

# Significance of the direct correlation of ammonite and radiolarian zones in the Izumi Group for integrated biostratigraphy of Late Cretaceous NW paleo-Pacific region

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## Abstract

The direct correlation of radiolarian and ammonite zones in the Izumi Group were reviewed and revised for integrated biostratigraphy across the Campanian – Maastrichtian boundary. The significance of the direct correlation between mega- and micro-, i.e. between relatively near-shore nektonic and slope-basin planktonic faunas in the same stratigraphic field, was discussed in relation with the litho- and biofacies of the group. The Late Cretaceous ocean climate change and surface seawater current inferred from the radiolarian fauna was considered as a marker event for the chronostratigraphic correlation in the middle latitude continental shelf to slope-basin facies facing towards the NW paleo-Pacific.

*Keywords: Late Cretaceous, Campanian – Maastrichtian, ammonite, radiolaria, biostratigraphy, Izumi Group.*

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## INTRODUCTION

The Izumi Group (Harada, 1890) of the Upper Cretaceous inter-arc basin deposit along the northern side of the Median Tectonic Line (ex. Takahashi and Yamasaki, 1991) is one of the most important fields for the direct correlation of ammonite and radiolarian biostratigraphy in Japan and NW Pacific region. Both taxa are widely used for the global correlation, whereas their distributions are generally facies controlled as ammonites were relatively near-shore and shallower than radiolarians that are dominantly found in pelagic and deeper marine facies. According to the last reports (Fig.1), the Campanian to Maastrichtian chronological correlation by radiolarian zonation is relatively younger than those by ammonite zonation. To improve the chronological accuracy, direct correlation of ammonite and radiolarian zonation within the same stratigraphic field is necessary. We review the recent status of research compiling the biostratigraphic occurrence of radiolarians and ammonites in the Izumi Group.

## GEOLOGICAL OUTLINE

The Izumi Group, nonconformably overlies the Upper Cretaceous Ryoke volcano-plutonic rock series (ca. 100 – 80 Ma), is distributed in Shikoku, Awaji and Kii areas. The Izumi Group is composed of the continental shelf facies and the slope-basin facies. The former is characterized by the occurrence of ammonites and inoceramids from the pelitic facies above the basal conglomerates. The latter is characterized by turbiditic successions with occurrence of “*Archeozostera*” that is strongly suggested as a trace fossil referable to *Zoophycus* ichnofacies (Kotake, 1994) where the fine sediments yields radiolarian faunas. The two lithofacies are intertonguing and well-controlled by the intercalations of acidic tuff key beds. The succession and lateral extension are both traceable well, because the group forms eastward plunging synclinal structures.

Ammonite Zones (Morozumi, 1985)		Radiolarian Zones (after Ishida and Hashimoto, 1998)	
Ma	<i>Pachydiscus aff.subcompressus</i>	<i>Amphipyndax tylotus</i> 2 (At 2)	Ma
	<i>Nostoceras hetonaianus</i>		
Ca	<i>Pachydiscus awajiensis</i>	<i>Amphipyndax tylotus</i> 1 (At 1)	Ca
	<i>Pravitoceras sigmoidale</i>	<i>Amphipyndax pseudoconulus</i> 2 (Ap 2)	
	<i>Didymoceras awajiense</i>		
	<i>Didymoceras</i> sp.	<i>Amphipyndax pseudoconulus</i> 1 (Ap 1)	
	<i>Baculites kotanii</i>		
	<i>Metaplacenticeras subtilistriatum</i>		
	<i>Sphenocerasmus schmidti</i>	<i>Stichomitra compsa</i>	

Fig. 1. The direct correlation of ammonite and radiolarian zonation in the Izumi Group.

#### AMMONITE BIOSTRATIGRAPHY

The Campanian – Maastrichtian ammonite zonation of the Izumi Group was subdivided into nine zones, and the Campanian – Maastrichtian boundary was tentatively proposed between the *Pachydiscus awajiensis* Zone and *Nostoceras hetonaianus* Zone (Fig. 1; Morozumi, 1985). Among the indices, *Pravitoceras sigmoidale*, a very short-range zone index assignable to the upper Campanian (Matsumoto et al., 1981), has also discovered within the *Inoceramus shikotanensis* Zone (Toshimitsu et al., 1995) of the Yezo Supergroup in Hokkaido (Matsunaga et al., 2008). The discovery shows the same situation as in the case of Izumi Group, and will be hopeful for much more precise biostratigraphic correlation between the Yezo Supergroup and the Izumi Group.

#### RADIOLARIAN BIOSTRATIGRAPHY

After the compile by Sanfilippo and Riedel (1985), the Cretaceous radiolarian taxonomy and biostratigraphy were reviewed (O'Dogherty et al., 2009). Hollis and Kimura (2001) reviewed the Japan's Campanian and Maastrichtian radiolarian zonation in terms of specific identifications and age determinations. Suyari and Hashimoto (1985) initially reported the occurrence of Campanian radiolarians from the Izumi Group. Yamasaki (1987) firstly

studied the radiolarian zonation of the group. Based on data from the Izumi Group and the selected hemipelagic chert-clastic sequences (mostly trench-slope facies) of the Shimanto Terrane, the Upper Cretaceous radiolarian zonation has proposed by Hashimoto and Ishida (1997) and Ishida and Hashimoto (1998) with respect to the first appearance datum (FAD) and last appearance datum (LAD) of selected indices (Fig.2) as follows in ascending order.

*Amphipyndax pseudoconulus* Zone (Ap Zone): The zone starts from FAD of *Amphipyndax pseudoconulus* to LAD of *Pseudodictyomitra koslovae*. The FAD of *Amphipyndax tylotus* subdivides this zone into Ap1 and Ap2 subzones.

*Amphipyndax tylotus* Zone (At Zone): The zone begins after LAD of *Dictyomitra koslovae* to the LAD of *Amphipyndax pseudoconulus*. The LAD of *Stichomitra compsa* subdivides this zone into At1 and At2 subzones.

Whereas the Maastrichtian radiolarian reports are few in Japan (Taketani, 1995), Hashimoto et al. (2001) reported that the At2 is correlative with the *Clathrocyclas? gravis* Zone (Hollis and Kimura, 2001) of Maastrichtian. The radiolarian fauna, characterized by the association of *Acaeniotyle diaphorogona*, *A. gedrangta* and *A. starka* with *Stichomitra* cf. *compsa*, is the lowest record from the Izumi Group (Tanaka and Yamasaki, 2000). The faunal horizons are regarded as lower part of the *Dictyomitra koslovae* (DK) Assemblage Zone (Yamasaki, 1987).

Radiolarian Zone Subzone	Sc	Ap		At	
		Ap 1	Ap 2	At 1	At 2
<i>Amphipyndax stocki</i> (Campbell & Clark)					
<i>Amphipyndax conicus</i> Nakaseko & Nishimura					
<i>Mita regina</i> (Squinabol)					
<i>Dictyomitra formosa</i> Squinabol					
<i>Dictyomitra tiara</i> (Campbell & Clark)					
<i>Archaeospongoprunum nishiyamae</i> Nakaseko & Nishimura					
<i>Stichomitra manifesta</i> Foreman					
<i>Artostrobium uma</i> Foreman					
<i>Allevium praegallowayi</i> Pessagno					
<i>Teocampe salillum</i> Foreman					
<i>Cryptamphorella sphaerica</i> (White)					
<i>Dictyomitra densicostata</i> Pessagno					
<i>Stichomitra asymbatos</i> Foreman					
<i>Dictyomitra koslovae</i> Foreman					
<i>Allevium gallowayi</i> (White)					
<i>Diacanthocapsa acuminata</i> Dumitrica					
<i>Amphipyndax</i> aff. <i>pseudoconulus</i> (Pessagno)					
<i>Dictyomitra multicostrata</i> Zittel					
<i>Stichomitra campi</i> (Campbell & Clark)					
<i>Rhopalosyringium magnificum</i> Empson-Morin					
<i>Stichomitra compsa</i> Foreman					
<i>Immersothorax cyclops</i> Dumitrica					
<i>Archaeospongoprunum huei</i> Pessagno					
<i>Dictyomitra</i> aff. <i>koslovae</i> Foreman					
<i>Afens liriodes</i> Riedel & Sanfilippo					
<i>Amphipyndax pseudoconulus</i> (Pessagno)					
<i>Pseudotheocampe abschnitta</i> Empson-Morin					
<i>Mylocercion acineton</i> Foreman					
<i>Archaeodictyomitra lamellicostata</i> (Foreman)					
<i>Amphipyndax tylotus</i> (Foreman)					

Fig. 2. Selected radiolarian ranges in the Izumi Group and hemipelagic chert-clastic sequences of the Shimanto Terrane (after Ishida and Hashimoto, 1998).

### OCEAN CLIMATE AND SURFACE SEAWATER CURRENT INFERRED FROM THE RADIOLARIAN FAUNA

Takahashi and Ishii (1993) indicated that the radiolarian fauna of their *At* Zone in the Izumi Group includes both boreal (relatively high latitude) and warm (low latitude) currents affinities. The former is represented by the association of *Stichomitra livermorensis*, *Lithomellisa* sp. and *Theocampe altamontensis*. The latter is characterized by *Amphipyndax pseudoconulus*, *Theocampe abschnitta*, *Dictyomitra lamellicostata* and *Mylocercion acineton*. The lower and upper zones (*Stichomitra compsa* Zone and *At2* Subzone) are dominated by warm current affinity, whereas the middle zones (*Ap* Zone to *At1* Subzone) are characterized by mixture of both boreal and warm currents affinities. Especially the radiolarian fauna from the upper *Ap2* Subzone, that is correlative with the ammonite *Praviloceras sigmoidale* Zone, is characterized by dominant occurrence of a boreal affinity *Lithomellisa* sp. At the period, the boreal current probably reached into the

middle latitude Izumi inter-arc basin. It is suggestive that the radiolarian faunal change in the Izumi Group coincides with the appearance of ammonite *Praviloceras sigmoidale* both in the Yezo Supergroup and Izumi Group. Phylogenetic relation between *Praviloceras sigmoidale* and *Didymoceras awajiense* is discussed from the view-points of morphological property and the existence of their transitional forms (Misaki et al., 2009; Misaki and Maeda, 2010).

### CHRONOLOGICAL DISCUSSION OF THE RADIOLARIAN ZONATION

Magnetostratigraphic chron 32r was recognized in the Izumi Group (Kodama, 1990), and was regarded as Upper Campanian (Kodama et al., 2002). The fission track dating of two acidic tuff beds in the *P. sigmoidale* Zone indicates 73 and 78 Ma (Morozumi, 1997: personal com.). Chronological viewpoint, last radiolarian reports suggested that the ammonite zones are relatively older than radiolarian ones around the Campanian – Maastrichtian border.

We mark the importance of their co-occurrence and stratigraphic intercalations in the same basin, and propose that the radiolarian zonal boundary of *Ap2* and *At1* is correlative with the ammonite zonal boundary between *Pacydiscus awajiensis* Zone and *Pravitoceras sigmoidale* Zone (Fig.1).

The confirmed ranges of the selected radiolarian species in the Izumi Group and Shimanto Supergroup (Fig. 2) represents the vertical faunal transition in the Late Cretaceous middle latitude inter-arc basin to trench slope facies facing towards the NW Pacific. The faunal change from *At1* to *At2* is marked by LAD of *S. compsa* as well as *A. nishiyamae*, *S. manifesta*, *A. praegallowayi*, *D. densicostata* and *D. multicostata*. The *At1* to *At2* faunal change represents the radiolarian faunal recovery by warm current affinities, and the change is remarkable than that from *Ap2* to *At1* marked by LAD of *D. koslovae*, *I. cyclops* and *T. salillum*. Conclusively, the ocean climate change event inferred from the radiolarian faunal transition will be useful for much more precise chronological correlation around the Campanian - Maastrichtian boundary.

## REFERENCES

- Harada, T., 1890, Die japonischen Inseln, eine topographisch geologische Übersicht. *Paul Parey*, Berlin, 126 p.
- Hashimoto, H. and Ishida, K., 1997, Correlation of selected radiolarian assemblages of the Upper Cretaceous Izumi and Sotoizumi groups and Shimanto Supergroup in Shikoku. *News of Osaka Micropaleontologists, Spec. Vol.*, no. 10, 245-257.
- Hashimoto, H., Kozai, T. and Ishida, K., 2001, Jurassic and Early Cretaceous radiolarians reworked into the Upper Cretaceous Izumi Group, Izumi Mountains. *News of Osaka Micropaleontologists, Spec. Vol.*, no. 12, 271-282.
- Hollis, C. J. and Kimura, K., 2001, A unified radiolarian zonation for the Late Cretaceous and Paleocene of Japan. *Micropaleontology*, **47** (3), 235-255.
- Ishida, K. and Hashimoto, H., 1998, Upper Cretaceous radiolarian biostratigraphy in selected chert-clastic sequences of the North Shimanto Terrane, East Shikoku. *News of Osaka Micropaleontologists, Spec. Vol.*, no. 11, 211-225.
- Kodama, K., 1990, Magnetostratigraphy of the Izumi Group along the Median Tectonic Line in Shikoku and Awaji Islands, Southwest Japan. *Journal of the Geological Society of Japan*, **96**, 265-278.
- Kotake, N., 1994, Population paleoecology of the *Zoophycus*-producing animal. *Palaios*, **9**, 84-91.
- Matsumoto, T., Morozumi, Y., Bando, Y., Hashimoto, H. and Matsuoka, A., 1981, Note on *Pravitoceras sigmoidale* (Cretaceous heteromorphy ammonite). *Transactions and Proceedings of the Paleontological Society of Japan, New Series*, no.123, 168-178.
- Matsunaga, T., Maeda, H., Shigeta, Y., Hasegawa, K., Nomura, S., Nishimura, T. Misaki, A. and Tanaka, G., 2008, First discovery of *Pravitoceras sigmoidale* Yabe from the Yezo Supergroup in Hokkaido, Japan. *Paleontological Research*, **12** (4), 309-319.
- Misaki, A. and Maeda, H., 2010, Two Campanian (Late Cretaceous) nostoceratid ammonoids from the Toyajo Formation in Wakayama, Southwest Japan. Tanabe, In: K., Shigeta, Y., Sasaki, T. and Hirano, H. (eds.) *Cephalopods - Present and Past*, Tokai University Press, Tokyo, p. 223-231.
- Misaki, A., Okamoto, T., Nomura, S., Ichida, M., Tanaka, G. and Maeda, H., 2009, Stratigraphic and morphological correlation of *Didymoceras awajense* and *Pravitoceras sigmoidale* (Late Cretaceous heteromorphy ammonoids). Abstracts with programs, 158th Regular Meeting of the Palaeontological Society of Japan, p. 47.
- Morozumi, Y., 1985, Late Cretaceous (Campanian and Maastrichtian) ammonites from Awaji Island, Southwest Japan. *Bulletin of Osaka Museum of Natural History*, **39**, 1-58.
- O'Dogherty, L., Carter, E. S., Dumitrica, P., Gorican, S., De Wever, P., Bandini, A.N., Baumgartner, P.O. and Matsuoka, A., 2009, Catalogue of Mesozoic radiolarian genera. Part 2: Jurassic – Cretaceous. *Geodiversitas*, **31** (2), 271-356.

## SUMMARY

The direct correlation of radiolarian and ammonite zones in the Izumi Group were reviewed and revised for more accurate biostratigraphy across the Campanian – Maastrichtian boundary. In relation with the litho- and biofacies property of the Izumi Group, the significance of the direct correlation in the same stratigraphic field was discussed for unified global correlation of different categories. The Late Cretaceous ocean climate change and surface seawater current inferred from the radiolarian fauna was considered as a marker event for the chronostratigraphic correlation in the middle latitude continental shelf to slope-basin facies facing towards the NW paleo-Pacific.

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- Sanfilippo, A. and Riedel, W., 1985, Cretaceous radiolaria. In Bolli, H. M., Saunders, J. B. and Perch-Nielsen, K. (eds.) "*Plankton Stratigraphy*" Volume 2, Cambridge University Press, Cambridge, 573-630.
- Suyari, K. and Hashimoto, H., 1985, A radiolarian assemblage from the Izumi Group of Eastern Shikoku. *Journal of Science, University of Tokushima*, **18**, 103-127.
- Takahashi, J. and Yamasaki, T., 1991, The Median Tectonic Line and the Izumi Group in central and east Ehime Prefecture. Field excursion guide book of the Geological Society 98<sup>th</sup> meeting, Matsuyama, 121-137.
- Takahashi, O. and Ishii, A., 1993, Paleo-oceanic environment in the Late Cretaceous time, inferred from radiolarian fauna of *Amphipyndax tylotus* Zone. News of Osaka Micropaleontologists, Special Vol., no.9, 261-270.
- Taketani, Y., 1995, A review of the Upper Cretaceous radiolarian biostratigraphy in Japan - Some radiolarian biohorizons, useful for international -. *Journal of the Geological Society of Japan*, **101**, 30-41.
- Tanaka, S. and Yamasaki, T., 2000, Radiolarian fossils of the Upper Cretaceous Izumi Group in the Aoshima Island, Nagahama Town, Ehime Prefecture. *Professor Naruhiko Kashima Commemorative Volume*, 45-54.
- Toshimitsu, S., Matsumoto, T., Noda, M., Nishida, T. and Maiya, S., 1995, Towards an integrated mega-, micro- and magnetostratigraphy of the Upper Cretaceous in Japan. *Journal of the Geological Society of Japan*, **101**, 19-29.
- Yamasaki, T., 1987, Radiolarian assemblages of the Izumi Group in Shikoku and western Awaji Island, southwest Japan. *Journal of the Geological Society of Japan*, **93**, 403-417.

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