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Report

Radiolarian age of Triassic striped chert within the Jurassic accretionary complex of the Ashio terrane in the Ashikaga area, Tochigi Prefecture, central Japan

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Abstract: A striped structure within a single chert bed has been observed in the Tamba–Mino and Ashio terranes, Jurassic accretionary complexes of the Inner Zone of Southwest Japan. This study reports striped chert beds in four sections of the Ashio terrane in Ashikaga and Sano cities of Tochigi Prefecture, namely, Hikoma, Oiwa, Tsukiya and Orihime sections, and their radiolarian ages, except for the Hikoma section. The striped chert comprises streaks and spacing. The streak indicates a thin part of a pin-striped structure within a chert bed and consists mainly of clay minerals. The spacings indicate a thick part between the streaks and is composed mainly of cryptocrystalline quartz. The Oiwa section, which contains numerous striped chert beds, partially corresponds to the middle Carnian–middle Norian (Upper Triassic). The Tsukiya and Orihime sections, which include a few striped chert beds, partially correspond to the middle–upper Anisian (Middle Triassic) and upper Norian–lower Rhaetian (Upper Triassic), respectively.

Keywords: radiolaria, accretionary complex, Ashio terrane, striped chert, Triassic

1. Introduction

Chert is a hard and dense microcrystalline or cryptocrystalline sedimentary rock (Bates and Jackson, 1984) and is one of the major components of Jurassic accretionary complexes (ACs) of East Asia. The age of chert had not been determined because index fossils were unobtainable. Extraction methods for microfossils such as conodont and radiolaria had been proposed in the 1960s to 1970s (e.g. Hayashi, 1968, 1969; Pessagno and Newport, 1972). This development made microfossils valuable age indexes and allowed the age of the Jurassic ACs to be clarified in the strata which had been treated as the Paleozoic (e.g. Yao and Mizutani, 1993; Isozaki *et al.*, 2010; Agematsu-Watanabe and Kamata, 2018). The age of chert within the Jurassic ACs ranges from Pennsylvanian (Carboniferous) to Late Jurassic (e.g. Matsuoka *et al.*, 1998; Nakae, 2000).

As stated above, microfossils within chert such as radiolaria are valuable index fossils. However, they cannot be always obtained from chert because of several reasons such as the diagenetic effect. The determination of an alternative age index for chert would be valuable for the investigation of geologic units without fossils.

The author discovered a striped structure within a single chert bed in the Ashikaga area of Tochigi Prefecture, Japan. The structure was reported from the Tamba–Mino and Ashio terranes in the previous studies (e.g. Iijima *et al.*, 1978; Kido, 1982; Yoshimura *et al.*, 1982; Kakuwa, 1991; Nikaido and Matsuoka, 2008, 2009, 2011). Based on these previous studies, the occurrences of the striped chert might be dominant in a specific age.

This study describes the striped chert beds in the Ashikaga area and determines their microfossil ages. Furthermore, the ages of striped chert reported in the previous studies are compiled for future references. This information would contribute to the discussion about the potential of the striped chert as an alternative age index for the Jurassic ACs in the Tamba–Mino and Ashio terranes.

2. Previous studies on the striped structure and terminology

Structures within chert beds were described in several international studies, particularly in the 1970s (e.g. Davis, 1918; Bastin, 1933; McBride and Thomson, 1970; Folk, 1973; Lowe, 1976; McBride and Folk, 1979). A research group from the University of Tokyo studied structures within the chert beds within the Jurassic ACs of Southwest Japan in the 1970s to early 1990s (e.g. Iijima *et al.*, 1978, 1979, 1985; Iijima and Utada, 1983; Kakuwa, 1991). Imoto (1983, 1984a, 1984b) focused on several characteristics

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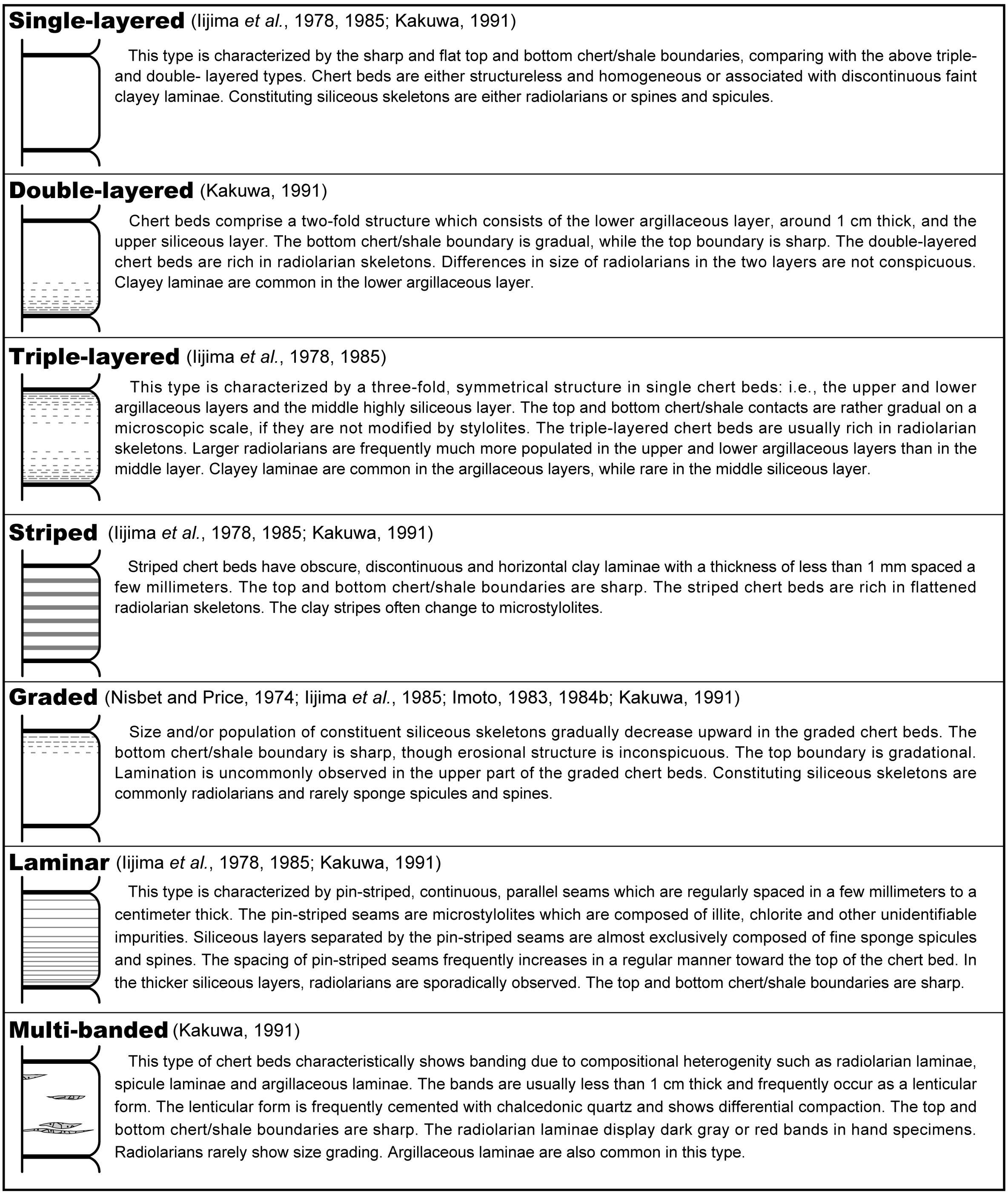

Fig. 1 Classification of the structure within a single chert bed based on previous studies with their characteristics and simplified images. The simplified images are based on Iijima and Utada (1983) and Kakuwa (1991). The characteristics of each structure are from Kakuwa (1991).

of chert, such as color and bed thickness, and classified their differences by age. Sugiyama (1997) classified chert into two types: B-type chert rather argillaceous and rich in siliceous organic remains; F-type chert highly silicified with very rare organic remains. The B- and F-types sensu Sugiyama (1997) can be corresponded to the B- and F-types sensu Imoto (1984b), respectively. Furthermore, Sugiyama (1997) proposed A-type alternating occurrences of B- and F-type chert beds within short interval (ca. less than 1 m).

Figure 1 shows classification of structures within chert bed and their images in the previous studies. Iijima *et al.* (1978) recognized four types of single chert beds showing the Triassic age: single-layered, triple-layered, laminar

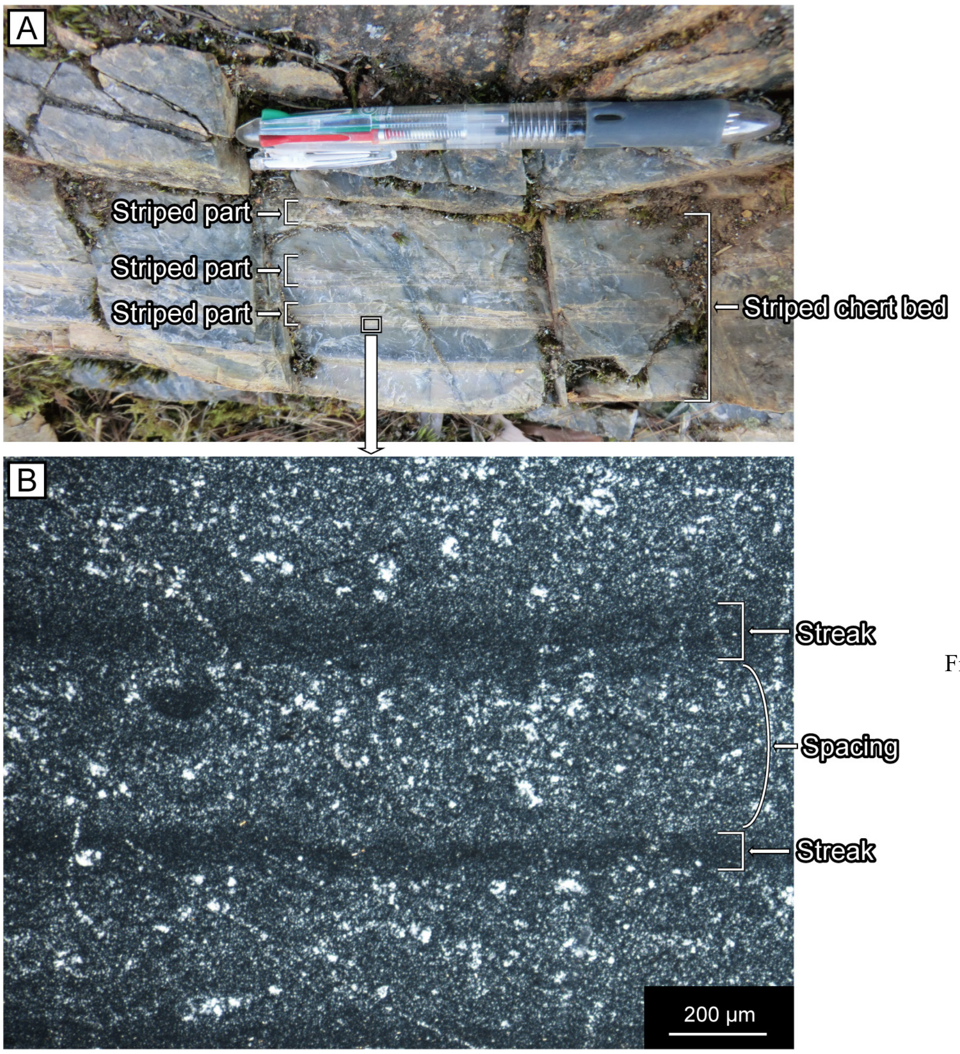

Fig. 2 Terminology of the description in this study. Field occurrence (A) and thin section (B) are from the lower part of the Tsukiya section. Striped chert bed: chert bed including striped part(s). Striped part: dominant part of the pin-striped structures. Streak: thin part of the pin-striped structure within the striped part. Spacing: a thick part between two streaks.

and striped. Iijima and Utada (1983) and Iijima *et al.* (1985) compiled siliceous rocks from Japan and reported a new graded type of single chert beds. Furthermore, Kakuwa (1991) recognized two additional types of chert beds: double-layered and multi-banded. Kakuwa (1991) synonymized the stylolite chert sensu Yoshimura *et al.* (1982) with the laminar chert. Sugiyama (1997) noted that the B-type is predominated by single-layered chert, whereas F-type by various degrees of triple-layered, striped and laminar types of Kakuwa (1991). Nikaido and Matsuoka (2009) described striped chert and classified them into three types according to the thickness changes of spacings between streaks in single chert beds: constant in thickness, thinning upward and thickening upward.

Both striped and laminar chert is characterized by having horizontal clay lamina-like structure (Kakuwa, 1991). Based on the description by Kakuwa (1991), the major difference between the striped and laminar chert is richness of the radiolarian skeletons. However, it can be greatly affected by secondary factors such as a surrounding igneous activity. The lamina-like structure of the striped chert often changes to microstylolite, and those of the laminar chert do likewise. This article regards the laminar chert as a type of the striped chert, i.e. the striped chert that has stylolite and less radiolarian skeletons with thickening-upward spacing is the laminar chert. The previous studies also used the name of "varved chert" (Yamada *et al.*, 1985; Mizutani and Koido, 1992; Nakano *et al.*, 1995); however, the term of "varve" is an annual layer and has a petrogenetic meaning. For these reasons, the stylolite and varved chert are used synonymously with the striped chert in this study.

The terminology of the description in this article is shown in Fig. 2. Striped chert bed is a chert bed including the striped part(s) (Fig. 2A). The striped part is dominant part of the pin-striped structures composed of streaks and spacing (Fig. 2B). The streak indicates a thin part of the pin-striped structure. The spacing indicates a thick part between the streaks.

3. Geologic setting

The Tamba–Mino and Ashio terranes are distributed over the Inner Zone of Southwest Japan (Nakae, 2000;

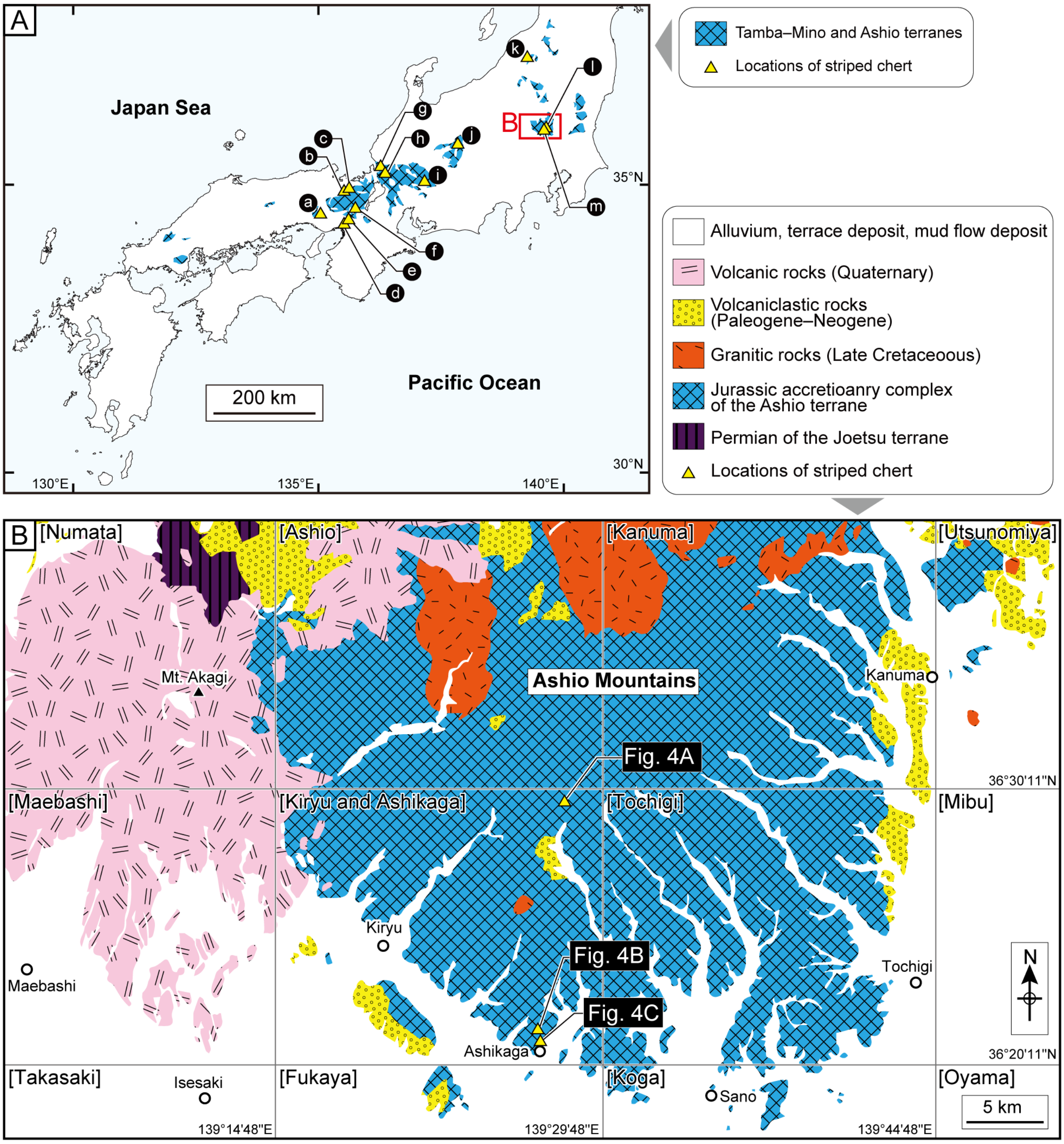

Fig. 3 Index maps of the study area. (A) Distribution of the Tamba–Mino and Ashio terranes (modified from Geological Survey of Japan, AIST, 2018) with locations of striped and related chert in the present and previous studies. The alphabets of lower-case within the black circle correspond to the locations (Loc.) shown in Table 1. (B) Simplified geologic map of the Ashio terrane in the Ashio Mountains (modified after Sudo *et al.*, 1991; Geological Survey of Japan, AIST, 2018). The geographical names in brackets indicate 1:50,000 topographic maps published by the Geospatial Information Authority of Japan.

Kojima *et al.*, 2016) (Fig. 3A). The Tamba–Mino terrane corresponds to the Ashio terrane. The terranes are mainly composed of late Carboniferous–Permian ocean ridge basalt and pelagic carbonate, late Carboniferous–Jurassic pelagic chert, Jurassic hemipelagic siliceous mudstone and trench-fill clastics, such as mudstone and sandstone (e.g. Nakae, 2000).

The components of the Ashio terrane are exposed in the Ashio Mountains in central Japan (Fig. 3B). The occurrences of microfossils such as radiolaria and conodont have been reported in this area since the 1960s (e.g. Hayashi, 1963, 1968; Koike *et al.*, 1971; Hayashi and Hasegawa, 1981; Aono, 1985; Kamata, 1996, 1997; Takayanagi *et al.*, 2001; Ito, 2019, 2020).

Kamata (1996) divided the Ashio terrane of the Ashio Mountains into three tectonostratigraphic units, namely, the Kuzu, Kurohone–Kiryu and Omama complexes. The Kuzu Complex is characterized by coherent facies and is mainly composed of repeated chert–clastic sequences with basalt–limestone blocks. The Kuzu Complex can be subdivided into three units: 1, 2 and 3 (Kamata, 1997). The Omama and Kurohone–Kiryu complexes are characterized by mixed facies that is represented by muddy mixed rocks including several types and sizes of blocks. Both complexes include chert, limestone and sandstone blocks. The Omama Complex contains large amounts of basalt and limestone, whereas the Kurohone–Kiryu Complex includes small amounts of these rocks.

4. Striped chert in the Ashikaga area

4. 1 Study sections

This study investigated four sections in Sano and Ashikaga cities, Tochigi Prefecture (Fig. 4). The Hikoma, Tsukiya, Orihime and Oiwa sections include one to several striped chert beds (Fig. 5). According to the tectonostratigraphic division by Kamata (1996) and the geological maps of Sudo *et al.* (1991), the Hikoma section is located in the distributional area of the Kurohone–Kiryu Complex, whereas the Oiwa, Tsukiya and Orihime sections in unit 3 of the Kuzu Complex. The chert of all sections predominantly corresponds to the F-type chert sensu Imoto (1984b) and Sugiyama (1997).

The Hikoma section crops out along the prefectural road 208 in Hikoma, Sano City (Fig. 4A). The total stratigraphic thickness of this section is about 4 m. The chert in this section is generally dark-gray and weakly bedded. The single bed thickness of the individual chert is 5–15 cm and accompanies claystone with sizes less than 1 mm. One striped chert bed is interbedded.

The Oiwa section is exposed on a hiking trail in Oiwa-cho, Ashikaga City and is located above the Oiwa Tunnel (Fig. 4B). The total stratigraphic thickness of this section is about 15 m. The chert from this section is generally bright-gray and clearly bedded. The single bed thickness of the individual chert is 3–15 cm and accompanies claystone with sizes less than 1 mm. Numerous striped chert beds can be observed in this section. The lower part of this sequence is folded.

The Tsukiya section crops out along a road in Tsukiya-cho, Ashikaga City (Fig. 4B). The total stratigraphic thickness of this section is about 2 m. The chert of this section is generally gray and clearly bedded. The single bed thickness of the chert is 3–15 cm and accompanies claystone with sizes less than 1 mm. The gray chert includes a 1–2 cm wide black-colored part. Five striped chert beds are observed.

The Orihime section crops out along the road to the Orihime-jinja Shrine in Nishinomiya-cho, Ashikaga City (Fig. 4C). The total stratigraphic thickness of this section is about 3 m. The chert from this section is generally gray to dark-gray and bedded. The single bed thickness of the gray chert is 5–10 cm and accompanies claystone with sizes less than 1 mm. Four striped chert beds are observed. Folded chert is recognized in the middle part.

4. 2 Characteristics of striped chert

The striped chert is continuously and laterally distributed, at least at the outcrop (Fig. 6A, B). The maximum thickness of the streaks is about 1 mm (Fig. 6C). The streaks are almost parallel to the bed surface (Fig. 6B, C). A large amount of the striped chert is observed in the Oiwa section (Fig. 6D). The streaks are also folded by a small fault within the bed (Fig. 6E).

The color of the streaks are generally paler than the spacings at the outcrop. For example, the streaks in the Tsukiya and Oiwa sections are caramel color whereas the spacings are dark-gray (Fig. 6). However, marginal parts of the spacings along the streaks represent paler color like the streaks. Consequently, the color of the streaks may be due to fading during the diagenesis.

The thin section observations indicate that the striped chert is composed of cryptocrystalline quartz and a few clay minerals (Fig. 7). The streaks are almost parallel (Fig. 7A, B), and the thickness of the spacing between the streaks is several hundred micrometres. The streaks are composed mainly of clay minerals; the spacings consist mainly of cryptocrystalline quartz. The streaks are composed of finer material than that found in the spacing (Fig. 7B, C). The streaks are stylolitic in some samples (Fig. 7D, E). The stylolitic seam is about 5 μm in thickness and is slightly undulated.

5. Microfossil occurrence and age assignment

A total of 17 chert samples were collected from the study sections. The following methods were used to extract microfossils from the samples. The samples were crushed into about 1 cm fragments and then soaked in hydrofluoric acid (ca. 5 %) at room temperature (ca. 20 °C–25 °C) for 24 h. The residues were collected using a sieve with a mesh diameter of 0.054 mm and then enclosed within a slide prepared with a photocrosslinkable mounting medium (GJ-4006, Gluelabo Ltd.). The slides were analyzed using a transmitted light microscope and then photographed. Several specimens from the residues were mounted on stubs, analyzed and then photographed using scanning electron microscopy.

Six chert samples, including one striped chert sample, were collected from the Hikoma section. However, microfossils for age determination could not be obtained from these samples.

Four samples of striped chert were collected from the Oiwa section. Two samples (IT18101413 and IT18101415) yielded radiolarian remains. The twisted spine (Fig. 8A) from sample IT18101413 resembles a spine of *Capnuchosphaera deweveri* Kozur and Mostler. On the basis of the occurrence range of Sugiyama

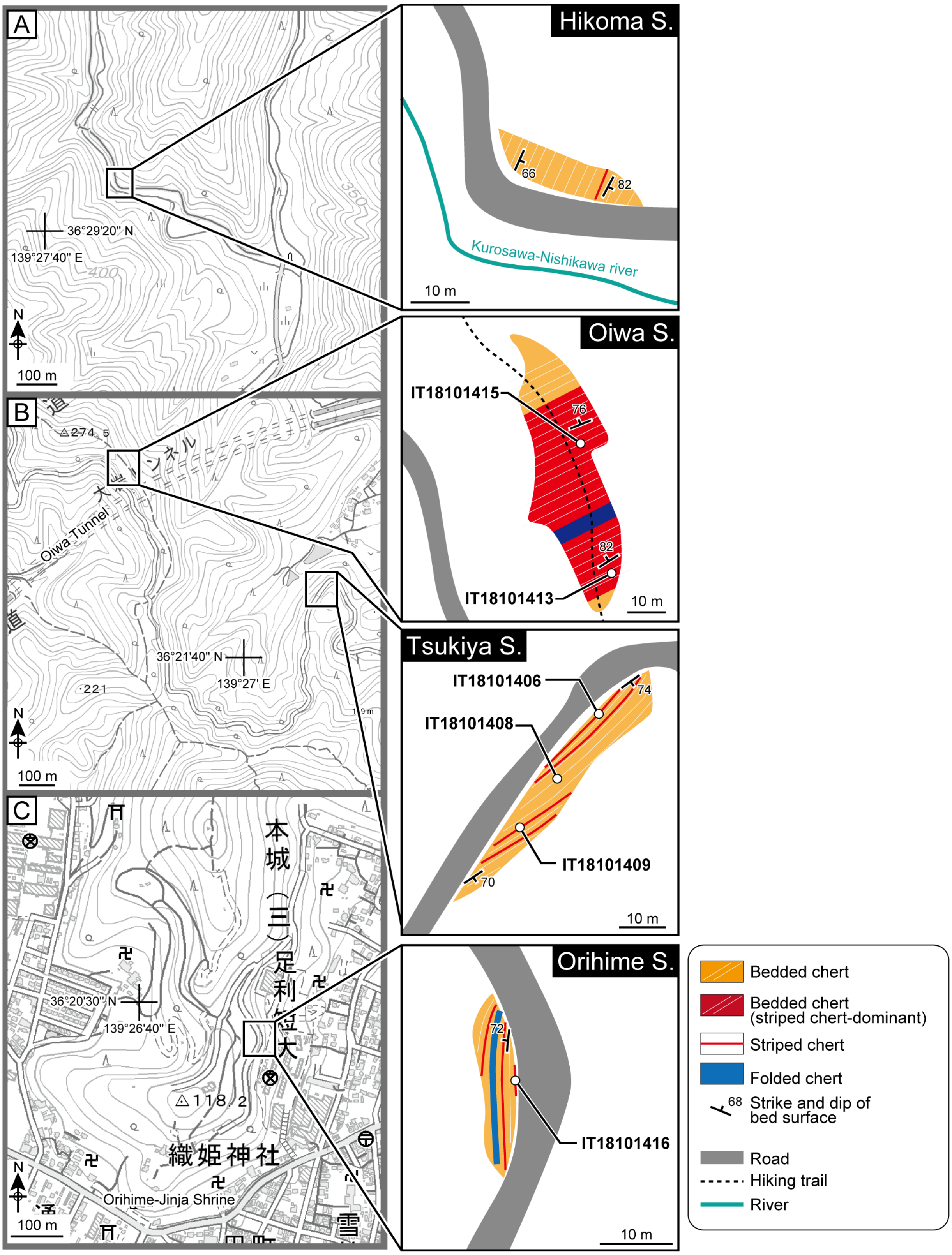

Fig. 4 Traverse maps of sections studied in this article. The maps are modified from the 1:25000 map of 'Bamba' and 'Ashikaga-Hokubu' by the Geospatial Authority of Japan. S.: section.

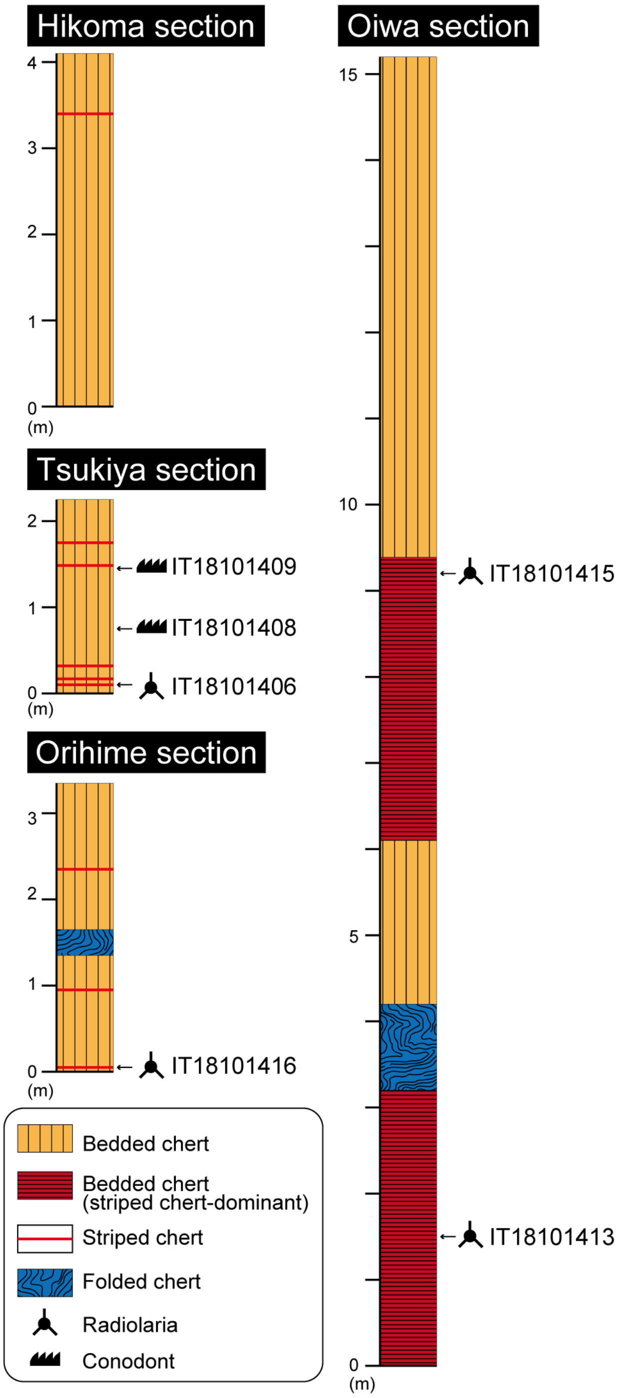

Fig. 5 Columnar illustration of the studied sections with microfossil horizons.

(1997), *C. deweveri* occurred in the *Capnuchosphaera* Lowest-Occurrence Zone (TR5A) to the *Trialatus robustus–Lysemelas olbia* Partial-Range Zone (TR6B). The results of this study indicate that sample IT 18101413 corresponds to the middle Carnian–middle Norian.

Six chert samples, including two striped chert samples, were collected from the Tsukiya section. Two chert samples (IT18101408 and IT18101409) yielded conodont fragments (Fig. 8B, C). One striped chert sample (IT18101406) yielded radiolarian fossils: *Paroertlispongus*? sp. (Fig. 8D), *Pararchaeospongoprunum*? sp. (Fig. 8E), twisted spine (Fig. 8F) and *Spinotriassocampe*? sp. (Fig. 8G). According to O'Dogherty *et al.* (2009), *Paroertlispongus*, *Pararchaeospongoprunum* and *Spinotriassocampe* occurred in the middle Anisian–lower Carnian, upper Permian–upper Anisian and middle Anisian–lower Carnian, respectively. Consequently, sample IT 18101406 might correspond to the middle–upper Anisian.

Two chert samples, including one striped chert sample, were collected from the Orihime section. Only one sample from the striped chert bed (IT18101416) yielded *Lysemelas* sp. cf. *L. olbia* Sugiyama (Fig. 8H). On the basis of the occurrence range reported by Sugiyama (1997), *L. olbia* occurred in the *L. olbia* Lowest-Occurrence Zone (TR7) to Skirt F Lowest-Occurrence Zone (TR8C). Sample IT 18101416 might correspond to the upper Norian–lower Rhaetian.

6. Ages of striped chert in other areas

6. 1 Tamba–Mino and Ashio terranes

Several researchers have noted the presence of the striped chert in the Tamba–Mino and Ashio terranes (Fig. 3A). In this chapter, the previous studies on the striped chert and their ages are reviewed (Table 1).

Kido (1982) described four sections including striped chert beds, namely, the Kashibara, Kamiaso Bridge, Hisuikyo and Hosobi-dani sections, and determined the ages of the former three sections. The striped chert bed in the Kashibara section is about 8 m below the sampling point of sample KC1 yielding *Praemesosaturnalis gracilis* Kozur and Mostler, which occurred in TR8A to TR8C (Sugiyama, 1997). One striped chert bed in the Kamiaso Bridge section is located between samples BC2 and BC3, which include several species of the genus *Pseudostylosphaera* Kozur and Mostler. *Pseudostylosphaera compacta* (Nakaseko and Nishimura) is observed in both samples, and *Pseudostylosphaera goestlingensis* (Kozur and Mostler) is observed in BC3. The occurrence range of the latter species is TR4A to TR5A (Sugiyama, 1997). Another chert bed in the Kamiaso Bridge section is located between samples BC4 and BC5. Sample BC5 yielded *Capnodoce sarisa* De Wever, which occurred in TR6A to TR7 (Sugiyama, 1997). One striped chert bed in the Hisuikyo section is about 5 m below sample HC1, which yielded *Yeharaia elegans* Nakaseko and Nishimura. The occurrence range of *Y. elegans* is TR3B to TR4A, Ladinian (Sugiyama, 1997). Another chert bed in the Hisuikyo section is located between samples HC2 and HC3. Sample HC2 yielded *Pentactinocarpus* sp. cf. *P. fusiformis* Dumitrica and sample HC3 yielded *Hexasaturnalis hexagonus* (Yao). *Pentactinocarpus fusiformis* occurred in TR3B (Sugiyama, 1997). Meanwhile, an occurrence range of *H. hexagonus* is from the late *Trillus elkhornensis* zone (JR2)

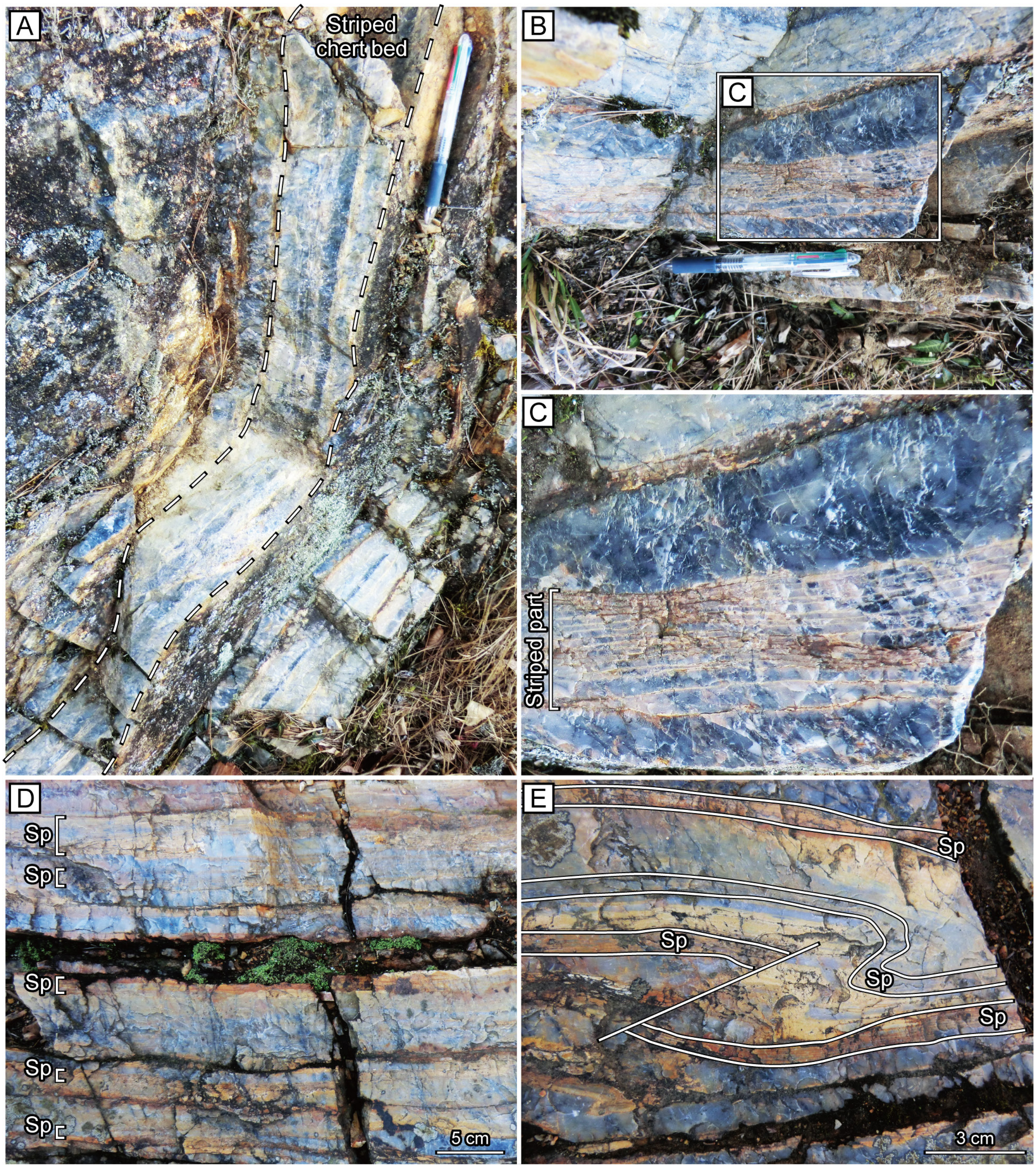

Fig. 6 Field occurrences of striped chert beds. (A) Laterally continuous striped chert beds from the lower part of the Tsukiya section. (B, C) Striped chert bed from the lower part of the Tsukiya section. The striped part is observed in the middle part within the striped chert bed. The bed surface and the streaks are almost parallel. (D) Bedded chert containing several striped parts (Sp) from the lower part of the Oiwa section. (E) Fold and fault within the chert bed and deformed striped parts (Sp) from the lower part of the Oiwa section. The streaks were deformed along the deformation of the chert beds by the fold and fault.

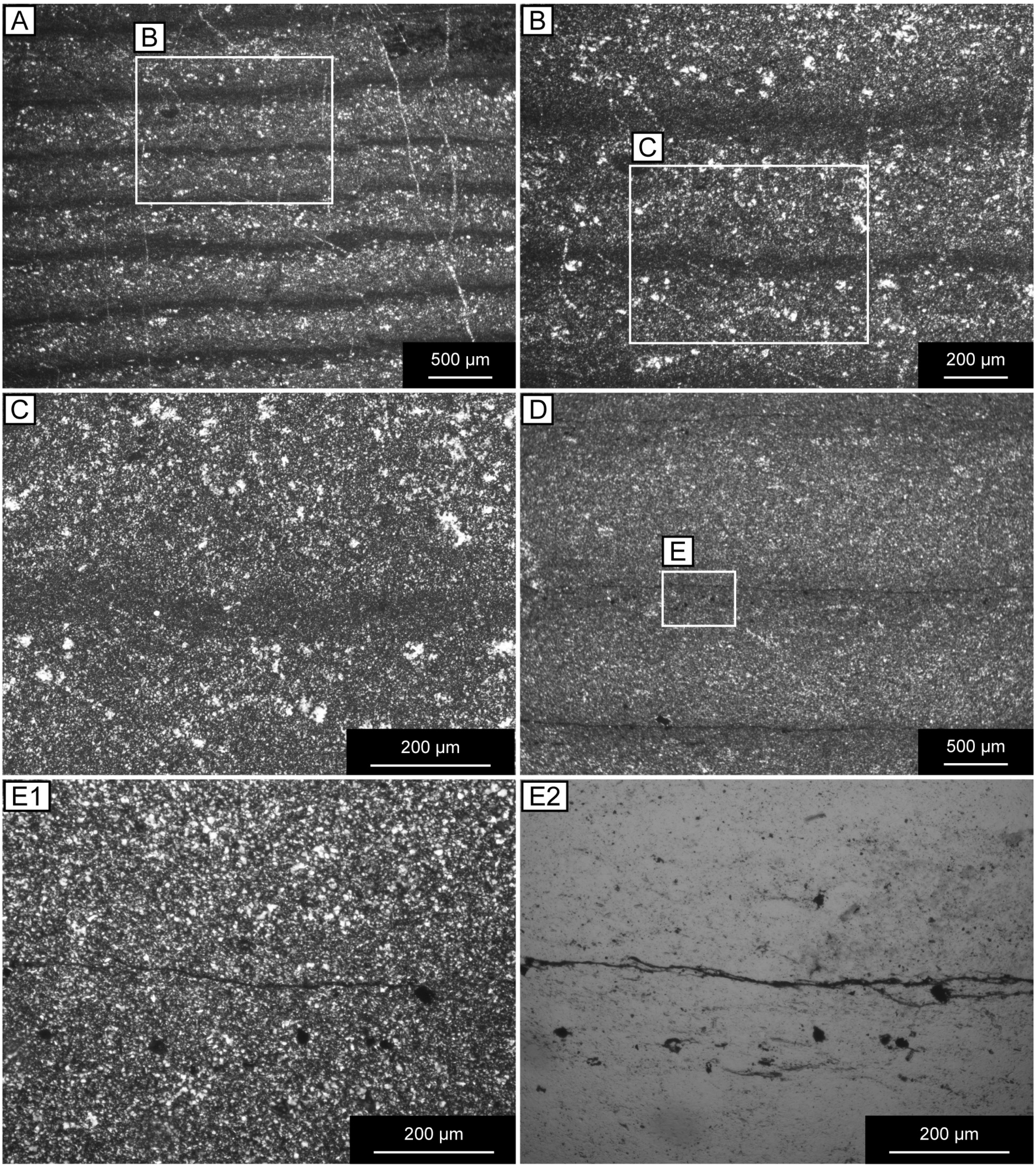

Fig. 7 Thin sections of the striped chert consisting of cryptocrystalline quartz and a few clay minerals. (A–C) Striped chert from the lower part of the Tsukiya section (sample IT18101406). The streaks are almost parallel. The thickness of the spacing is several hundred micrometres. The streaks are composed of finer material (mainly of clay minerals) than that found in the spacings. (D, E) Striped chert from the upper part of the Hikoma section (sample IT18101404). The streaks are stylolitic and slightly undulated in some samples. (A–D, E1) Crossed nicols. (E2) Open nicols.

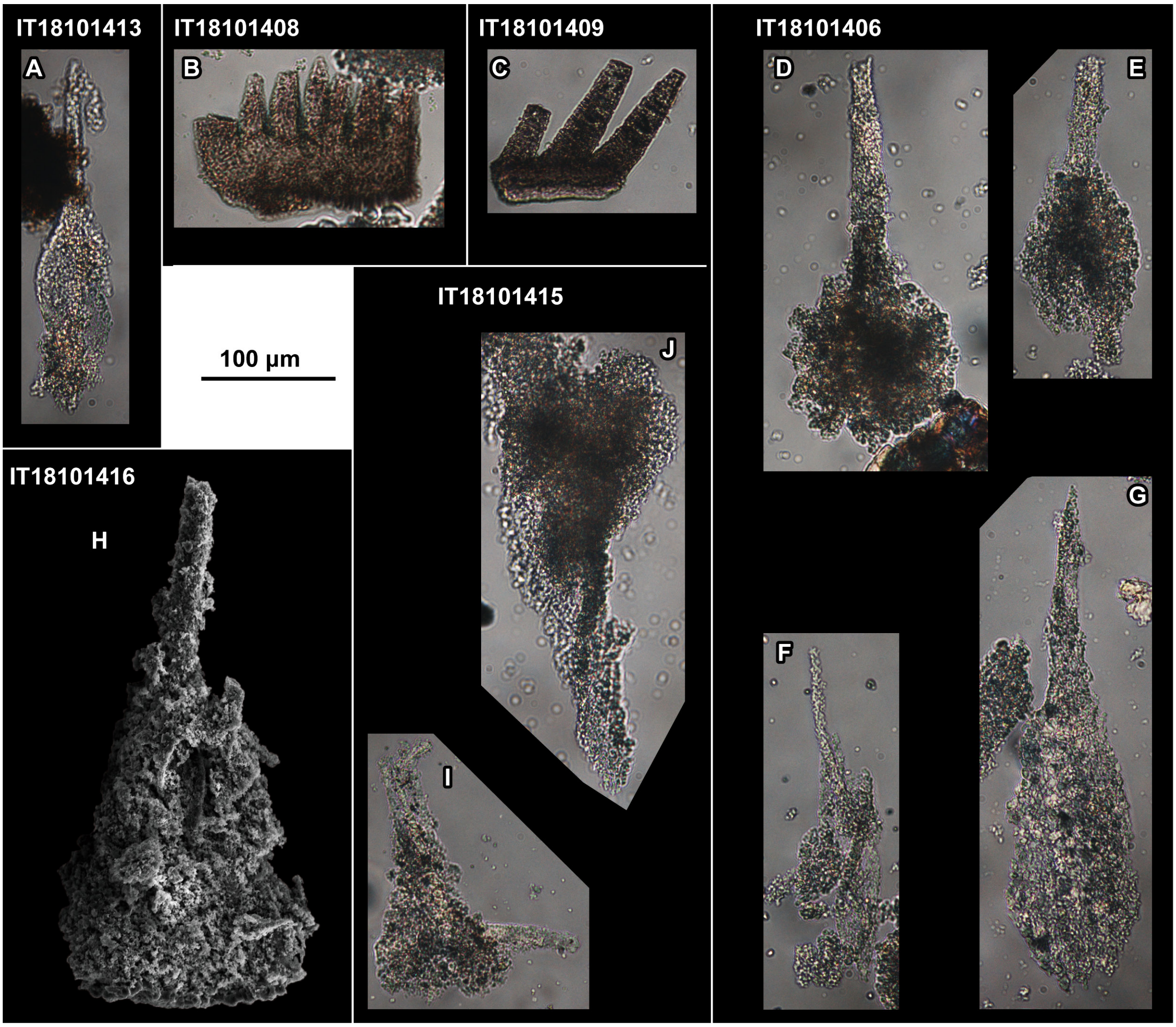

Fig. 8 Radiolarian and conodont fossils obtained from the studied sections. (A, F) Twisted spine. (B, C) Conodont fragment. (D) *Paroertlispongus*? sp. (E): *Pararchaeospongoprunum*? sp. (G) *Spinotriassocampe*? sp. (H) *Lysemelas* sp. cf. *L. olbia* Sugiyama. (I, J) Spumellaria gen. et sp. indet. with twisted spine.

to *Striatojaponocapsa plicarum* zone (JR4) (Matsuoka, 1995) corresponding to the Toarcian–middle Bathonian, late Early–Middle Jurassic (Matsuoka and Ito, 2019). Consequently, the age of the striped chert bed between samples HC2 and HC3 is some age between the Late Triassic and Early Jurassic.

Yoshimura *et al.* (1982) described “stylolitic chert” in the Imajo area of the Nanjo Massif, Fukui Prefecture. The age of the “stylolitic chert” was undetermined.

Imoto (1984a, b) studied Paleozoic and Mesozoic chert in the Tamba area. Imoto (1984b) noted that both Permian and Triassic–Jurassic chert contains sedimentary structures such as parallel lamination, and showed their photographs.

Yamada *et al.* (1985), Mizutani and Koido (1992) and Nakano *et al.* (1995) noted the presence of “varved chert”. Yamada *et al.* (1985) stated that the age of the “varved chert” is the Triassic.

Kakuwa (1991) focused on structures within single chert beds and described them in several areas. Most of the striped chert beds of these sections correspond to the Triassic (Table 1). Among the sections including the striped chert beds studied by Kakuwa (1991), better ages were obtained from four sections by using conodont and radiolaria. The Koze section corresponds to the Spathian, Anisian and Norian; the Unuma section corresponds to the Norian; the Hisuikyo section corresponds to the Carnin–Rhaetian; and the Karasawa section corresponds to the Carnian.

The Sakahogi section, which is exposed along the Kiso River, mainly consists of successive Triassic bedded chert. Therefore, most researchers have studied this section and

Table 1 The description of the striped chert and related chert based on previous studies. The alphabets of lower-case in the locations (Loc.) correspond to Fig. 3A.

Reference	Loc.	Area or section	Chert description	Stage, Series and System
Kido (1982)	i	Kashibara section	Striped chert	Norian–Rhatian (Upper Triassic)
	i	Kamiaso Bridge section	Striped chert	Ladinian–Carnian (Middle–Upper Triassic)
	i	Hisuikyo section	Striped chert	Triassic–Jurassic?
	i	Hosobi-dani section	Striped chert	-
Yoshimura *et al*. (1982)	g	Imajo	Stylolitic chert	-
Imoto(1984b)	c	Yagi	Parallel lamination	middle Prmian and Triassic
Yamada *et al*. (1985)	j	Takayama	Varved chert	Upper Triassic
Kakuwa (1991)	d	Kinzoji section	Laminar chert	Triassic–Jurassic
	e	Kurio section	Laminar chert	Upper Triassic
	a	Kuwahara section	Striped chert	Triassic–Jurassic
	f	Okuhatcho section	Laminar chert; Striped chert	Triassic–Jurassic
	b	Ohtaki-kita section	Laminar chert	Triassic–Jurassic
	d	Koze sction	Striped chert	Spathian, Anisian, Norian (Lower, Middle and Upper Triassic)
	i	Unuma secion	Laminar chert	Norian (Upper Triassic)
	i	Hisuikyo section	Laminar chert	Carnin–Rhaetian (Upper Triassic)
	h	Kammuriyama section	Laminar chert	Triassic–Jurassic
	m	Yamamae section	Laminar chert	Triassic–Jurassic
	l	Karasawa section	Laminar chert; Striped chert	Carnin (Upper Triassic) and lower Jurassic
	k	Kuromatagawa section	Laminar chert	Triassic–Jurassic
Mizutani and Koido (1992)	i	Kanayama	Varved chert	-
Nakano *et al.* (1995)	j	Norikuradake	Varved chert	-
Nikaido and Matsuoka (2009)	i	Sakahogi section	Striped chert	upper Ladinian–upper Norian (Middle–Upper Triassic)
This study	m	Hikoma section	Striped chert	-
	m	Oiwa section	Striped chert	middle Carnian–middle Norian (Upper Triassic)
	m	Tsukiya section	Striped chert	upper Anisian (Middle Triassic)
	m	Orihime section	Striped chert	upper Norian–lower Rhaetian (Upper Triassic)

the surrounding area in detail (e.g. Sugiyama, 1997; Onoue *et al.*, 2012, 2016, 2017; Nozaki *et al.*, 2019). Nikaido and Matsuoka (2009) studied the stratigraphic distribution of the striped chert beds of the Sakahogi section and correlated it with the radiolarian zonation proposed by Sugiyama (1997). On the basis of the correlation, the first occurrence of the striped chert is TR4A, their dominant intervals are in TR5A to TR6B, and their last occurrence is observed in TR8A (Fig. 9).

6. 2 Permian and Jurassic ACs in other areas

Permian and Jurassic ACs other than the Tamba–Mino and Ashio terranes exist in the Japanese Islands such as the Akiyoshi terrane (Permian AC) of the Inner Zone of Southwest Japan, Chichibu composite terrane of the Outer Zone of Southwest Japan and the North Kitakami terrane of Northeast Japan (e.g. Kojima *et al.*, 2016). Furthermore, the Jurassic ACs extend to adjacent regions of Japan, such as Northeast China, Far Eastern Russia and the Philippines (e.g. Kojima and Kametaka, 2000). The occurrence of the striped chert in geologic units other than the Tamba–Mino and Ashio terranes is noted in this section for future reference.

According to the results of fieldworks (e.g. Ito and Matsuoka, 2018 and reference therein), the presence of striped chert beds has rarely been noted in the Chichibu composite terrane. The author discovered striped chert beds near Mt. Gusuku on Ie Island, Okinawa Prefecture. Although the age of the striped chert beds has not been determined, the chert in Ie Island ranges from upper Permian to Lower Jurassic (Shen *et al.*, 1996; Ito and Matsuoka, 2017). The author could not find the description of stripe chert beds from the North Kitakami terrane and corresponding geologic units in Northeast China and Far East Russia. The author studied the Akiyoshi terrane (Ito and Matsuoka, 2015, 2016); however, according to field works and the literature, striped chert beds have never been found.

Matsuoka (2002) and Matsuoka *et al.* (2009) noted a large number of striped chert beds in the North Palawan Block of the Philippines which is the southwestern extension of the Jurassic ACs on the Japanese Islands. Matsuoka *et al.* (2009) found Early Jurassic radiolarians from intervals of dominant striped chert beds in the North Palawan Block.

Previous studies proposed that global cyclic phenomena, such as the 20 kyr- to Myr-scale Milankovitch cycle, led to the rhythmical bedding of chert (e.g. Hori *et al.*, 1993; Ikeda *et al.*, 2010, 2017). Matsuoka *et al.* (2009), however, noted that the mm-scale striped structure within a single chert bed is probably related to shorter periodic events on ~kyr timescale. Therefore, other factors might have affected the formation of striped chert beds.

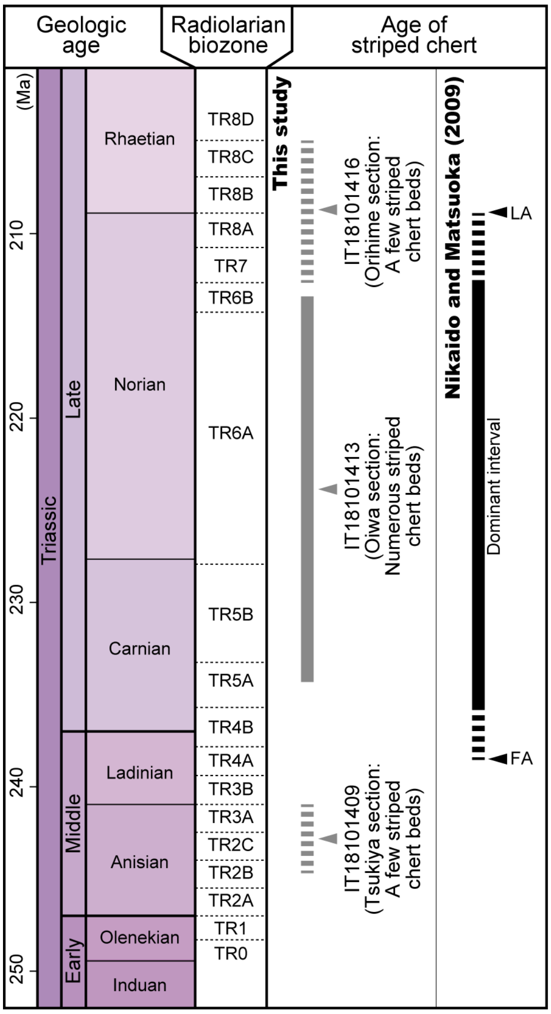

Fig. 9 Geologic time scale of the Triassic including the distribution of striped chert beds. Geologic time scale is after Ogg *et al.* (2016). Radiolarian biozones are after Sugiyama, 1997 and are partially modified based on the calibration by Yamashita *et al.* (2018).

7. Concluding remarks

The ages of the sections including the striped chert beds in the Ashikaga area were determined in this study. The Tsukiya and Orihime sections, including a few striped chert beds, correspond to the middle–upper Anisian and upper Norian, respectively. The Oiwa section, which contains numerous striped chert beds, corresponds to the middle Carnian–lower Norian. The results of the present study are consistent with the description of Nikaido and Matsuoka (2009) (Fig. 9). Likewise, the age determinations for other areas (e.g. Kido, 1982; Kakuwa, 1991) indicated that the striped chert beds are generally the Carnian–lower Norian.

Consequently, the striped chert might be used as an alternative age index, at least for studies in the Tamba–Mino and Ashio terranes. That is, several striped chert beds likely indicate the Triassic age, and the dominant interval of the striped chert beds is probably the Carnian–lower Norian. Meanwhile, a few striped chert beds correspond to the Permian (Imoto, 1984a) and Lower Jurassic (Kakuwa, 1991). Further descriptions and age assignments of striped chert beds, including petrogenetic work, will provide additional information on past ocean conditions.

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栃木県足利地域の足尾テレーンジュラ紀付加体に含まれる三畳系ストライプチャートの放散虫年代

伊藤　剛

要　旨

チャートの単層中に発達するストライプ構造は，西南日本内帯のジュラ紀付加体丹波 - 美濃テレーン及び足尾テレーンでみられる．本研究では，栃木県足利市及び佐野市の 4 セクション（飛駒・大岩・月谷・織姫セクション）中にみられるストライプチャートについて記載するとともに，飛駒セクションを除く 3 セクションの放散虫化石年代について検討する．ストライプチャートは，ストリークとスペーシングからなる．ストリークは，ピンストライプ状構造における薄い部分を指し，主に粘土鉱物からなる．スペーシングは，ストリークの間の厚い部分であり，隠微晶質石英を主体とする．ストライプチャートに富む大岩セクションは，上部三畳系カーニアン階中部～ノーリアン階中部に部分的に対比される．ストライプチャートを部分的に含む月谷セクションと織姫セクションは，中部三畳系アニシアン階中部～上部と上部三畳系ノーリアン階上部～レーティアン階下部にそれぞれ対比される．