Triassic and Jurassic radiolarians from the chert-clastic sequence of the Takatori Unit in the Torinoko Block, Yamizo Mountains

HORI Nobuharu*

Abstract A detailed litho- and biostratigraphic examination was carried out on six sections consisting of chert-clastic sequence of the uppermost thrust sheet of the Takatori Unit in the Torinoko Block, Yamizo Mountains. As a result, moderately well-preserved Middle Triassic to Late Jurassic radiolarians were recovered from these sections. Middle Triassic to early Early Jurassic (Triassocampe deweveri Assemblage Zone to Parahsuum simplex Zone) radiolarians are obtained from bedded chert sequences. Early Middle to middle Late Jurassic (Striatojaponocapsa plicatum Zone to Transhsuum maxwelli Zone) and middle to late Late Jurassic (Transhsuum maxwelli Zone to Mirijussus baileyi Assemblage Zone) radiolarians occurred in siliceous shale and shale sequences, respectively. Gray shale which is intercalated within elastic rock sequence of the upper part of the Takatori Unit yields youngest Jurassic radiolarians. Based on the lithological and radiolarian chronological data, the Takatori Unit of the Yamizo, Torinoko and Keisoku Blocks can be correlated each other.

Key words: chert-clastic sequence, Jurassic, radiolarians, Takatori Unit, Torinoko Block, Triassic, Yamizo Mountains

Introduction

Jurassic sedimentary complexes are widely distributed in the Tamba, Mino and Ashio areas (Fig. 1). In those areas, the sedimentary complex is subdivided into six to seven tectonostratigraphic units on the basis of the lithological, chronological and structural characters (e.g. Wakita, 1988; Otsuka, 1988: Nakae, 1993; Kamata, 1996). The microfossil mapping (Isozaki, 1996) using the same methods as those in the Tamba-Mino-Ashio Terrane has recently been undertaken in the Yamizo Mountains (Sashida and Hori, 2000). Concerning the radiolarian evidence, after the establishment of the extracting method with hydrofluoric acid (HF method) presented by Pessagno and Newport (1972) and the detailed observation of individuals of radiolarian specimens with scanning electron microscope (SEM), the pioneering reports on the occurrence of the Late Jurassic radiolarians were presented in the early 1980’s in the Yamizo Mountains (Sashida et al. 1982a, b). Subsequently, the occurrence of the Triassic to Late Jurassic radiolarians were reported by several researchers (Sashida et al., 1993; Nakae, 1997; Hori and Sashida, 1998, 1999; Nakae and Takizawa, 1998, Hori, 1998a, b, 1999; Hori et al., 1999; Kasai et al., 2000) from this mountains. These investigations provide the chronological data not only to recognize the tectonostratigraphic units in the Yamizo Mountains, but also to correlate these units of the Yamizo Mountains to those of the Tamba-Mino-Ashio Terrane.

Reconstructed original stratigraphy is important to discuss the development history of each tectonostratigraphic unit. It also plays an important role in broad correlation with the tectonostratigraphic units discriminated in other areas. The age of the lithologic boundary in the original stratigraphy (e.g. the age between chert and siliceous shale) and the youngest age of the elastic rocks especially have an importance in the correlation among the tectonostratigraphic units. However, Kimura and Hori (1993) pointed out that the decollement tends to develop at the lithologic boundary. Therefore, the complete ocean plate stratigraphy has scarcely preserved in the accretionary complex owing to the deformation during the accretionary process. For this reason, there are not enough investigations which focus on the continuous sections crossing the lithologic boundary (e.g. Matsuda and Isozaki, 1991; Kamata, 1997; Hori and Sashida, 1998).

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I have investigated the Jurassic sedimentary complex of the Yamizo Mountains in order to clarify the development history of the complex based on the microfossil mapping since 1993. In the course of the study, I tried to extract radiolarians for the determination of the depositional age of chert, siliceous shale and shale in six sections which are crossing the lithologic boundary in the chert-clastic sequence of the Takatori Unit (Hori and Sashida, 1999) in the Torinoko Block, Yamizo Mountains (Fig. 2). As a result, age diagnostic radiolarians were identified from chert, siliceous shale and shale in those sections. In this report, I discuss the radiolarian age of the chert-clastic sequence of the Takatori Unit and the correlation of the Takatori Unit among the Yamizo, Torinoko and Keisoku Blocks of the Yamizo Mountains.

Geologic framework

The Yamizo Mountains range from southern part of Fukushima Prefecture, through the border between Ibaraki and Tochigi Prefectures, to Mt. Tsukuba. They are divided geographically into the Yamizo, Torinoko, Keisoku and Tsukuba Blocks from north to south by valleys or lowlands (Fig. 1). The former three blocks are composed mainly of the Jurassic sedimentary complex, which is regarded as the northeastern extension of that of the Tamba-Mino Terrane. On the contrary, granitic and metamorphic rocks, which are correlated with those of the Ryoke Belt, southwest Japan, are distributed in the southernmost Tsukuba Block. Represented by the chert sequences, the Jurassic sedimentary complex of the Yamizo Mountains strikes nearly N-S in the Yamizo Mountains, NNW-SSE to NNE-SSW in the Torinoko Block, and NE-SW in the Keisoku Block, and dips westward. The sedimentary complex of the Yamizo Mountains is made up mainly of sandstone, shale and chert. Greenstone and limestone, which are common in the sedimentary complexes of other areas in the Tamba-Mino-Ashio Terrane, are very minor components.

Before the breakthrough of the plate tectonics paradigm, the traditional stratigraphic work had been undertaken by Kawada (1953) and Kanomata (1961) in the Yamizo Mountains. After that, the tectonostratigraphic division of the sedimentary complex of the Yamizo Mountains has been done by several authors in each mountain block as follows: Kasai and Amano (1997), Hori and Sashida (1998) and Sashida and Hori (2000) in the Keisoku Block; Sashida et al. (1993), Nakae and Takizawa (1996) and Hori and Sashida (1999) in the Torinoko Block; Hori (1998b) in the Yamizo Block. Recently, Sashida and Hori (2000) revised the tectonostratigraphic division presented by Hori and Sashida (1998) and proposed the Kasama and Takatori Units in structurally ascending order which are applicable...
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Fig. 1. Geologic map of the Torinoko Block.

Fig. 2. Geologic map of the Torinoko Block.
throughout the sedimentary complex of the Yamizo Mountains. They paid attention to the existence of the laterally continuous chert-clastic sequences through the mountains, and they placed the boundary between the Kasama and Takatori Units at the base of the lowest chert-clastic sequence of the Takatori Unit. Hori and Sashida (1999) discriminated the Karasuyama Unit, which is composed of mélange including slabs and blocks of chert and sandstone in the shaly matrix, in the western marginal area of the Torinoko Block (Fig. 2).

Although reports on the occurrence of radiolarians from the Yamizo Mountains are restricted to that from fine-grained clastic rocks (e.g. Kanomata, 1959, 1960a, b by thin-section method; Sashida et al., 1982a, b by HF method), chronological data by radiolarians were rapidly accumulated in this decade (e.g. Sashida et al., 1993; Hori, 1998a, 1999; Hori and Sashida, 1998; Nakae and Takizawa, 1998; Kasai et al., 2000). Among them, radiolarian age of chert-clastic sequence, which is one of the fundamental information for reconstructing the geologic history and for the tectonostratigraphic division, was reported by Hori and Sashida (1998) and Kasai et al. (2000) only from the Keisoku Block. The superficial distribution of the Jurassic sedimentary complex is discontinuous between the Keisoku and Torinoko Blocks because of the covering by the Tertiary and Quaternary strata. Therefore, for the tectonostratigraphic division through the sedimentary complex of the Yamizo Mountains, it is important to correlate the chert-clastic sequences between the Keisoku and Torinoko Blocks.

The Takatori Unit in the Torinoko Block includes at least three sheets of chert-clastic sequences in its lower part. I examined radiolarian ages of six sections consisting of chert-clastic sequence of the uppermost sheet which yields abundant radiolarians (Figs. 3, 4).

**Description of each section and its radiolarian age**

As mentioned above, radiolarians were extracted from chert and fine-grained clastic rocks of six sections composed of chert-clastic sequence of the uppermost thrust sheet of the Takatori Unit in the Torinoko Block. The locations of examined sections are shown in Fig. 3 and Fig. 4, and the Triassic to Jurassic radiolarians obtained from these sections are listed in Table 1 to Table 4.

The examined sections are described from north to south, and their radiolarian ages are discussed in detail below.
Radiolarians from the chert-clastic sequence in the Torinoko Block

unumaense (Yao) and others were obtained from the siliceous shale sample (YNKS-1d) collected from the layer just above the boundary. They are the characteristics of the early Middle Jurassic Striatojaponocapsa plicarum Zone (Matsuoka, 1995). Siliceous shale (YNKS-1e) of the early Late Jurassic Kilinora spiralis Zone (Matsuoka, 1995) overlies the siliceous shale of YNKS-1d with fault contact. Siliceous shale (YNKS-2), which yields Kilinora spiralis (Matsuoka), Gongylothorax sakawaensis (Matsuoka), Striatojaponocapsa conexa (Matsuoka) and others, crops out at the vicinity of the siliceous shale of YNKS-1d with a lack of exposure. Furthermore, siliceous shale (YNKS-3), including Hiscocapsa naradaniensis (Matsuoka), Eucyrtidium ptyctum (Riedel and Sanfilippo), Transhsuum maxwelli (Pessagno) and others, overlies the siliceous shale of YNKS-2. Striatojaponocapsa conexa (Matsuoka) has not yet been found from this siliceous shale sample (YNKS-3). The middle Late Jurassic Transhsuum maxwelli Zone is defined by the interval between the last occurrences of Striatojaponocapsa conexa (Matsuoka) and Transhsuum maxwelli (Pessagno) (Matsuoka, 1995). Therefore, the radiolarian fauna of this siliceous shale (YNKS-3) represents the Transhsuum maxwelli Zone (Matsuoka, 1995).

The shale samples (YNKS-4 and 5) are collected from gray shale which crop out south of the siliceous shale (YNKS-3) with a lack of exposure. Late Jurassic radiolarians such as Tethysetta mashitaensis (Mizutani), Archaeospongoprunum inlayi Pessagno, Cinguloturris carpatica Dumitrica and others are obtained from these shale samples. These radiolarians are the component species of the Mirifusus baileyi Assemblage (Mizutani, 1981). According to Yao (1986), the geologic age of the Mirifusus baileyi Assemblage is late half of Late Jurassic. *Mirifusus dianae* (Karrer) group which is one of the characteristic species of this assemblage has not yet been recovered from these shale samples, so the age may assigned to be the middle Late Jurassic.

As a result, the age of siliceous shales of this section is assigned to early Middle to middle Late Jurassic. The age of shale of this section is middle Late Jurassic.

2. TDCH Section (Fig. 6, Table 1)

The TDCH Section is located along a road about 1.5 km south of the YNKS Section. This section consists of chert, siliceous shale and shale (Fig. 6). They constitute a chert-clastic sequence. The boundary between each rock-type cannot be observed because of lack of exposure. *Triassocampe scalaris* Dumitrica, Kozur and Mostler, *Pentactinocarbus fusiformis* Dumitrica, *Eptingium nakaseki* Kozur and Mostler and others were obtained.
from the lower part of the chert sequence (TDCH-6). These radiolarians are characteristics of the early Middle Triassic *Triassic campe deweveri* Assemblage (Yao, 1982).

From the siliceous shale sample (TDCH-2), *Eucyrtidium semifactum* Nagai and Mizutani, *Straitoaponicoscapa* cf. *conexa* (Matsuoka) and others are obtained. Therefore, the age of this siliceous shale (TDCH-2) is possibly late Middle Jurassic. Another siliceous shale sample (TDCH-11), which was collected from the upper level of the sample TDCH-2, contains *Hisocapsa naradaniensis* (Matsuoka), *Eucyrtidium nodosum* Wakita and others. These radiolarians may be slightly younger than those of the lower silicic shale (TDCH-2).

**Table 1.** List of radiolarians obtained from the YNKS and TDCH Sections. ch: bedded chert, ss: silicic shale, sh: shale.

<table>
<thead>
<tr>
<th>Radiolarian species</th>
<th>Locality number</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eucyrtidium</em> s.o.</td>
<td>TDCH-1</td>
<td>all ss</td>
</tr>
<tr>
<td><em>Eucyrtidium</em> s.o.</td>
<td>TDCH-2</td>
<td>all ss</td>
</tr>
<tr>
<td><em>Straitoaponicoscapa</em> cf. <em>conexa</em></td>
<td>TDCH-11</td>
<td>ss.ch</td>
</tr>
<tr>
<td><em>Eucyrtidium</em> s.o.</td>
<td>TDCH-11</td>
<td>all ss</td>
</tr>
</tbody>
</table>

The shale sample (TDCH-1) which is collected from shale sequence cropping out west of the above mentioned silicic shale yields Late Jurassic radiolarians, but few age diagnostic species were discriminated. Since *Cinguloturrus carpathica* Dumitrica and *Dictyomitra* (?) *kamoensis* Mizutani and Kido are discriminated only from this shale in this section, radiolarian fauna of this shale seems to be younger than that of the underlying silicic shale. Black shale including no radiolarians is exposed above this shale (Fig. 6).

In conclusion, the age of chert is early Middle Triassic. The age of silicic shale is assigned to late Middle to early Late Jurassic. The age of shale is Late Jurassic.

**3. TDCH-12 Section** (Fig. 7, Table 2)

The TDCH-12 Section is exposed along a stream about 0.2 km south of the TDCH Section. This section comprises chert, silicic shale and shale in ascending order (Fig. 7). The contact relation between each rock-type is not observed because of lack of outcrop.

*Annotriassicampe eoladinica* Kozur and Mostler and others are obtained from the lower part of the chert sequence (TDCH-12a). This species is described from southern Alps in Italy by Kozur and Mostler (1994), and indicates late Middle Triassic (Ladinian) in age. However, some radiolarians which have double or more rings are also obtained. These radiolarians resemble *Spongiosaturnalis* (?) *diplocyclis* Yao and others which was described from the Inuyama area of central Japan by Yao.
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(1972). Radiolarians having similar form with them were also reported from the upper Norian in Austria by Kozur and Mostler (1972). Therefore, *Annullotriasaccampe eoladinica* Kozur and Mostler which indicates Ladinian age was possibly derived by reworking. The same phenomenon is observed in radiolarian fauna in the chert sample (TDCH-12b). In this chert sample, *Annullotriasaccampe eoladinica* Kozur and Mostler co-occurs with the above mentioned ring-type radiolarians.

On the other hand, from the middle part of the chert sequence, *Capnodoce sarissa* De Wever and others were recovered. *Capnodoce sarissa* De Wever was described from the Upper Triassic in Sicily and Turkey by De Wever et al. (1979). De Wever et al. (1979) determined the age of Norian on the basis of conodonts and bivalves. *Mesosaturnalis aff. artus* (Donofrio and Mostler) and others are obtained from the upper part of the chert sequence (TDCH-12c). *Mesosaturnalis artus* (Donofrio and Mostler) occurs in the middle Norian (Sugiyama, 1997). No radiolarians were obtained from the uppermost part of the chert sequence.

**Siliceous shale (TDCH-12g), yielding Striatopina conoidea (Matsuoka), Eucyrtidiellum unumaense (Yao), Eucyrtidiellum semifactum Nagai and Mizutani and others, crops out above the chert sequence with a lack of exposure. These radiolarians characterize the late Middle Jurassic *Striatopina conoidea* Zone (Matsuoka, 1995). A sheared zone, 2 m in thickness, is recognized within the siliceous shale sequence, but the
component species of radiolarian faunas of both above and below the sheared zone are almost the same. The upper part of the siliceous shale sequence (TDCH-12k) yields **Stylocapsa tecta** Matsuoka. The occurrence of this species is limited to the uppermost part of the **Striatojaponocapsa conjeca** Zone and the lowest part of the **Kilinora spiralis** Zone (Matsuoka, 1983). Thus the siliceous shale sequence of this section may partly include the **Kilinora spiralis** Zone.

Gray shale overlies the siliceous shale sequence with unknown contact relation. The rock samples from this shale (TDCH-12m and TDCH-12n) yield **Archaeodictyomitra minoensis** (Mizutani), **Mirisus dianae** (Karrer) and others. These radiolarians are included in the **Mirisus baileyi** Assemblage (Mizutani, 1981).

Therefore, geologic ages of chert, siliceous shale and shale of this section are assigned to probably Late Triassic, late Middle Jurassic to early Late Jurassic and late Late Jurassic, respectively.

4. **IHZW Section** (Fig. 8, Table 2)

The IZW Section is made up only of the chert sequence (Fig. 8). The lower part of this section yields some Triassic radiolarians, such as **Capnodice crystallina** Pessagno, **Nakasekoellus pessagnoi** (Nakaseko and Nishimura), **Canesium lentum** Blome, **Japonocampe fam. nova** (Yao) and others. These radiolarians are the component species of the **Japonocampe fam. nova** Assemblage (Yao, 1982) and indicate the Carnian to Norian age of Late Triassic. These radiolarians are also yielded from the late Carnian to early Norian **Capnodice Zone** (Yoshida, 1986).

The middle part of this section yields few age diagnostic radiolarians. In the sample IZW-4, many radiolarians having ring-shaped shell like **Palaeosaturnalis** are included. Among them, **Pseudoheliodiscus hettangicus** (Kozur and Mostler) and **Mesosaturnalis sp. B** of Carter (1993) were discriminated in species level. **Pseudoheliodiscus hettangicus** (Kozur and Mostler) was reported from the Hettangian of southern Germany by Kozur and Mostler (1990). According to Kozur and Mostler (1990), this genus ranges from Late Triassic to Early Jurassic. **Mesosaturnalis sp. B** was reported and described from the Rhaetian in the Queen Charlotte Islands, Canada, by Carter (1993). Therefore, co-occurrence of these two species probably suggests the Rhaetian in age.

On the other hand, the upper part of this section yields **Parahsuum simplum** Yao, **Katroma westermannii** Whalen and Carter, **Charlottea sp.** and others. **Parahsuum simplum** Yao is the nominal species of the early Early Jurassic **Parahsuum simplum** Assemblage (Yao, 1982). According to Hori (1990), **Parahsuum simplum** Yao is yielded throughout the Lower Jurassic. The younger elements, such as **Trillus elkhornensis** Pessagno and Blome and **Mesosaturnalis hexagonus** (Yao), were not found from the upper part of this section, so the obtained radiolarians suggest the lower part of the **Parahsuum simplum** Zone (Hori, 1990). Furthermore, occurrences of the genus **Charlottea** is limited in the Lower Jurassic, and **Katroma westermannii** Whalen and Carter described from the Queen Charlotte Islands, Canada, indicates late Sinemurian age (Carter et al., 1998). Therefore, the radiolarian ages of the lower part and the upper part of this section are late Midd
Radiolarians from the chert-clastic sequence in the Torinoko Block

Fig. 9. Route map showing the mode of occurrence of the chert-clastic sequence of the IGZW Section. The columnar section and stratigraphic distribution of the selected radiolarian species are also shown in this figure.

Table 3. List of radiolarians obtained from the IGZW Section. ch: bedded chert, ss: siliceous shale.

<table>
<thead>
<tr>
<th>Radiolarian species</th>
<th>Locality number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camptopus triassicus Yao</td>
<td>NOKD-16-1a, b</td>
</tr>
<tr>
<td>Camphorophora ramosa Sugiura</td>
<td>NOKD-16-1b</td>
</tr>
<tr>
<td>Livarella densiporata Kozur &amp; Moita</td>
<td>NOKD-16-1c</td>
</tr>
<tr>
<td>Livarella gigantea Yoshida</td>
<td>NOKD-16-1d</td>
</tr>
<tr>
<td>Livarella longa Yoshida</td>
<td>NOKD-16-1e</td>
</tr>
<tr>
<td>Pararosea pacifica Kato</td>
<td>NOKD-16-1f</td>
</tr>
<tr>
<td>Cingulatella auroniae Dominica</td>
<td>NOKD-16-1g</td>
</tr>
<tr>
<td>Eucryphiellum nodosum Wakis</td>
<td>NOKD-16-1h</td>
</tr>
<tr>
<td>Eucryphiellum pycnoma (Riedel &amp; Sandifippo)</td>
<td>NOKD-16-1i</td>
</tr>
<tr>
<td>Gongylodora salomonensis Matsusaka</td>
<td>NOKD-16-1j</td>
</tr>
<tr>
<td>Haeurochaera robusta (Matsusaka)</td>
<td>NOKD-16-1k, l</td>
</tr>
<tr>
<td>Haeurochaera crenata (Matsusaka)</td>
<td>NOKD-16-1m</td>
</tr>
<tr>
<td>Haeurochaera spiralis (Matsusaka)</td>
<td>NOKD-16-1n</td>
</tr>
<tr>
<td>Protunana cf. japonica Matsusaka &amp; Yao</td>
<td>NOKD-16-1o</td>
</tr>
<tr>
<td>Protunana (TJ) cf. ochreata Matsusaka</td>
<td>NOKD-16-1p</td>
</tr>
<tr>
<td>Protunana spp.</td>
<td>NOKD-16-1q</td>
</tr>
<tr>
<td>Seriocyclus sp.</td>
<td>NOKD-16-1r</td>
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<tr>
<td>Striatopyocyclus cornea (Matsusaka)</td>
<td>NOKD-16-1s</td>
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<tr>
<td>Striatopyocyclus plicatum (Yao)</td>
<td>NOKD-16-1t</td>
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<td>Stylocyclus acuta Matsusaka</td>
<td>NOKD-16-1u</td>
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<tr>
<td>Stylocyclus (T) sp.</td>
<td>NOKD-16-1v</td>
</tr>
<tr>
<td>Taxopera diminutispina dimenensis (Baumgartner)</td>
<td>NOKD-16-1w</td>
</tr>
<tr>
<td>Trachycrinus nanus (Pasquare)</td>
<td>NOKD-16-1x</td>
</tr>
<tr>
<td>Triplodina spp.</td>
<td>NOKD-16-1y</td>
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<tr>
<td>Wilbertella carpatica Dominica</td>
<td>NOKD-16-1z</td>
</tr>
</tbody>
</table>

Table 4. List of radiolarians obtained from the IHZS Section. ch: bedded chert, ss: siliceous shale, sh: shale.

<table>
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<td>Eucryphiellum nodosum Wakis</td>
<td>NOKD-16-1h</td>
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<tr>
<td>Eucryphiellum pycnoma (Riedel &amp; Sandifippo)</td>
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<tr>
<td>Gongylodora salomonensis Matsusaka</td>
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<tr>
<td>Haeurochaera robusta (Matsusaka)</td>
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<tr>
<td>Haeurochaera crenata (Matsusaka)</td>
<td>NOKD-16-1m</td>
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<td>Haeurochaera spiralis (Matsusaka)</td>
<td>NOKD-16-1n</td>
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<tr>
<td>Protunana spp.</td>
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<tr>
<td>Seriocyclus sp.</td>
<td>NOKD-16-1r</td>
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<tr>
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<td>Triplodina spp.</td>
<td>NOKD-16-1y</td>
</tr>
<tr>
<td>Wilbertella carpatica Dominica</td>
<td>NOKD-16-1z</td>
</tr>
</tbody>
</table>

latest Triassic and early Early Jurassic, respectively. The Triassic/Jurassic (T/J) boundary may exist in this section, but the boundary has not been detected due to lack of radiolarian fossils.

5. IGZW Section (Fig. 9, Table 3)

The IGZW Section consists of chert and siliceous shale that is a part of a chert-clastic sequence. Late Triassic radiolarians, such as Livarella densiporata Kozur and
Mostler, Livarella gifuensis Yoshida, Livarella longa Yoshida, Canoptum triassicum Yao and others, were obtained from the chert samples (NKKD-4a and NKKD-4c). According to Yoshida (1986), the Livarella-Canoptum Zone which yields above-mentioned species indicates Late Triassic Rhaetian age.

Siliceous shale overlies the chert sequence with unknown contact relation. The first appearance biohorizon of Kilinora spiralis (Matsuoka) is recognized in the middle part of this siliceous shale sequence. The base of the Kilinora spiralis Zone is defined by the first occurrence biohorizon of Kilinora spiralis (Matsuoka, 1995). Thus the siliceous shale sequence of this section includes the Striataporocapsa conexa Zone and the Kilinora spiralis Zone in part.

Consequently, chert and siliceous shale of this section include the Upper Triassic and the upper Middle to lower Upper Jurassic, respectively.

6. IHZS Section (Fig. 10, Table 4)

The IHZS Section consists of chert, siliceous shale and shale. The lower part of this section is a chert-clastic sequence and it is overlain by a sequence composed of siliceous shale and shale with fault contact (Fig. 10). The chert sequence of this section contains early Middle to middle Late Triassic radiolarians. The chert sample (IHZS-29) yields Eptingium nakasekoi Kozur and Mostler, Triassocampe sp. and others. Eptingium nakasekoi Kozur and Mostler occurs from the upper Anisian and lower Ladinian (Kozur and Mostler, 1994). The sample (IHZS-28) contains Capnuchosphaera triassica De Wever, Triassocampe sp. and others. Capnuchosphaera triassica De Wever was reported from the lower Norian in Sicily and Turkey by De Wever et al. (1979). From the sample IHZS-27, Capnodoce sp. and others were discriminated. The occurrence of genus Capnodoce characterizes the lower Norian (Yoshida, 1986). Muelleritortis cochleata (Nakaseko and Nishimura) and others were obtained from the chert sample (IHZS-8). According to Sugiyama (1997), the occurrence of Muelleritortis cochleata (Nakaseko and Nishimura) ranges from TR4A to TR4B. This biostratigraphic range corresponds to the upper Ladinian. The Late Jurassic Kilinora spiralis Zone and Transshum maxwelli Zone were discriminated from the overlying siliceous shale sequence (IHZS-10-16). In the siliceous shale sequence, disturbance of the strata caused by faulting, folding or fragmentation is inferred from the evidence of biostratigraphic disorder of radiolarians. The shale sequence (IHZS-23) also yields radiolarians of the Transshum maxwelli Zone. This shale sequence is in fault contact with the overlying siliceous shale sequence (IHZS-
Radiolarians from the chert-clastic sequence in the Torinoko Block

including Late Jurassic radiolarians of the *Kilinora spiralis* Zone and the *Transhsuum maxwelli* Zone. Manganese carbonate nodules were recovered as floats just below the exposure of siliceous shale (IHZS-17). They contain well-preserved radiolarians which characterize the *Transhsuum maxwelli* Zone. The shale sequence (IHZS-20-22) which contains radiolarians of the *Transhsuum maxwelli* Zone overlies the siliceous shale sequence. The boundary between them is not observed because of lack of exposure.

In conclusion, the ages of chert, siliceous shale and shale of this section are assigned to early Middle to early Late Triassic, early to middle Late Jurassic and middle Late Jurassic, respectively.

7. Gray shale of the localities MTZK-1 and MTZK-2

Radiolarian-bearing gray shale intercalated within massive or thickly bedded sandstone is exposed along the logging road about 1.5 km north of the YNKS Section (Fig. 3). This shale includes latest Jurassic radiolarians, such as *Archaeodictyonitra apiarium* (Rüts), *Eucyrtidium pyramis* (Aita), *Loopus primitivus* (Matsuoka and Yao), *Mirifusus dianae*, *Protunuma japonicus* (Matsuoka and Yao), *Pseudodictyonitra cf. carpathica* (Lozyniak) and others. These radiolarians are yielded from the *Loopus primitivus* Zone (Matsuoka, 1995). Therefore, the youngest age of the clastic rocks is assigned to Latest Jurassic (Tithonian).

Tectonostratigraphic correlation of the chert-clastic sequences of the Takatori Unit among the Keisoku, Torinoko and Yamizo Blocks.

Although no complete section of rock sequence, composed of siliceous claystone, chert, siliceous shale and clastic rocks in ascending order, could be observed in this study, chronological data derived from radiolarians are summarized as follows: the age of chert is early Middle Triassic to early Early Jurassic; that of siliceous shale is Middle Jurassic to middle Late Jurassic; that of shale is middle to late Late Jurassic (Fig. 11). Some shale layers including latest Jurassic radiolarians are intercalated within massive or thickly bedded sandstone of the Takatori Unit in the Torinoko Block. Therefore, the youngest age of the clastic rocks is probably assigned to latest Jurassic (Fig. 11).

On the other hand, in the Takatori Unit in the Keisoku Block, which is situated at the south of the Torinoko Block, radiolarian age of chert-clastic sequence is examined by Hori and Sashida (1998) as follows: the age of siliceous claystone is late Early Triassic; that of chert is early Middle...
Triassic to early Middle Jurassic; that of siliceous shale is Middle Jurassic; that of shale is Late Jurassic.

Subsequently, Kasai et al. (2000) reported the radiolarian age of the chert-clastic sequence from the Takatori Formation, similar to the Takatori Unit of Sashida and Hori (2000), in the northern part of the Keisoku Block. They recognized the *Stylocapsa spiralis* Zone in the siliceous shale sequences.

Comparing the age of the chert-clastic sequences of the Takatori Unit in the Torinoko Block and that in the Keisoku Block, the *Transhsuum hisuiyoense* Assemblage Zone is absent in the Torinoko Block. The lithologic boundary between chert and siliceous shale is probably placed within the lower Middle Jurassic in the Keisoku Block, while in the Torinoko Block it is settled within lower Middle Jurassic or lower. At present, the Lower Jurassic siliceous shale has not yet been discovered throughout the sedimentary complex of the Yamizo Mountains. Therefore, the lower limit of the age of siliceous shale is appropriate to be early Middle Jurassic in both mountain blocks.

In the Yamizo Block, north of the Torinoko Block, both of occurrence and preservation of radiolarians are very poor. Only siliceous shale including Middle Jurassic radiolarians are recognized from the Takatori Unit in the Yamizo Block (Hori, 1998b). Although the radiolarian fossil evidence is insignificant in the Yamizo Block, the Takatori Unit of the Yamizo Block can be correlated to that of the Torinoko Block.

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*: in Japanese with English abstract
**: in Japanese
Explanation of Plates

Scanning electron photomicrographs of Middle Triassic to Late Jurassic radiolarians from the chert-clastic sequence of the six sections (YNKS, TDCH, TDCH-12, IHZW, IGZW, IHZS sections) of the Takatori Unit in the Torinoko Block, Yamizo Mountains.

Plate 1 Middle Triassic to Early Jurassic radiolarians.

Fig. 1. Triassocampe scalaris Dumitrca, Kozur & Mostler. x150, TDCH-6, IGUT-NH2855. Fig. 2. Anulatriasscocampe eoladinica Kozur & Mostler. x150, TDCH-12b, IGUT-NH2897. Fig. 3. Pararuesticellum(?) sp. x225, TDCH-12b, IGUT-NH2896. Fig. 4. Japonocampe cf. nova (Yao). x225, IHZW-3, IGUT-NH2623. Fig. 5. Canoptum triassicum Yao. x150, NKKD-4a, IGUT-NH2598. Fig. 6. Parahsuum simplum Yao. x150, IHZW-7, IGUT-NH2568. Fig. 7. Katroma westermannii Whalen & Carter. x150, IHZW-9, IGUT-NH2775. Fig. 8. Nakasekoellus pessagnoi (Nakaseko & Nishimura). x150, IHZW-3, IGUT-NH2622. Fig. 9. Pentactinocarpus fusiformis Dumitrca. x150, TDCH-6, IGUT-NH2852. Fig. 10. Trialosus robusta (Nakaseko & Nishimura). x150, IHZW-3, IGUT-NH2617. Fig. 11. Camesium lentum Blome. x150, IHZW-3, IGUT-NH2619. Fig. 12. Muelleriortis cochleata (Nakaseko & Nishimura). x100, IHZS-8, IGUT-NH3058. Fig. 13. Tiborella agricra Sugiyama. x100, TDCH-6, IGUT-NH2853. Fig. 14. Eptionium nakasekoi Kozur & Mostler. x75, TDCH-6, IGUT-NH2854. Fig. 15. Cupnuchosphaera oma Sugiyama. x100, NKKD-4e, IGUT-NH2601. Fig. 16. Cupnuchosphaera triassica De Wever. x100, IHZS-28, IGUT-NH3639. Fig. 17. Capnodoce anapetes De Wever. x100, IHZS-27, IGUT-NH3637. Fig. 18. Capnodoce sarisa De Wever. x100, TDCH-12d, IGUT-NH2892. Fig. 19. Capnodoce crystallina Pessagno. x100, IHZW-3, IGUT-NH2618. Fig. 20. Livarella densispora De Wever & Mostler. x150, NKKD-4a, IGUT-NH2596. Fig. 21. Livarella gifuensis Yoshida. x100, NKKD-4a, IGUT-NH2594. Fig. 22. Livarella longa Yoshida. x150, NKKD-4a, IGUT-NH2602. Fig. 23. Paronella pacofiensis Carter. x100, NKKD-4a, IGUT-NH2597. Fig. 24. Charlottea sp. x150, IHZW-8, IGUT-NH2586. Fig. 25. Spongiosaturnalisis(?) sp. A. x100, TDCH-12a, IGUT-NH2730. Fig. 26. Spongiosaturnalisis(?) sp. B. x100, TDCH-12a, IGUT-NH2731. Fig. 27. Praesosarturnalisis(?) sp. x100, TDCH-12b, IGUT-NH2895. Fig. 28. Mesosarturnalisis aff. artus (Donofrio & Mostler). x75, TDCH-12e, IGUT-NH2891. Fig. 29. Pseudeolidiscus hetanicus (Kozur & Mostler). x75, IHZW-4, IGUT-NH2625. Fig. 30. Mesosartunalisis sp. B of Carter (1993). x100, IHZW-4, IGUT-NH2626.

Plate 2 Middle Jurassic radiolarians.

Fig. 1. Striatojaponocapsa plicarum (Yao). x225, YNKS-1d, IGUT-NH2721. Fig. 2. Striatojaponocapsa conexa (Matsuoka). x225, TDCH-12g, IGUT-NH3022. Fig. 3. Striatojaponocapsa cf. conexa (Matsuoka). x225, TDCH-2, IGUT-NH3022. Fig. 4. Diacanthocapsa normalis Yao. x225, TDCH-12g, IGUT-NH2764. Fig. 5. Gonylothorax siphonator Dumitrca. x225, TDCH-2, IGUT-NH3023. Fig. 6. Euycrytidium semifactum Nagai & Mizutani. x225, TDCH-12g, IGUT-NH2762. Fig. 7. Euycrytidium nodosum Wakita. x225, IGZW-1b, IGUT-NH2979. Fig. 8. Euycrytidium umumae (Yao). x225, TDCH-12g, IGUT-NH2747. Fig. 9. Euycrytidium sp. A of Yao (1997). x225, TDCH-12g, IGUT-NH2763. Fig. 10. Hiscocapsa japónica (Yao). x225, YNKS-1d, IGUT-NH2723. Fig. 11. Praeheroidium aff. ruesti (Tan). x150, YNKS-1d, IGUT-NH2726. Fig. 12. Tricocolapsa sp. B of Yao (1997). x150, YNKS-1d, IGUT-NH2727. Fig. 13. Japonocapsa fusiformis (Yao). x225, TDCH-12g, IGUT-NH2736. Fig. 14. Japonocapsa aff. fusiformis (Yao). x225, TDCH-12g, IGUT-NH2741. Fig. 15. Tricocolapsa sp. M of Baumgartner et al. (1995). x225, TDCH-12g, IGUT-NH2754. Fig. 16. Tricocolapsa sp. A. x225, TDCH-12g, IGUT-NH2735. Fig. 17. Tricocolapsa sp. B. x225, YNKS-1d, IGUT-NH2718. Fig. 18. Unuma latuscostatus (Aita). x225, YNKS-1d, IGUT-NH2720. Fig. 19. Unuma echinatus Ichikawa & Yao. x150, TDCH-12h, IGUT-NH2848. Fig. 20. Prot unuma(?) sp. x225, TDCH-12g, IGUT-NH2752. Fig. 21. Protunuma sp. A. x225, TDCH-12g, IGUT-NH2757. Fig. 22. Protunuma sp. B. x225, TDCH-12g, IGUT-NH2737. Fig. 23. Parahsuum sp. A. x225, TDCH-12h, IGUT-NH2844. Fig. 24. Archaeodictyomitra sp. A. x225, YNKS-1d, IGUT-NH2716. Fig. 25. Archaeodictyomitra sp. B. x225, TDCH-12g, IGUT-NH2749. Fig. 26. Archaeodictyomitra sp. C. x225, TDCH-12g, IGUT-NH2756. Fig. 27. Tethyseta dhimenensis dhimenensis (Baumgartner). x150, IGZW-1b,
Plate 3 Early Late Jurassic radiolarians.

Fig. 1. Kilinora spiralis (Matsuoka). x150, YNKS-2, IGUT-NH2928. Fig. 2. Kilinora catesarum (Matsuoka). x225, IGZw-1h, IGUT-NH3072. Fig. 3. Stylocapsa (?) sp. x225, IGZw-1h, IGUT-NH3071. Fig. 4. Eucyrtidieium pycatum (Riedel & Sanfilippo). x225, TDCH-12, IGUT-NH2935. Fig. 5. Eucyrtidiellum aff. nodosum Wakita. x225, IHZS-13, IGUT-NH2866. Fig. 6. Williriedellum carpathicum Dumitrice. x150, IGZw-1e, IGUT-NH3011. Fig. 7. Arcanicapsa sp. C of Arakawa (1998). x150, IHZS-19, IGUT-NH2692. Fig. 8. Hiscocapsa naradaniensis (Matsuoka). x225, TDCH-11, IGUT-NH2867. Fig. 9. Hiscocapsa aff. naradaniensis (Matsuoka). x225, IHZS-17, IGUT-NH2973. Fig. 10. Hiscocapsa robusta (Matsuoka). x150, IHZS-19, IGUT-NH2695. Fig. 11. Stylocapsa tecta Matsuoka. x225, IGZw-1d, IGUT-NH3014. Fig. 12. Unuma sp. A. x150, IHZS-13, IGUT-NH2645. Fig. 13. Protunuma cf. japonicus Matsuoka & Yao. x225, IGZw-1f, IGUT-NH3054. Fig. 14. Protunuma sp. C. x225, TDCH-12k, IGUT-NH2877. Fig. 15. Protunuma sp. D. x150, IHZS-19, IGUT-NH2688. Fig. 16. Protunumum (? ) cf. ochiensis Matsuoka. x150, IGZw-1d, IGUT-NH3026. Fig. 17. Sethocapsa sp. x150, IGZw-1d, IGUT-NH3033. Fig. 18. Stichocyrtidium sp. B of Yao (1997). x225, YNKS-2, IGUT-NH2926. Fig. 19. Transhsuum sp. A. x150, TDCH-12k, IGUT-NH2881. Fig. 20. Transhsuum sp. B. x150, IHZS-13, IGUT-NH2655. Fig. 21. Canoptum sp. x150, IHZS-13, IGUT-NH2649. Fig. 22. Archaeodictyomitra sp. D. x150, TDCH-11, IGUT-NH2870. Fig. 23. Dicyotimetrella (?) kamoensis Mizutani & Kido. x150, IHZS-13, IGUT-NH2647. Fig. 24. Gongylothorax sakawaensis Matsuoka. x225, IGZw-1b, IGUT-NH2981. Fig. 25. Gongylothorax (?) sp. x225, YNKS-1e, IGUT-NH2857. Fig. 26. Tethysetta sp. A. x225, IHZS-13, IGUT-NH2642. Fig. 27. Tethysetta cf. mashitaensis (Mizutani). x150, TDCH-12k, IGUT-NH2883. Fig. 28. Pararonaella sp. A. x100, TDCH-12k, IGUT-NH2888. Fig. 29. Triactoma sp. A. x150, IHZS-13, IGUT-NH2654. Fig. 30. Tritrabs sp. x75, TDCH-12k, IGUT-NH2880. Fig. 31. Nassellaria gen. et sp. indet. x225, IGZw-1d, IGUT-NH3030.

Plate 4 Middle Late Jurassic radiolarians.

Fig. 1. Mirifusus guadalupensis Pessagno. x150, IHZS-22, IGUT-NH3692. Fig. 2. Mirifusus cf. guadalupensis Pessagno. x100, IHZS-16, IGUT-NH2658. Fig. 3. Tethysetta mashitaensis (Mizutani). x150, IHZS-16, IGUT-NH2661. Fig. 4. Tethysetta aff. boessi (Parona). x150, IHZS-16, IGUT-NH2670. Fig. 5. Transhsuum maxwelli (Pessagno). x100, IHZS-10, IGUT-NH2530. Fig. 6. Transhsuum brevicostatum (Ozvoldova). x150, IHZS-16, IGUT-NH2662. Fig. 7. Podobursa typica (Rüst). x150, IHZS-16, IGUT-NH2684. Fig. 8. Pseudoecyrtis sp. J of Baumgartner et al. (1995). x150, YNKS-5, IGUT-NH3006. Fig. 9. Parivingcula sp. x225, IHZS-24, IGUT-NH3184. Fig. 10. Cinguloterris carpathica Dumitrice. x225, IHZS-24, IGUT-NH3175. Fig. 11. Ristola cf. procera (Pessagno). x150, IHZS-24, IGUT-NH3190. Fig. 12. Ristola procera (Pessagno). x100, IHZS-23, IGUT-NH3161. Fig. 13. Ristola firma Hull. x150, IHZS-16, IGUT-NH2657. Fig. 14. Sponcocapsula palmerae Pessagno. x150, IHZS-24, IGUT-NH3186. Fig. 15. Unuma sp. B. x150, IHZS-24, IGUT-NH3179. Fig. 16. Protunuma japonicus Matsuoka & Yao x225, IHZS-10, IGUT-NH2544. Fig. 17. Unuma aff. typicus Ichikawa & Yao. x150, IHZS-14, IGUT-NH2963. Fig. 18. Syringocapsa sp. x150, IHZS-10, IGUT-NH2539. Fig. 19. Pseudoecyrtis sp. levis Hori. x150, IHZS-20, IGUT-NH2707. Fig. 20. Stichocyrtidium (?) sp. A. x150, IHZS-20, IGUT-NH2709. Fig. 21. Tethysetta sp. B. x150, IHZS-23, IGUT-NH3158. Fig. 22. Williriedellum sp. A of Matsuoka (1983). x225, IHZS-10, IGUT-NH2527. Fig. 23. Zhamoidellum ovum Dumitrice. x225, IHZS-11, IGUT-NH2971. Fig. 24. Tricolocapsa sp. C. x350, IHZS-15, IGUT-NH2967. Fig. 25. Gongylothorax zelkoviensis Widz & De Wever. x150, IHZS-11, IGUT-NH2972. Fig. 26. Archaeodictyomitra apiarium (Rüst). x225, IHZS-16, IGUT-NH2667. Fig. 27. Archaeodictyomitra sp. E. x150, IHZS-20, IGUT-NH2700. Fig. 28. Archaeodictyomitra sp. F. x150, IHZS-22, IGUT-NH3695. Fig. 29. Archaeodictyomitra sp. G. x150, IHZS-24, IGUT-NH3178. Fig. 30. Parahsuum sp. B. x150, IHZS-24, IGUT-NH3200. Fig. 31. Parahsuum sp. C. x150, IHZS-22, IGUT-NH3699.
Plate 5  Middle Late to late Late Jurassic radiolarians.

Fig. 1. *Haliodictya(?)* *hojosi* Riedel & Sanfilippo. x150, IHZS-10, IGUT-NH2537. Fig. 2. *Crucella theokaftensis* Baumgartner. x100, IHZS-10, IGUT-NH2524. Fig. 3. *Emiluvia premogii* Baumgartner. x150, IHZS-10, IGUT-NH2548. Fig. 4. *Emiluvia salensis* Pessagno. x75, IHZS-16, IGUT-NH2676. Fig. 5. *Acanthocircus suboblongus* (Yao). x100, IHZS-16, IGUT-NH2683. Fig. 6. *Paronaella* sp. B. x150, IHZS-10, IGUT-NH2541. Fig. 7. *Tritrabs ewingi ewingi* (Pessagno). x75, IHZS-10, IGUT-NH2528. Fig. 8. *Tritrabs casmaiaensis* (Pessagno). x100, IHZS-10, IGUT-NH2520. Fig. 9. *Paronaella broennimanni* Pessagno. x75, IHZS-10, IGUT-NH2525. Fig. 10. *Paronaella bandyi* Pessagno. x100, IHZS-10, IGUT-NH2517. Fig. 11. *Paronaella mulleri* Pessagno. x150, IHZS-10, IGUT-NH2535. Fig. 12. *Triactoma blakei* (Pessagno). x75, IHZS-16, IGUT-NH2675. Fig. 13. *Triactoma jonesi* (Pessagno). x100, IHZS-10, IGUT-NH2538. Fig. 14. *Pantanellium* sp. D. x225, IHZS-16, IGUT-NH2674. Fig. 15. *Pantanellium* sp. E. x225, IHZS-10, IGUT-NH2532. Fig. 16. *Archaeospongoprunum imlayi* Pessagno. x100, IHZS-10, IGUT-NH2546. Fig. 17. *Bernoullius* sp. x150, IHZS-16, IGUT-NH2672. Fig. 18. *Orciculiforma(?) kanayamaensis* Mizutani. x150, IHZS-16, IGUT-NH2659. Fig. 19. *Orciculiforma(?) plana* Hori. x150, IHZS-23, IGUT-NH3165. Fig. 20. *Dactyliodiscus* sp. x100, IHZS-23, IGUT-NH3155. Fig. 21. *Mirifusus dianae* (Karrer). x150, TDCH-12n, IGUT-NH2950. Fig. 22. *Eucyrtidiellum pyramis* (Aita). x225, MTZK-i, IGUT-NH3078. Fig. 23. *Gongylothorax favosus* Dumitrica. x150, TDCH-1, IGUT-NH2901. Fig. 24. *Williriedellum crystallinum* Dumitrica. x224, TDCH-12n, IGUT-NH2941. Fig. 25. *Tricologoa* sp. S of Baumgartner et al. (1995). x150, TDCH-12n, IGUT-NH2943. Fig. 26. *Stichocapsa(?)* sp. B. x150, TDCH-12n, IGUT-NH2949. Fig. 27. *Wrangellium okamurai* (Mizutani). x150, MTZK-2, IGUT-NH3090. Fig. 28. *Archaeodictyonmitra minoensis* (Mizutani). x150, TDCH-12m, IGUT-NH2938. Fig. 29. *Pseudodictyonmitra* cf. *carpatica* (Lozyniak). x225, MTZK-2, IGUT-NH3094.
Plate 1
Radiolarians from the chert-clastic sequence in the Torinoko Block

Plate 2
Plate 3
Radiolarians from the chert-clastic sequence in the Torinoko Block
Plate 5