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Chert-clastic sequence of the Yamizo Group in the southern Keisoku massif, central Japan

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Abstract

An outcrop consisting of bedded chert, siliceous shale and alternating shale and sandstone was confirmed over a length of about 50 m in the construction site of the Dono-ike Maintenance Project in Kasama City, Ibaraki Prefecture. This site belongs to the southernmost part of the Keisoku massif. Bedded chert is overlain by siliceous shale, and then siliceous shale is overlain by alternating shale and sandstone. In this study, radiolarian fossils useful for dating could not be obtained from bedded chert, but it can be regarded as a chert-clastic sequence based on its lithological gradual and transitional change. The ill-preserved radiolarian fossils result probably from thermal effect of local granite intrusion. The section reported here may correspond to the relatively less deformed part in the chaotic facies of the Kasama unit as parts of the Jurassic accretionary prism.

Keywords: Chert-clastic sequence, Jurassic, Accretionary prism, Kasama unit, Yamizo Group.

Introduction

The Japanese Islands include Permian, Jurassic, and Late Cretaceous-Cenozoic accretionary prisms; among them, the Jurassic accretionary prism is distributed over a larger area. In the Nankai Trough, where the Philippine Sea Plate is subducting, the accretionary prism is formed on the island side. Ogawa and Hisada (2005) summarized the characteristic elements of the internal structure of accretionary prisms. Regarding these as important elements, one of the characteristics of the accretionary prism is that the pelagic to hemipelagic rocks are conformably overlain by and in contact with faults in the terrestrial coarse-grained clastics within each thrust sheet. This sequence is referred to as ocean plate stratigraphy, which includes basalt and limestone (Ogawa and Hisada, 2005).

Ocean plate stratigraphy is characterized by the inclusion of basaltic seamounts capped by coral reef limestone. Thus, it represents the ocean floor basalt, basalt accompanied with limestone, chert, and siliceous shale as pelagic and hemipelagic sediments, and terrigenous turbidite, in ascending order (i.e., Wakita, 1997). In general, however, parts of chert, siliceous shale and turbidite are defined as chert-clastic sequences (Matsuoka, 1984; Otsuka 1985). These sequences suggest sediment accumulation due to plate motion toward a trench from an oceanic ridge. Black claystone, which is often intercalated within the chert, formed during the ocean floor anoxic event during the Permo-Triassic boundary, and later became a slip surface at the time of accretion to the continental side (e.g. Nakae 1993). In other words, because ocean plate stratigraphy is separated into upper and lower parts, the lower part is brought deeper by the subducting plate and the upper part is incorporated into the accretionary prism (Isozaki and Maruyama, 1991). Therefore, the chert-clastic sequence is considered an important element of the accretionary prism on land.

The Yamizo Group is distributed in the Yamizo Mountains, whichi are divided into the Yamizo, Torinoko, Keisoku and Tsukuba massifs from the north to the south. The

Yamizo Group in the Keisoku massif has been geologically studied for a long time (e.g. Kawada, 1953; Kanomata, 1961). In this study, the name of the Yamizo Group and its contents were based on Metal Mining Agency of Japan (1987). That is, the sedimentary age of the Yamizo Group was considered to be Permian to the Early Cretaceous. Later studies reported that the Yamizo Group is in fact a Jurassic accretionary prism (Hori and Sashida, 1998; Sashida and Hori, 2000), and the source rocks of the Mt. Wagakuni and Tsukuba metamorphic rocks of the Tsukuba massif are also part of the group (Miyazaki et al., 1996).

In August 2017, the appearance of chert outcrops over a length of approximately 50 m at the construction site of the Kasama City Dono-ike Maintenance Project was verified (Fig. 1). This study investigated the occurrence and significance of the outcrops. In the field survey, route maps were created, and outcrop photographs and/or sketches and chert samples were collected. This paper will describe the occurrence of the chert-clastic sequence here and briefly discuss its geologic significance.

Geological outline of the Keisoku massif

Fujimoto and Hatakeyama (1938) reported the occurrence of fusulinids in the Keisoku massif. Kawada (1953) corrected the ages of the Keisoku Group from the Upper

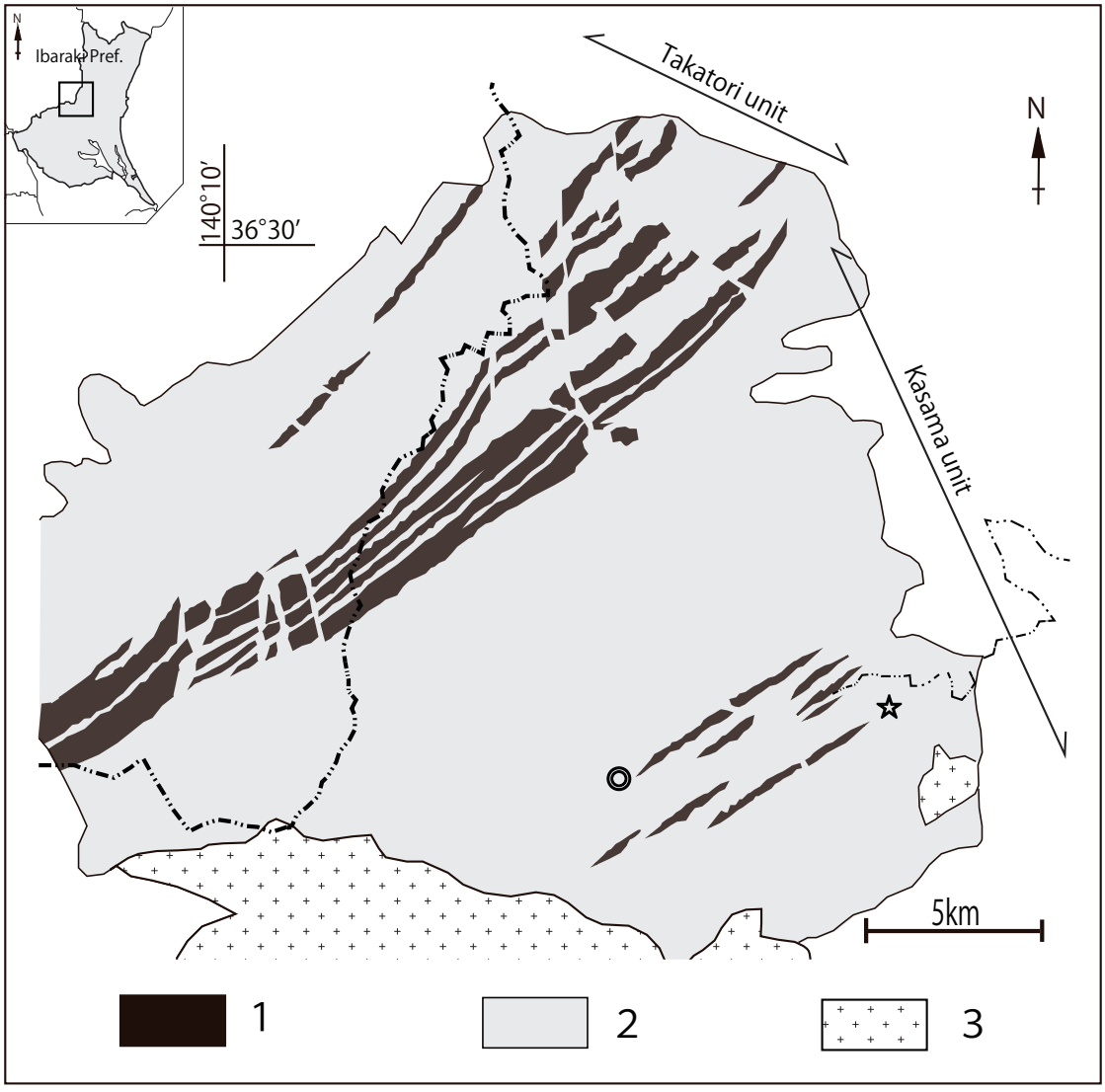

Fig. 1. Location of the present study and distribution of chert in the Keisoku massif.

1; chert, 2; shale and sandstone, 3; granite (1-3; after Seamless Digital Geological Map of Japan (1:200,000), Geological Survey of Japan, AIST(ed.) (2019; Renewal, July 1). Double circle; location of the present study, star mark; after Sashida and Hori (2000). The ranges of Takatori and Kasama units are based on Sashida and Hori (2000).

Carboniferous to the Permian based on the ages of the fusulinids. Kanomata (1961) divided the stratigraphy of the Keisoku massif into the Permian Kasama Group and the Mesozoic Yamizo Group. In studying this age assignment, however, it has been pointed out that "the percentage method using radiolarian fossils in thin-sections has no biostratigraphic meaning at present" (Hori and Sashida, 1998, p495). Later, Igo (1972) reported Triassic conodont fossils from the chert exposed in the northeastern part of the Keisoku massif, while Suzuki and Sato (1972) reported Late Jurassic Oxfordian ammonites from the black shale in the western part.

The occurrence of radiolarian fossils has been reported in many areas of the Mino Belt, western extension of the Keisoku massif. Research on structural stratigraphy based on the framework of accretionary prism geology and radiolarian fossil stratigraphy has also progressed in the Keisoku massif. The tectono-stratigraphic unit consisting of the accretionary prism is based on the characteristics of the ocean plate stratigraphy (i.e., the lithological combination and its ages) and the degree of deformation (Nakae, 2001).

From the northwest side of the Keisoku massif, which belongs to the Jurassic accretionary prism, tectono-stratigraphic units are the Ayuda, Takatori, Kunimiyama, and Kasama units (Hori and Sashida, 1998). The Ayuda unit consists of alternating sandstone and shale and pale green shale. The Takatori unit repeats the chert-clastic sequence, which is accumulated in the stratigraphic order of chert, siliceous shale, and clastics from the bottom, three or four times. The Kunimiyama unit consists of sandstone-dominant alternating layers of sandstone and shale. The Kasama unit consists of alternating sandstone and shale with subordinate chert.

Later, Sashida and Hori (2000) redefined the above four units and grouped them into two: Kasama unit (redefined) and Takatori unit (redefined) (Fig. 1). The new Kasama unit consists of a combination of the lower chert-clastic sequence repetition (Kasama unit) and the upper coarse-grained clastic rock (Kunimiyama unit). In contrast, the new Takatori unit is also composed of the lower Takatori and upper Ayuda units with the same lithological feature.

Sashida and Hori (2000) confirmed the following sequence of the Kasama unit on the forest road near Kanayama, Yatsu-cho, Mito City (Fig. 1): light green shale including lenticular sandstone, bluish green chert, red tuff, light green shale, alternating sandstone and shale mainly composed of sandstone, and massive sandstone, in ascending order. The chert, siliceous mudstone, and sandstone mudstone is assigned to the Early Triassic to Early Jurassic, Middle to Late Early Jurassic, and Late Jurassic, respectively (Sashida and Hori, 2000; Hori, 2008; Kasai et al., 2000).

Kasai et al. (2000) investigated the Jurassic accretionary prism in the northern part of the Keisoku massif and confirmed that the chert-clastic sequence was repeated six times in the part corresponding to the Takatori unit (redefinition) of Sashida and Hori (2000). Moreover, based on conodonts and radiolarian fossils, the geological age of the chert-clastic sequence was inferred to be Early Triassic to Late Jurassic.

Recently, based on the unit division of Hori and Sashida (1998), the Abukuma Mountains Rock Minerals Study Group (Yamizo Mountains Party) (2013) identified overturned layers (Kasai, 1978) with a thickness of about several hundred meters in the Kunimiyama unit of the Keisoku massif. This suggests that the Kunimiyama unit has developed an inclined fold with a half-wavelength of 1 km or more.

Lithology of sequence

At the outcrops exposed on the east and west banks of Dono-ike pond (Fig. 2), a stratigraphy of the chert-clastic sequence was observed. However, siliceous claystone at the bottom was not detected.

This was confirmed by the continuous upward outcrops of the stratigraphy of bedded chert, siliceous shale with intercalation of black shale, and alternating and shale sandstone (Fig. 3). In addition, some of the above sequences were confirmed on the opposite bank of the pond. Although it has been deformed, the strike and dip were approximately N70–80° W and 60–70° N, respectively (Fig. 3). In addition, the upper part was covered by the Kanto loam, which is Pleistocene volcanic ash. In peculiar, the Akagi-Kanuma Tephra (ca 44 ka; Yamamoto, 2013) is noticeably developed in the Kanto loam. The Kanto loam is also partly covered by soil from conversion (=soilization).

Bedded chert

The bedded chert was exposed to the east bank of the Dono-ike pond. The single layer of the bedded chert had a thickness of 3–10 cm (Fig. 4). It was deformed as a whole, and slightly deformed in the kink band with a width of about 50 cm and the shear band with a width of 2–3 m. The folds were well developed. Moreover, there was a clear transition to the siliceous shale at the top (Fig. 5). The color of the chert was grayish white at the bottom and dark gray from the middle to the top.

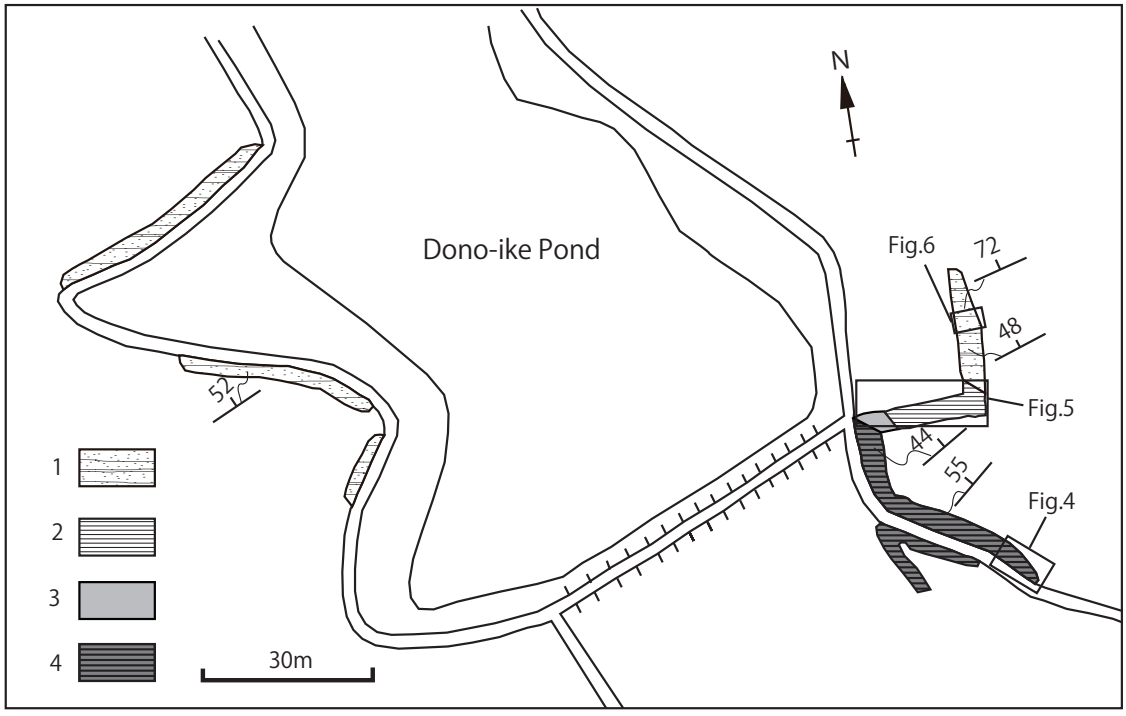

Fig. 2. Route map around Dono-ike pond Park. 1; alternating shale and sandstone, 2; black shale, 3; siliceous shale, 4; bedded chert.

Fig. 3. Panoramic view of chert-clastic sequence at Dono-ike Pond Park.

Siliceous shale

It had a black to dark grayish-green color and a slightly clear bedding surface (Fig. 5). The black part is not so siliceous and is referable to black shale. The layer thickness was approximately 5–7 m, and it gradually shifted to the upper alternating shale and sandstone.

Fig. 4. Bedded chert. See at Fig. 2 for its location.

Fig. 5. Transitional zone from bedded chert to siliceous shale. See at Fig. 2 for its location.

Alternating shale and sandstone

In the lower part of the alternating shale and sandstone, shale and siliceous shale were relatively predominant, and the massive sandstone was lens-shaped (Fig. 6). In general, the sandstone was generally fine-grained, and some sandstone lenses were included in the shale. The massive sandstone tended to increase in the upper part. The shale, including the sandstone lens, was also distributed on the opposite bank of the pond and correlated to the upper part.

Preservation degree of radiolarians

In this study, the usual methods where radiolarian fossils were extracted from the bedded chert were adopted. The extraction was carried out by soaking the radiolarian specimens in 5% hydrofluoric acid for approximately 12 h, following the extraction method of Pessagno and Newport (1972). The extracted radiolarian specimens were spherical and did not show any patterns or ornaments peculiar to radiolarians on the surface. Therefore, it is difficult to identify radiolarians and to estimate the geological age. Such spherical shells are often extracted from chert in contact with granite; it is considered that

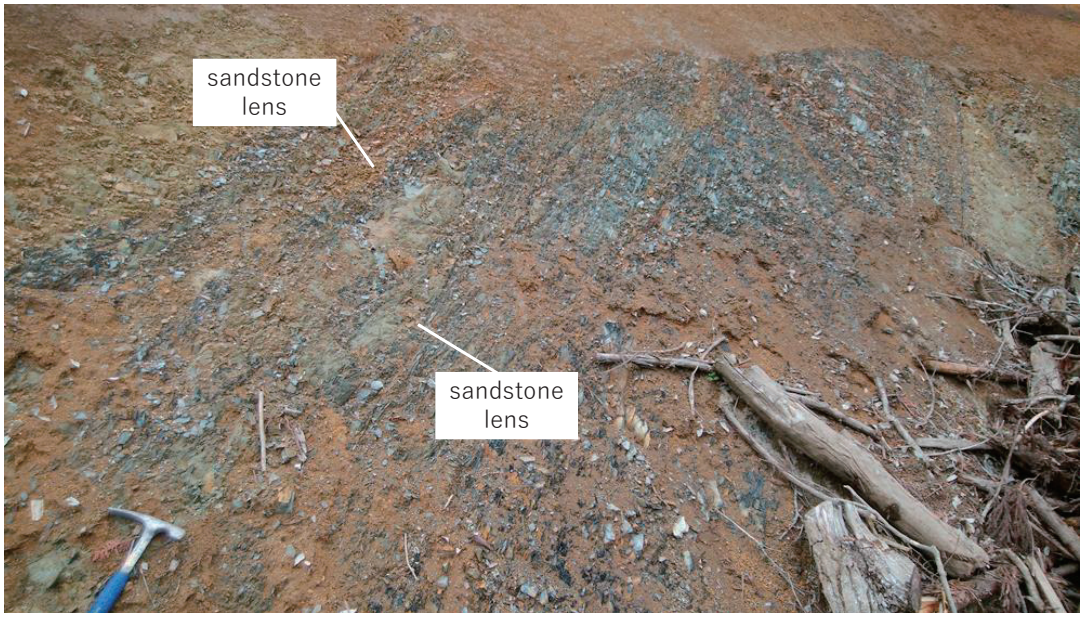

Fig. 6. Alternating shale and sandstone. See at Fig. 2 for its location. Note that sandstone layers present lens-shaped.

quartz is recrystallized by the thermal effect of contact metamorphism, and the original ornament and pattern of the radiolarian shells are almost lost.

Discussion; significance of the sequence

The sequence in the Yamizo Group appeared during the construction of Dono-ike pond Park., and the sequence had a thickness of approximately 45 m. The depositional ages of each bed could not be examined by radiolarian fossil age. On the other hand, the continuous upward outcrops of the stratigraphy of bedded chert, siliceous shale, and alternating shale and sandstone was confirmed. Considering the findings of previous studies, it is highly possible that it is a chert-clastic sequence. No fault development was observed at the boundary of each lithology, which was characterized by the appearance of a consistent gradual transition.

The geological maps showing the chert exposure around Dono-ike pond Park were obtained from Geological Survey of Japan (2019), Abukuma Mountains Rock and Mineral Research Group (Yamizo Mountains Party) (2013), and Metal Mining Agency of Japan (1987). There is no existing report of chert exposure in the Dono-ike pond Park; the present study is a pioneering effort in that regard.

The Takatori (redefined) and Kasama units (redefined) are extensively distributed in the Keisoku massif (Sashida and Hori, 2000; Hori, 2008). Hori (2008) points out that the lower part of the Takatori unit is characterized by an imbricate structure in which the chert-clastic sequence repeats several times, and the lower part of the Kasama unit develops chaotic lithology. The chert-clastic sequence found this time can be considered a part of a chert-clastic sequence rather than a chaotic lithology. It is generally understood that chaotic lithology, including chert blocks, is formed by the progress of deformation from the chert-clastic sequence underplated on the accretionary prism (Wakida, 2000). The apparent conformable sequence of bedded chert, siliceous shale, and alternating shale and sandstone reported in this study may correspond to the less deformed part of the chaotic lithology of the Kasama unit (redefined).

Conclusion

The chert-clastic sequence discussed in this paper has not been reported in the Kasama unit of the southern Keisoku massif. It is considered an important reference for examining the accretionary prism geology of the Yamizo Mountains.

Acknowledgments

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