Updated radiolarian zonation for the Jurassic in Japan and the western Pacific

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Abstract

An updated version from radiolarian zonal scheme in the 1990s for the Jurassic in Japan and the western Pacific is presented and vertical distributions of selected radiolarian species are illustrated. The major modifications are as follows: The *Bipedis horiae* Zone (JR0) is added below the *Parahsuum simplum* Zone (JR1). The base of the *Bipedis horiae* Zone (JR0) is defined by the last occurrence biohorizon of *Haeckelicyrtium breviora* Sugiyama and corresponds to the Triassic–Jurassic boundary. The base of the *Parahsuum simplum* Zone is dated within the Sinemurian. The *Tricolocapsa plicarum* Zone (JR4), *Tricolocapsa conexa* Zone (JR5), *Stylocapsa*(?) *spiralis* Zone (JR6), and *Pseudodictyomitra primitiva* Zone (JR8) are modified to the *Striatojaponocapsa plicarum* Zone (JR4), *Striatojaponocapsa conexa* Zone (JR5), *Kilinora spiralis* Zone (JR6), and *Loopus primitivus* Zone (JR8), respectively, in accordance to the change of generic assignment of zone-nominal species.

Key words: Jurassic, radiolaria, zonation, revision, Japan, western Pacific.

Introduction

Radiolarian zonation for the Jurassic and Lower Cretaceous using data from land sections in Japan and deep sea cores in the western Pacific was proposed in Matsuoka (1995a). Since then, taxonomic and biostratigraphic studies on Jurassic radiolarians have been actively carried out in Europe (e.g., Steiger, 1992; O'Dogherty et al., 2006, 2017), North

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America (e.g., Hull, 1997; Carter et al., 1998; Yeh, 2009; Pessagno et al., 2009), Asia (e.g., Sugiyama, 1997; Hori, 1999; Matsuoka et al., 2002), and Antarctica (Kiessling, 1999). International joint research on taxonomy and biostratigraphy of Jurassic radiolarians has been performed continuously (Carter et al., 2010; Goričan et al., 2006, 2013, 2018; O'Dogherty et al., 2009). The accumulation of new data in the last two decades requires a revision of the zonation and age assignments. Although revision of the zonation was briefly reported in Matsuoka (2006), detailed explanations have not been demonstrated yet. An updated version of the zonal scheme of Matsuoka (1995a) for the entire Jurassic in Japan and the western Pacific is presented in this paper.

A brief review of Jurassic radiolarian zonation in Japan and the western Pacific

Mesozoic radiolarian studies in Japan were carried out to clarify the geology of accretionary complexes since the 1970s. In the early 1980s several research groups started radiolarian biostratigraphic work at almost the same time so that several independent zonal schemes were proposed. A historical review on Jurassic radiolarian biostratigraphic research in Japan is given in Goričan et al. (2018).

Interval zones for the entire Jurassic were established by Matsuoka and Yao (1986). Deep sea cores in the western Pacific obtained from Leg 129 of the Ocean Drilling Program (ODP) contributed to testifying the zonal scheme for the Middle and Upper Jurassic established in Japan (Matsuoka, 1992). Combining data from land sections in Japan with data from the ODP materials, Matsuoka (1995a) proposed a zonal scheme for the Jurassic and Lower Cretaceous. A detailed data set for this zonation was presented in Matsuoka (1995b). The Jurassic succession includes the *Parahsuum simplum* Zone (JR1), *Trillus elkhornensis* Zone (JR2), *Laxtorum*(?) *jurassicum* Zone (JR3), *Tricolocapsa plicarum* Zone (JR4), *Tricolocapsa conexa* Zone (JR5), *Stylocapsa*(?) *spiralis* Zone (JR6), *Hsuum maxwelli* Zone (JR7), and *Pseudodictyomitra primitiva* Zone (JR8) in ascending order. In addition to these zones, the *Pseudodictyomitra carpatica* Zone (KR 1) includes the uppermost Jurassic as well. Most of these zones are introduced in a popular text book on radiolarians presented by De Wever et al. (2001). The zonal scheme has been widely utilized for the dating of marine sequences accumulated in the Panthalassa and Tethys (e.g., Matsuoka et al., 1998, 2002; Zamoras and Matsuoka, 2001, 2004; Li et al., 2016, 2018; Ito and Matsuoka, 2018).

Radiolarian zonation

As stated in "Introduction", much effort has been made on taxonomic and biostratigraphic research for Jurassic radiolarians. It is necessary to update zonal names and definition in accordance with the progress in radiolarian research for the last two decades. The updated zonal scheme for the Jurassic in Japan and the Pacific is summarized in Fig. 1. Vertical distributions of selected radiolarian species, especially zone-diagnostic taxa, are also illustrated in Fig. 1.

To define zones, radiolarian bio-events such as the evolutionary first appearance biohorizon (EFAB), first occurrence biohorizon (FOB), and last occurrence biohorizon (LOB) were used. The EFAB, which is the most synchronously reliable among various kinds of biohorizons, is selected as often as possible.

Bipedis horiae Zone
Code. JR0
Base. LOB of *Haeckelicyrtium breviora* Sugiyama.
Top. FOB of *Parahsuum simplum* Yao.
Remarks. Sugiyama (1997) established the *Haeckelicyrtium breviora–Bipedis horiae* Partial-range Zone (JR0A) and the *Bipedis horiae* Lowest occurrence Zone (JR0B) in the Sakahogi section of the Mino Terrane, central Japan. The *Bipedis horiae* Zone (JR0) of the present study is a zonal unit for the lowest portion of the Jurassic, combining JR0A and JR0B proposed by Sugiyama (1997). The LOB of *H. breviora* Sugiyama corresponds to the Triassic–Jurassic boundary (TJB) in the Sakahogi section (Sugiyama, 1997). Since species belonging to the genus *Bipedes* are common in marine sequences around the TJB, the phyletic analysis of *Bipedis* species can contribute to further refinement of this zone. The first occurrence of *B. horiae* Sugiyama has been reported only in the Sakahogi section so far, which is located just above the TJB.
Age. Hettangian to early Sinemurian.

Parahsuum simplum Zone
Code. JR1
Base. FOB of *Parahsuum simplum* Yao.
Top. FOB of *Trillus elkhornensis* Pessagno and Blome.
Remarks. Sugiyama (1997) showed the first occurrence of *Parahsuum simplum* Yao in the Sakahogi section, being higher than the FOB of *B. horiae*. The first occurrence biohorizon of *P. simplum* is located within the Sinemurian in Haida Gwaii, Canada (Carter et al., 1998).
Age. Late Sinemurian to middle Early Pliensbachian.

Trillus elkhornensis Zone
Code. JR2
Base. FOB of *Trillus elkhornensis* Pessagno and Blome.
Top. FOB of "*Laxtorum*" *jurassicum* Isozaki and Matsuda.
Remarks. Carter et al. (2010) reported that *Trillus elkhornensis* Pessagno and Blome first

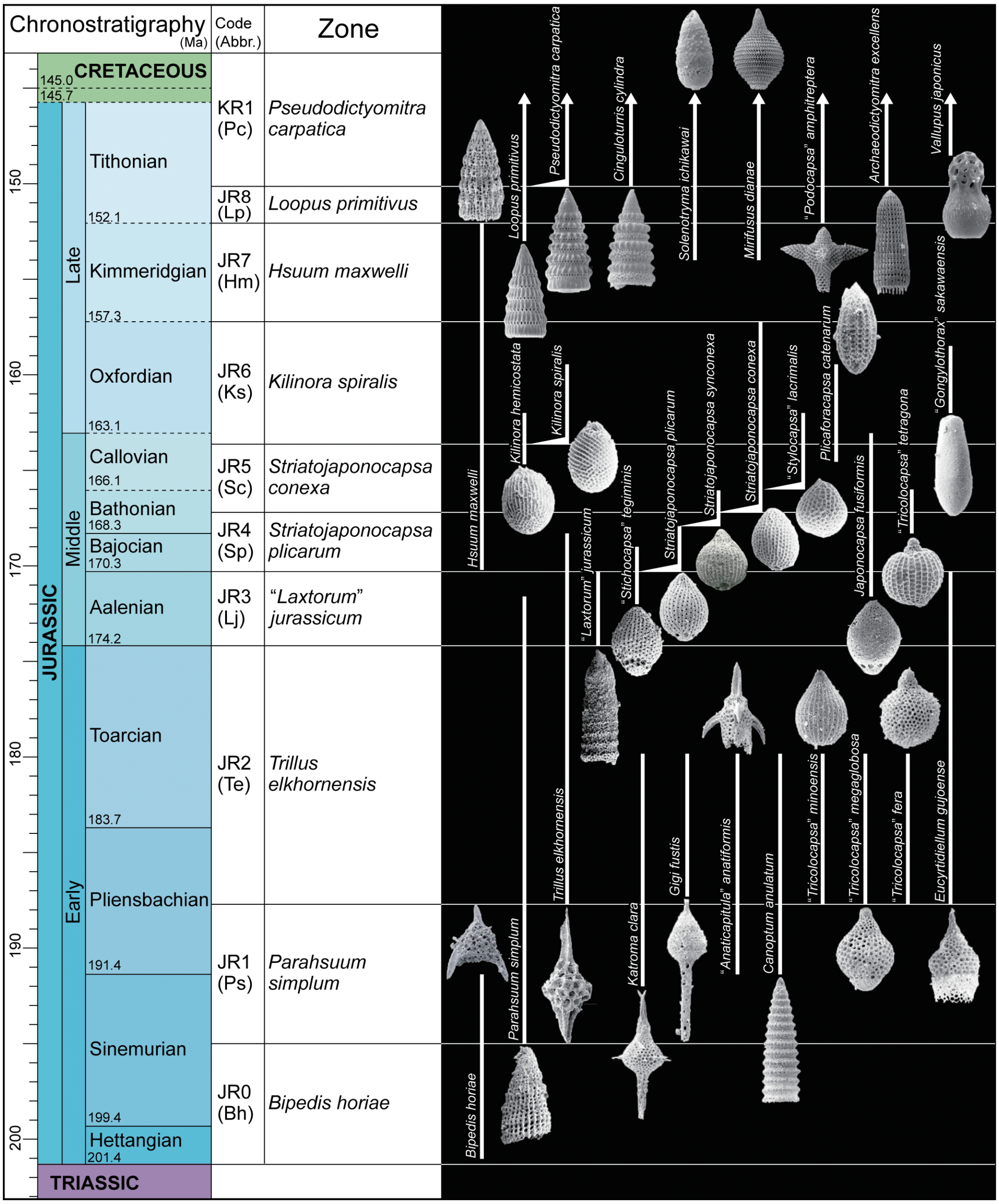

Fig. 1. Updated radiolarian zonation for the Jurassic in Japan and the western Pacific. Chronostratigraphy is based on Ogg et al. (2016). Images of index radiolarians are reprinted from authors' previous papers (Matsuoka, 1983, 1998, 2004) and unpublished data. Arrows in the range chart indicate that the vertical ranges extend beyond the Jurassic–Cretaceous boundary.

occurs in the *Hsuum mulleri–Trillus elkhornensis* Zone of middle Lower Pliensbachian.
Age. Middle Early Pliensbachian to Toarcian.

"Laxtorum" jurassicum Zone
Code. JR3
Base. FOB of *"Laxtorum" jurassicum* Isozaki and Matsuda.
Top. EFAB of *Striatojaponocapsa plicarum* (Yao).
Age. Aalenian.

Striatojaponocapsa plicarum Zone
Code. JR4
Base. EFAB of *Striatojaponocapsa plicarum* (Yao).
Top. EFAB of *Striatojaponocapsa conexa* (Matsuoka).
Remarks. *Striatojaponocapsa* was established by Kozur (1984), taking *Tricolocapsa plicarum* Yao as the type species. The evolutionary lineage from the ancestor *S. plicarum* to the descendant *S. conexa* was first demonstrated by Matsuoka (1983). O'Dogherty et al. (2006) described two new species of *Striatojaponocapsa* in the Austrian Alps; *S. synconexa* O'Dogherty, Goričan, and Dumitrica and *S. riri* O'Dogherty, Goričan, and Dumitrica. Hatakeda et al. (2007) examined in detail the evolutionary history of the *Striatojaponocapsa* lineage in continuous sections in Japan. They concluded that *S. plicarum* continuously and gradually changed into *S. synconexa*, then *S. synconexa* was rapidly replaced by *S. conexa* in a phyletic evolutionary process. In accordance with the change of generic assignment of the nominal species, the zonal name is changed to the *Striatojaponocapsa plicarum* Zone.
Age. Bajocian to early Bathonian.

Striatojaponocapsa conexa Zone
Code. JR5
Base. EFAB of *Striatojaponocapsa conexa* (Matsuoka).
Top. EFAB of *Kilinora spiralis* (Matsuoka).
Remarks. In relation to the change of generic assignment of the nominal species (Hull, 1997), the zonal name is changed to the *Striatojaponocapsa conexa* Zone.
Age. Late Bathonian to middle Callovian.

Kilinora spiralis Zone
Code. JR6
Base. EFAB of *Kilinora spiralis* (Matsuoka).
Top. LOB of *Striatojaponocapsa conexa* (Matsuoka).
Remarks. The genus *Kilinora* was established by Hull (1997) who took *Stylocapsa*(?) *spiralis*

Matsuoka as the type species. In accordance with the change of generic assignment of the nominal species, the zonal name is changed to the *Kilinora spiralis* Zone. The evolutionary lineage form the ancestor *Kilinora hemicostata* (Matsuoka) to the descendant *K. Spiralis* was first reported at several land sections in Japan (Matsuoka, 1983, 1995a). The same lineage was recognized at DSDP Site 534 in the north-western Central Atlantic as well (Matsuoka and Baumgartner, 1997).
Age. Late Callovian to Oxfordian.

Hsuum maxwelli Zone
Code. JR7
Base. LOB of *Striatojaponocapsa conexa* (Matsuoka).
Top. LOB of *Hsuum maxwelli* Pessagno.
Age. Kimmeridgian.

Loopus primitivus Zone
Code. JR8
Base. LOB of *Hsuum maxwelli* Pessagno.
Top. EFAB of *Pseudodictyomitra carpatica* Lozyniak.
Remarks. Yang (1993) established the genus *Loopus*, taking *Pseudodictyomitra primitiva* Matsuoka and Yao as the type species. In relation to the change of generic assignment of the nominal species, the zonal name is changed to the *Loopus primitivus* Zone. The evolutionary first appearance of *Pseudodictyomitra carpatica* was reported at Site 801 of ODP Leg 129 (Yang and Matsuoka, 1997; Matsuoka and Yang, 2000). Zügel (1997) showed the occurrence of *P. carpatica* in the lower Tithonian of the Solnhofen area, southern Germany.
Age. Early Tithonian.

Pseudodictyomitra carpatica Zone
Code. KR1
Base. EFAB of *Pseudodictyomitra carpatica* (Lozyniak).
Top. EFAB of *Cecrops septemporatus* (Parona).
Remarks. The Jurassic–Cretaceous boundary is located within this zone.
Age. Late Tithonian to early Valanginian.

Concluding remarks

The current status and future directions in Mesozoic radiolarian biochronological research are recently documented by Goričan et al. (2018). They stress the importance of detailed documentation of evolutionary first and last appearance in different radiolarian phylogenetic lineages. In the last two decades, some new taxa have been proposed and their biostratigraphic significance has been discussed. On the basis of the progress, this article updated Jurassic radiolarian zonation.

Generic assignment of many species, even zone-diagnostic species (i.e., "*Laxtorum*" *jurassicum*), is still debatable. Furthermore, phylogenetic relationships among Early and Late Jurassic radiolarians are not entirely clear compared to those of Middle Jurassic radiolarians. We expect this article to act as a stepping stone to further progress.

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