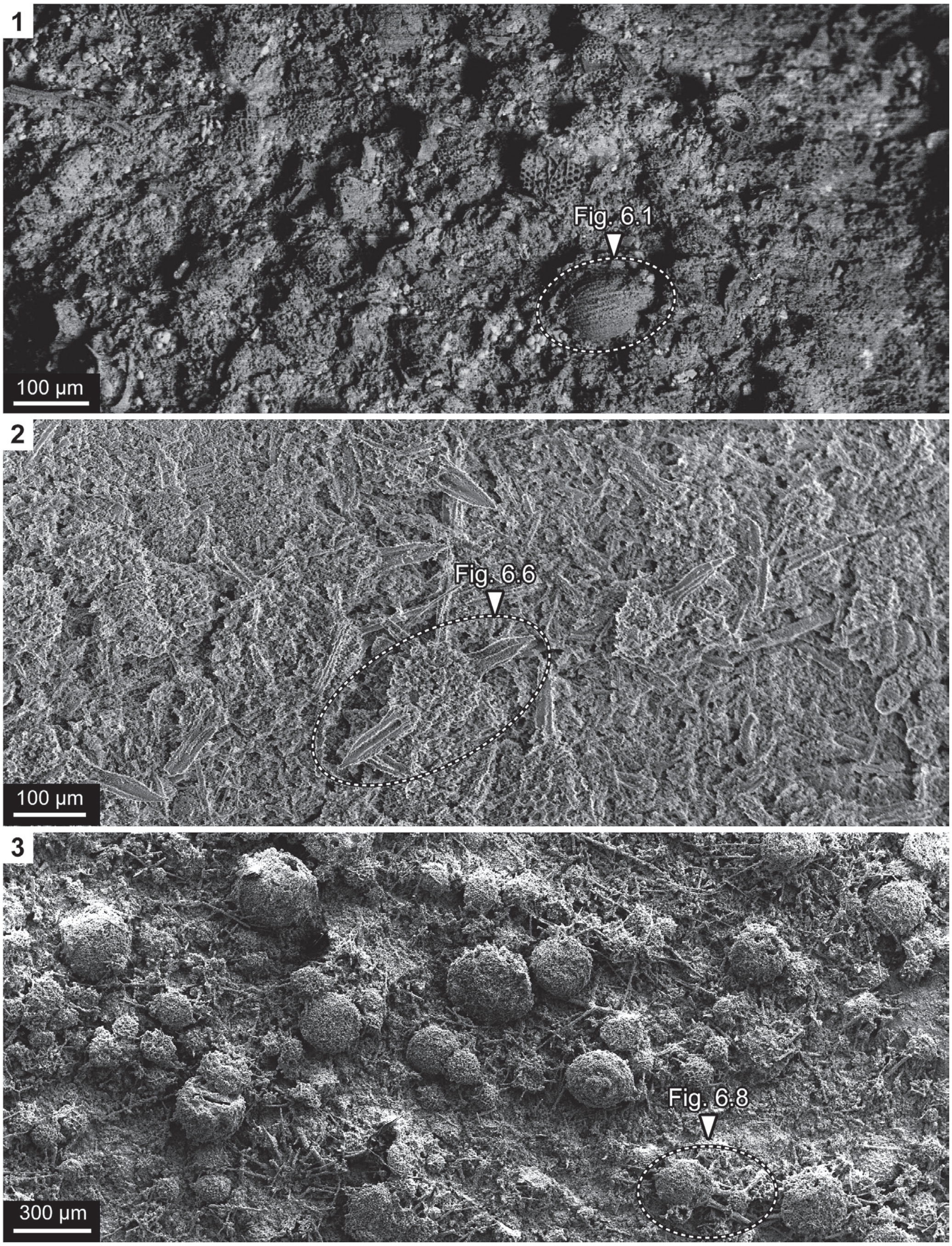

Fig. 5. Scanning electron microscope (SEM) images of the etched surfaces of pebbles within conglomerates in the Itoigawa area. **1:** Siliceous mudstone (IT12050102-1) from the Mizukamidani Formation (?) in Ichiburi; **2:** Chert (IT10050201-1) from the Mizukamidani Formation (?) in Ichiburi; **3:** Radiolarite (IY-FMM-K2) from float block in Kotaki.

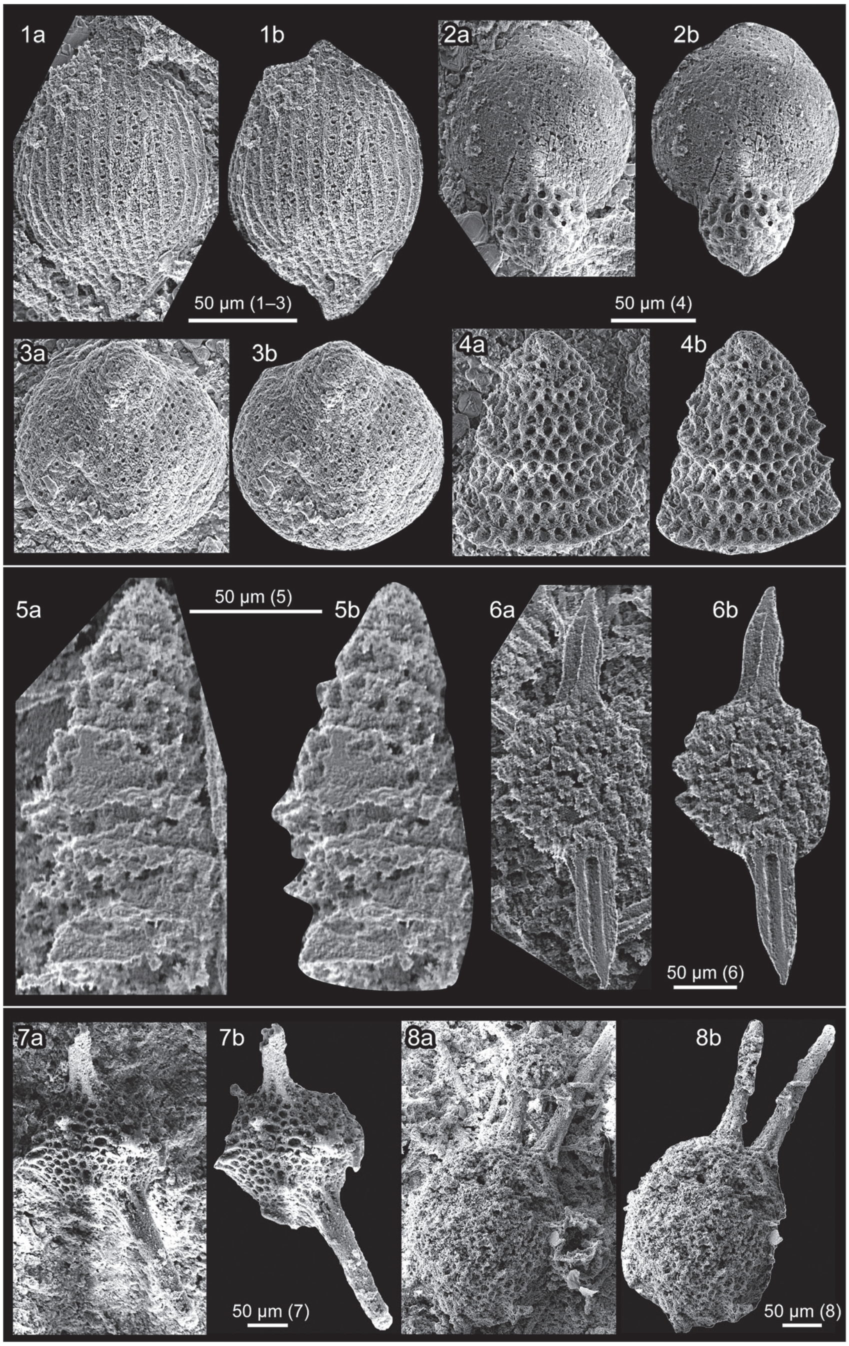

Fig. 6. Scanning electron microscope (SEM) images of radiolarians on etched surfaces (a) and trimmed images (b) from pebbles within conglomerates in the Itoigawa area. **1:** *Striatojaponocapsa plicarum* (Yao); **2:** *Cyrtocapsa mastoidea* Yao; **3:** closed nassellaria; **4:** *Parvicingula* sp.; **5:** multi-segmented Nassellaria; **6:** *Pseudostylosphaera* sp. cf. *P. japonica* Nakaseko and Nishimura; **7:** *Futobari morishitai* Furutani; **8:** Inaniguttidae gen. et sp. indet. 1–4: Siliceous mudstone (IT12050102-1) from the Mizukamidani Formation (?) in Ichiburi; 5, 6: Chert (IT10050201-1) from the Mizukamidani Formation (?) in Ichiburi; 7, 8: Radiolarite (IY-FMM-K2) from float block in Kotaki.

from chert clasts within conglomerates of sections exposed in the right bank of the Sakai River. Ito et al. (2014) obtained Bajocian to early Bathonian (Middle Jurassic) radiolarians (Figs. 5.1, 6.1–6.4) from siliceous mudstone clasts within the conglomerate of the same sections. Ito et al. (2012, 2014) assigned the conglomerate to the Mizukamidani Formation. Takeuchi et al. (2015a) however designated the sections as the type locality of the Shiritakayama Formation.

3. Silurian–Devonian radiolarians from a radiolarite clast within conglomerate of a float block

Ito et al. (2017a, 2017b) recently discovered a radiolarian assemblage from a radiolarite rock pebble of a float block of conglomerate, which was collected in the banks of the Kotaki River in the Kotaki area, Itoigawa. *Futobari morishitai* Furutani, Inaniguttidae gen. et sp. indet., and Palaeoscenidiidae gen. et sp. indet. were recognized on etched surfaces of the pebble (Figs. 5.3, 6.7, 6.8), whereas *Pseudospongoprunum* sp., *Zadrappolus* sp., and *Rotasphaera* sp. were discovered in residues obtained by chemically treating the conglomerate.

The former assemblage can be compared to that of the *Futobari solidus*–*Zadrappolus tenuis* Assemblage Zone of Kurihara (2004, 2007). The latter assemblage can be compared to that of the *Pseudospongoprunum tauversi* Assemblage Zone of Kurihara (2004, 2007). According to the U–Pb zircon dating by Manchuk et al. (2013), the age around the boundary between the *P. tauversi* and *F. solidus*–*Z. tenuis* assemblage zones is Ludlow to Pridoli (late Silurian).

The discovery was the first occurrence report of Silurian radiolarians in Niigata Prefecture, which was also the oldest fossil record in the prefecture. Additionally, the clasts are also one of the oldest radiolarian-bearing clasts within conglomerates of the Japanese Islands.

Stops in geosites

Twenty-four geosites are designated in the Itoigawa UNESCO Global Geopark (Fig. 1). These geosites deal with several themes ranging from geology to culture (Table 2). The City of Itoigawa is planning to publish pamphlets of all geosites. Among them, 21 geosites' pamphlets are currently published. They can be downloaded via the official webpage of the geopark [URL2]. In this section, we introduce outlines of two stops in the Geosite Nos. 9 and 16. Detailed explanations are shown in each pamphlet.

STOP 1. Kotakigawa Jade Gorge and Mt. Myojo (in Geosite No. 9)

The Kotakigawa Jade Gorge is located along the Kotaki River flowing along the south

Table 2. Geosites of the Itoigawa UNESCO Global Geopark and their themes .

No.	Name	Theme	Atractions
1	Ichiburi	Jade and Jurassic Fossils	Ichiburi Coast; Kikyoya Inn Site; Tamanoki Landslide; Ichiburi Customs Gate and Hackberry Tree; Jurassic fossils
2	Oyashirazu	A Cliff becomes a Highway	Tenken Oyashirazu; Oyashirazu Community Road; Katsuyama Fort Site; Letters on the Cliff; The Start of the Tsugami Shindo Trail
3	Omi Coast	Jomon Culture and Jade Coast	Omi Coast; Teraji Archeological Site; Lavender Beach; Suzawa Seaside Park and Omi Seaside Park; Salt Trail (Western Route)
4	Omigawa Jade Gorge	Geological Phenomena in the Depth of the Earth	Omigawa Jade Gorge; Albitite Boulders and New Minerals; Crystalline Schist Formations
5	Imai	Rocks and Formations Created alongside Fossa Magna	Fudotaki Falls; Mushikawa Customs Gate; Salt Trail (West Route); Suzawa Swamp Lanterns; Imai Mine Site; Yatsuroishi Quarry Site
6	Itoigawa–Shizuoka Tectonic Line and Salt Trail (North)	An Ancient Trail along a Gigantic Fault	Exposed Fault of the Itoigawa-Shizuoka Tectonic Line; Salt Trail (Matsumoto Highway); Pillow Lava; Utou
7	Maikomidaira	Karst Topography and Alpine Plants	Senrido Cave; Maikomidaira; Mt. Kurohimeyama; Byakurendo Cave
8	Hashidate Gold Mine	Remains of Itoigawa’s Largest Gold Mine	Remains of the Gold Mine Office; Millstone used to crush ore; Sakata Toge Pass
9	Kotakigawa Jade Gorge	Jade Boulders and the Great Rock Face of Mt. Myojo	Mt. Myojo; Kotakigawa Jade Gorge; Takanami-no-ike Pond; Jade Gorge Fishing Park; Great Limestone Face
10	Tsugami Shindo	From Coast to Peak, 3,000 Vertical Meters of Geo Trail	Mt. Korenge; Mt. Yukikuradake; Mt. Asahidake; Alpine Plants; Jurassic Fossils
11	Himekawa Gorge via Oito Line	Geotourism via the Oito Line	Itoigawa Station; Himekawa Station; Kubiki Ono Station; Nechi Station; Kotaki Station; Hiraiwa Station
12	Itoigawa–Shizuoka Tectonic Line and Salt Trail (South)	An Ancient Trail along a Gigantic Fault	Salt Trail; Shiroike Pond; Mt. Tokurayama; Interbeds of sandstone and mudstone; Salt Trail Museum; Bokkajaya Tea House and Shionomichi Hot Spring
13	Himekawa Gorge	Erosion and Denudation of Giant Mountains	Collapsed geology (colluvium) at Kuzuha Pass; Bokka Horse Chestnut—Once an important landmark for travelers; Himekawa River; Cenotaph for the Debris Flow Disaster
14	Renge	Volcanic Fumaroles and Glacial Wetlands	Heimanotaira Wetlands; Renge Onsen Outdoor Hot Springs; Shiraike Pond; Former Site of Renge Mine
15	Itoigawa Coast	Vanished Sand Dunes and the Jade Coast	Itoigawa Coast (Jade Coast); Sea of Japan Sunset Lookout; Souma Gyofu House; Itoigawa Museum of History and Folklore; Tanimura Art Museum and Gyokusuien Garden; Amatsu Shrine
16	Miyama Park and Museum	Geopark Information Center	Miyama Park; Poetic Monument of Gyofu Soma; Fossa Magna Museum; Chojagahara Archeological Museum and Chojagahara Archeological Site; Observation Tower
17	Tsukimizunoike	Landslides, Terraced Rice Fields and Stone Images of Buddha	88 Stone Buddha Pilgrimage; The Yamaguchi House - A Historic Snow Country Residence; Tsukimizu-no-ike Pond; Nikkoji Temple; Former Site of Fudoyama Castle; Terraced Rice Fields
18	Umidani Gorge	Scenic Highlands and a Large Cross Section of Submarine Volcano	Umidani Highland; Umidani Sankyo Park; Cliff of Mt. Senjogatake; Mt. Hachiyama; Mt. Komagatake
19	Amakazariyama	One of the 100 Famous Moutains of Japan—Beloved by Climbers	Mt. Amakazariyama; Sasadaira; Amakazari Lodge and Amakazari Hot Spring
20	Yakeyama	Hot Springs and Disaster Prevention beneath an Active Volcano	Mt. Yakeyama; Erosion Control Dam; Carbonized Trees at Kamihayakawa Elementary School; Standing Beech Trees
21	Benten-iwa	Maritime Culture Fostered by Submarine Volcanoes	Benten-iwa; Hakusan Shrine; Tottoko-iwa; Site of the Kodomari Landslide; Road Station "Marine Dream Nou"
22	Shindosan	Submarine Volcanoes and Traditional Farmland Scenery	88 Stone Steps of Mt. Shindosan; Beech Forest; Mt. Hokogatake; Shindosan Park; Sacred Birthplace of Princess Nunakawa
23	Gongendake	Curious Area of Deformation in the Mountains	Mt. Gongendake; Avalanche Protection Fences; Avalanche Trenches; Maseguchi Hot Springs District; Commemorative monument of the 1986 Maseguchi Avalanche
24	Tsutsuishi Hamatokuai	Beautiful Stratification and Traditional Fishing Villages	Interbeds of sandstone and mudstone; Tsutsuishi Station; Weeping Cherry Tree Road; Tsutsuishi Fishing Port

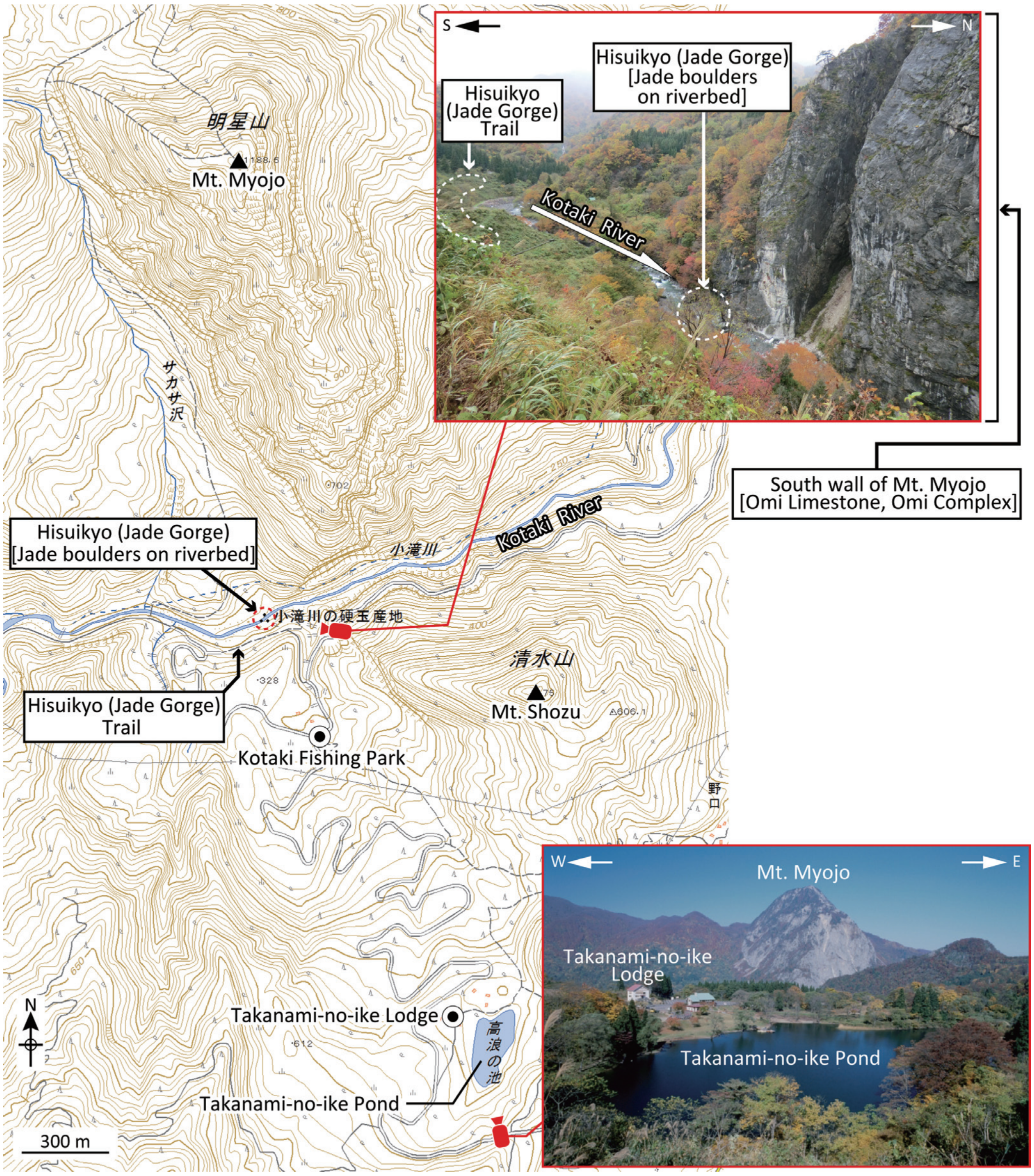

Fig. 7. Map of the Kotakigawa Jade Gorge Geosite (modified from topographic map "Kotaki" scale 1:25000 published by Geospatial Information Authority of Japan).

side of Mt. Myojo (Fig. 7). The Kotakigawa Jade Gorge was confirmed as the first natural source of jade in Japan in 1939 (Kawano, 1939), and was then designated as a natural monument of the nation in 1956 (Miyajima, 2010). Jade was established as the Municipal Stone of Itoigawa in 2008 and as the Niigata Prefectural Stone and National Stone of Japan in 2016.

Jadeitite, jadeite-albitite, and albitite lie as float blocks along the river bed of the Kotaki

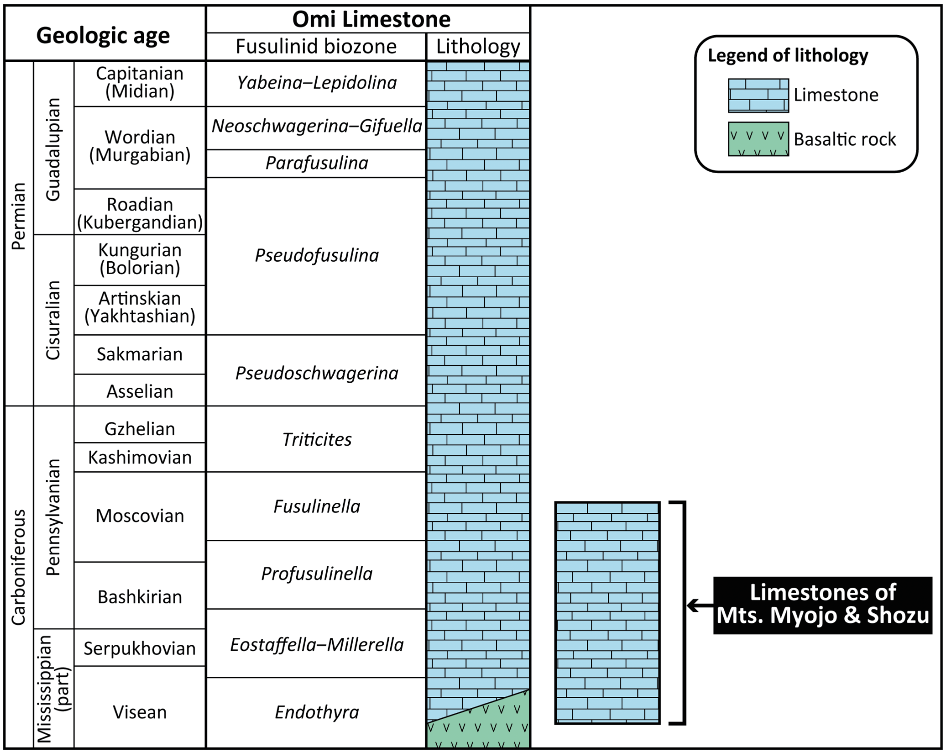

Fig. 8. Fusulinid biostratigraphy and lithology of the Omi Limestone with limestones of Mts. Myojo and Shozu (based on Hasegawa and Goto, 1990).

River (Takeuchi et al., 2015b). The jade-bearing rocks were derived from serpentines near the Kotaki River at the Kotakigawa Jade Gorge (Iwao, 1953). The serpentines are located between Carboniferous–Permian limestones of the Omi Complex of the Akiyoshi terrane and the Permian Kotaki Formation of the Hida Gaien belt (Takeuchi et al., 2015b).

Mounts Myojo and Shozu are located in the southernmost part of the distributional area of the Omi Limestone. The Omi Limestone, belonging to the Omi Complex of the Akiyoshi terrane, ranges from the Mississippian (Early Carboniferous) to the Guadalupian (Middle Permian) based on the fusulinid fossils (Hasegawa and Goto, 1990). Because of the absence of terrigenous clastics within the Omi Limestone, the seamount had been situated in an open-ocean setting (e.g., Nakazawa, 2001). Figure 8 shows fusulinid biostratigraphy of the Omi Limestone. Hasegawa and Goto (1990) stated that Mts. Myojo and Shozu are composed mainly of limestones of the *Endothyra*, *Eostaffella–Millerella*, *Profusulinella*, and *Fusulina–Fusulinella* zones.

A visitor can approach the Kotaki River from the Hisuikyo (Jade Gorge) Trail (Fig. 7). Several kinds of pebble and cobble are observable in the Kotaki River. Mount Myojo can be seen well from a viewing deck on opposite bank of Mt. Myojo.

STOP 2. Fossa Magna Museum (in Geosite No. 16)

The Fossa Magna Museum was opened in 1994 and then it was renovated in March 2015 (Table 1). The museum displays several exhibits (Fig. 9). Jade, the municipal stone of Itoigawa and national stone of Japan, can be seen in several places in the museum, such as in the courtyard (Fig. 9A) and the entrance of the exhibit rooms (Fig. 9B). Various fossils collected from Itoigawa and other areas are exhibited (Fig. 9C). Exhibits introduce the biography and works of Dr. H. E. Naumann, known as the discoverer of the Fossa Magna (Fig. 9D). A preparing peel of pyroclastic flow deposits of Mt. Yakeyama (Fig. 9E) and a replica of marine deposits in the Japan Sea (Fig. 9F) show geologic characteristics around Itoigawa.

The Fossa Magna Museum is located in Miyama Park, which is one of the geosites of the Itoigawa UNESCO Global Geopark. The Chojagahara Archaeological Museum and the Chojagahara Archaeological Site, a Nationally Designated Historical Site, are also in Geosite No. 16. The oldest jadeite artifacts in the world, made by Japanese indigenous Jomon people, were discovered from the Chojagahara Archaeological Site. The artifacts are exhibited in the Chojagahara Archaeological Museum.

Concluding remarks

Various rocks ranging in age from the Cambrian to Quaternary are exposed in Itoigawa, indicating its potential for several studies, such as geologic, paleontological, and petrological ones. Furthermore, the Itoigawa–Shizuoka Tectonic Line lies in the central part of the City of Itoigawa, also indicating the potential for studies of structural geology and Cenozoic tectonic framework in East Asia. In contrast to the investigative potential, there remains much to be researched in Itoigawa. We expect that several researchers will explore the frontiers of Itoigawa.

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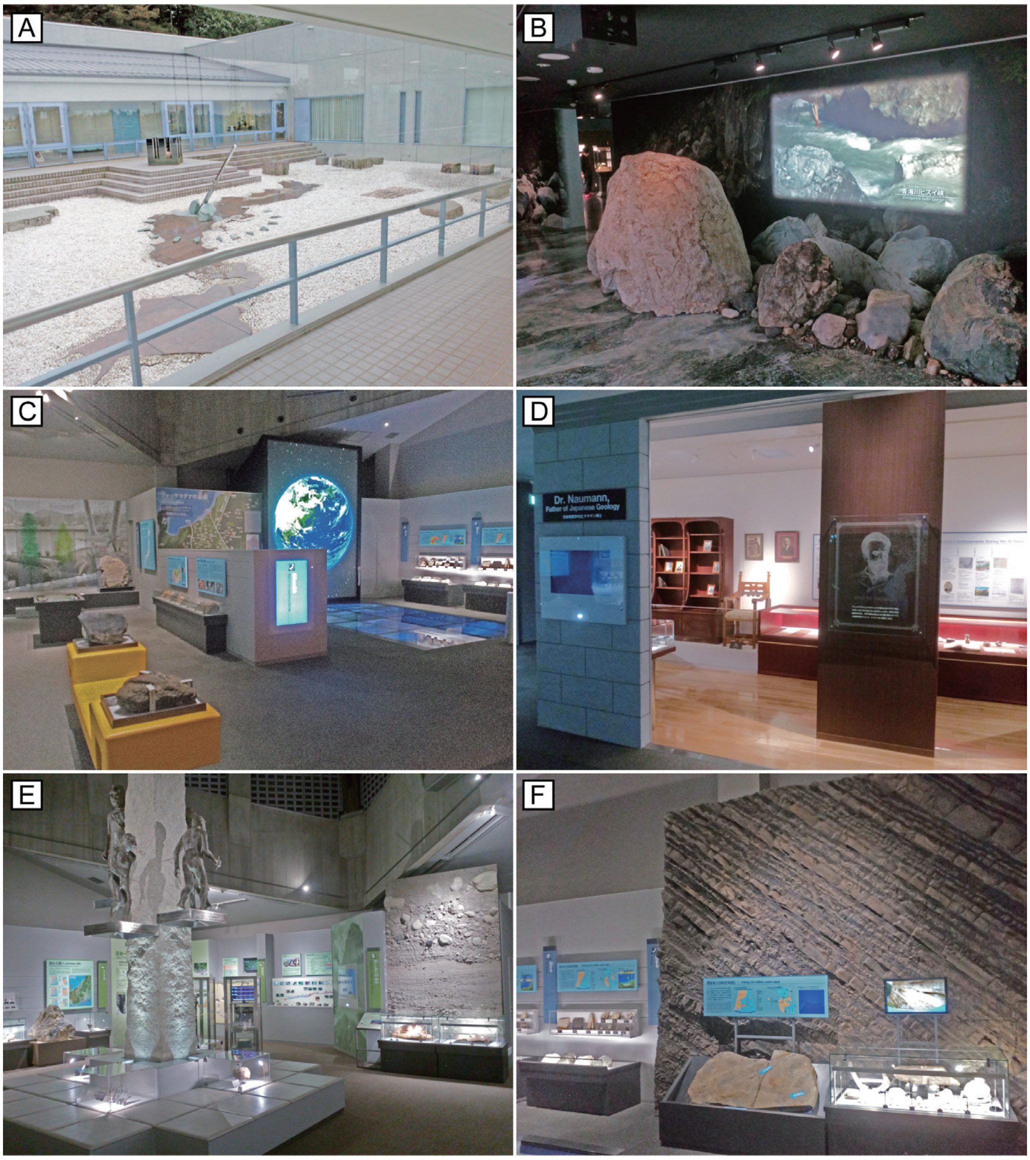

Fig. 9. Fossa Magna Musuem in Itoigawa, Niigata Prefecture, central Japan. **A:** Solar clock of jade stones on stone-clad Japanese Islands in the courtyard. **B:** Large jade gemstones at the entrance of the exhibit rooms. **C:** Fossa Magna Theater showing the birth of the Japanese Islands. **D:** Introduction of the lifetime of Dr. H. E. Naumann and exhibition of his works. **E:** Figures of hominids and preparing peel of pyroclastic flow deposits of Mt. Yakeyama. **F:** Replica of marine deposits in the Sea of Japan in 12 Ma.

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