RADI LARIA

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NEWSLETTER

THE INTERNATIONAL ASSOCIATION OF RADIOLARISTS

ISSN: 0297.5270

INTER RAD

15th InterRad Niigata 2017

NIIGATA UNIVERSITY

gsj

The Geological Society of Japan
×125 years
2018
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SCIENCE on FORM

Palaeontological Society of Japan
日本古生物学會

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INTERRAD is an international non-profit organization for researchers interested in all aspects of radiolarian taxonomy, palaeobiology, morphology, biostratigraphy, biology, ecology and paleoecology. INTERRAD is a Research Group of the International Paleontological Association (IPA), is affiliated to The Micropalaeontological Society (TMS). Since 1978 members of INTERRAD meet every three years to present papers and exchange ideas and materials.

*Because of the partnership between INTERRAD and Revue de Micropaléontologie the current INTERRAD President is also one of the Editors of this journal.

Membership: The International Association of Radiolarists is open to anyone interested on receipt of subscription. Triennial fees are fixed at the General Assembly. Membership queries and subscription should be send to Treasure.

Bibliographies: The bibliographies are produced by the Secretary. Any suggestion, reprints of articles and details of omission should be sent to him directly.

Cover photo: Ikarashi Campus of Niigata University, venue for InterRad XV in Niigata 2017

RADIOLARIA

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VOLUME 40 **October 2017**

Editors: Tsuyoshi Ito, Takashi Yoshino, Takuya Itaki, Yukihisa Nishizono & Atsushi Matsuoka

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The 15th Meeting of the International Association of Radiolarists

22/Oct–27/Oct 2017
Niigata University (Japan)

Program & Abstracts

THE ORGANIZING COMMITTEE FOR INTERRAD XV IN NIIGATA 2017
（第 15 回国際放散虫研究集会実行委員会）

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Excursion Coordinator: **Tsuyoshi ITO**

Excursion Leaders:

Pre-conference Excursions

Excursion A (Boso) [cancelled]: **Isao MOTOYAMA**, **Takuya ITAKI**, **Shin'ichi KAMIKURI**, **Yojiro TAKETANI** and **Makoto OKADA**

Excursion B (Inuyama): **Tetsuji ONOUE**, **Rie S. HORI** and **Satoru KOJIMA**

Mid-day Excursions

Excursion C (Itoigawa): **Tsuyoshi ITO**, **Yousuke IBARAKI** and **Atsushi MATSUOKA**

Excursion D (Tai'nai): **Isao MOTOYAMA**, **Toshiyuki KURIHARA** and **Takuya ITAKI**

Post-conference Excursion

Excursion E (Okinawa): **Atsushi MATSUOKA**, **Tsuyoshi ITO**, **Noritoshi SUZUKI**, **Katsunori KIMOTO**, **Akihiro TUJI**, **Xin LI** and **Ryo ICHINOHE**

Executive Members: **Satoshi NAKAE**, **Yukihisa NISHIZONO**, **Yoshihito KAMATA** and **Takashi YOSHINO**

Webmaster: **Takashi YOSHINO**

ORAL SESSIONS AND CONVENERS

SPECIAL SYMPOSIUM I

SESSION 1 PALEOCEANOGRAPHY OF TETHYS AND PANTHALASSA

Conveners: **Satoshi TAKAHASHI** and **Peter O. BAUMGARTNER**

SESSION 2 CENOZOIC PALEOCEANOGRAPHY OF MARGINAL SEAS

Conveners: **Takuya ITAKI**, **Yusuke OKAZAKI** and **Richard W. JORDAN**

SPECIAL SYMPOSIUM II

SESSION 3 BIOLOGY AND PALEOBIOLOGY OF SHELLED PROTISTA

Conveners: **Katsunori KIMOTO** and **Fabrice NOT**

SESSION 4 FORMS: AN INTERFACE BETWEEN FUNCTION AND EVOLUTION

Conveners: **Yuki TOKUDA** and **Yuta SHIINO**

SESSION 5 JURASSIC–CRETACEOUS BOUNDARY

Conveners: **Atsushi MATSUOKA** and **Gang LI**

GENERAL SYMPOSIUM I

SESSION 7 INSIGHTFUL STUDIES FOR RADIOLARIANS

Convener: **Yoshiaki AITA**

SESSION 8 BIOSILICEOUS RECORDS

Convener: **John ROGERS**

SESSION 9 MODERN BIOGEOGRAPHY

Convener: **Rie S. HORI**

SESSION 10 PALEOBIOGEOGRAPHY

Convener: **Kiyoko KUWAHARA**

GENERAL SYMPOSIUM II

SESSION 11 EVOLUTION AND DIVERSITY

Convener: **Weihong HE**

SESSION 12 BIOSTRATIGRAPHY

Convener: **Marco CHIARI**

SESSION 13 TIBETAN TECTONICS

Convener: **Taniel DANELIAN**

SESSION 14 EUROPEAN TECTONICS

Convener: **Hui LUO**

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* at the present time of September 11, 2017.

Session Places

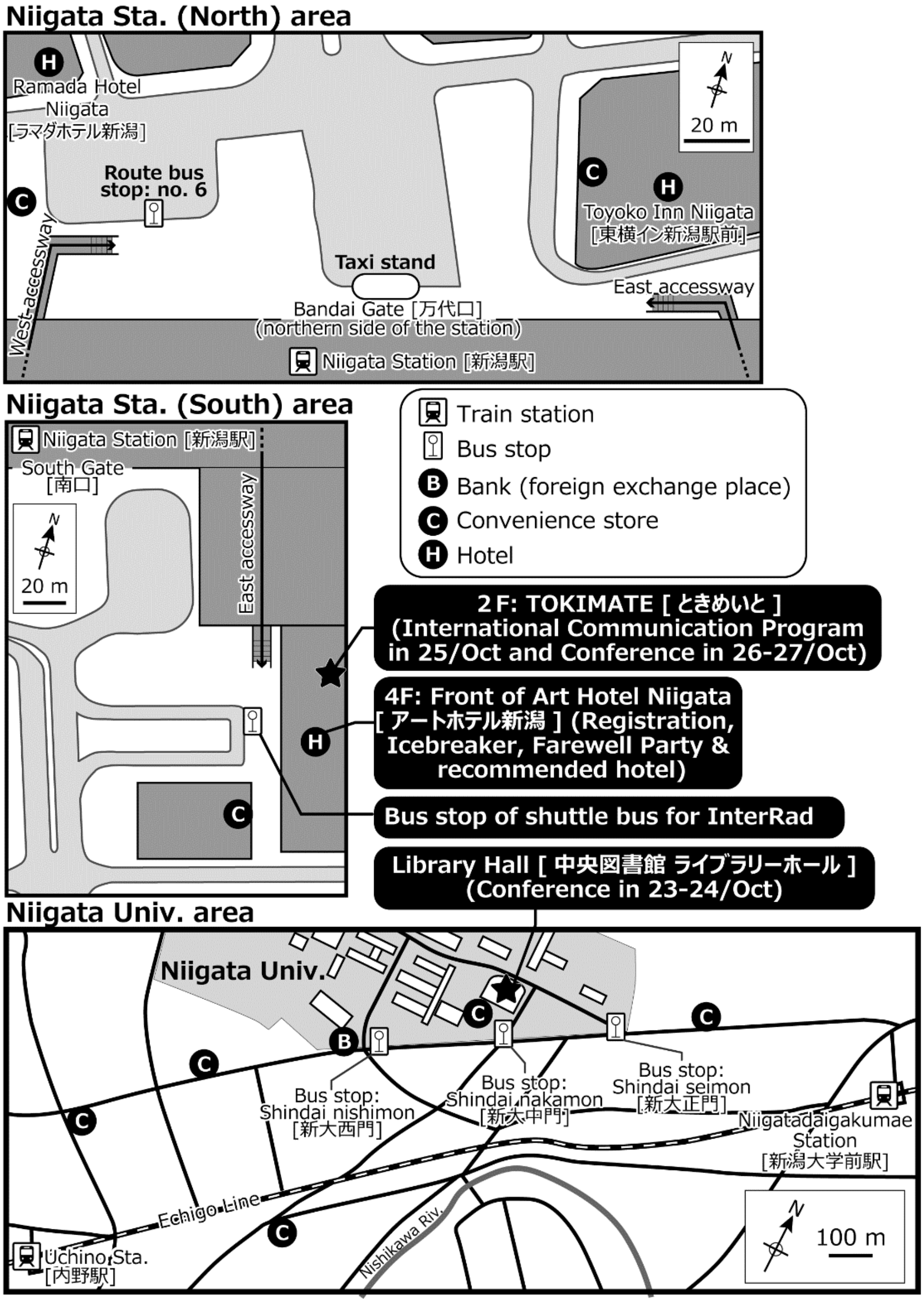
—23/Oct (Mon) & 24/Oct (Tue)—

- The Library Hall and Library Gallery of "Central Library" (新潟大学中央図書館 Building S5) in the Ikarashi Campus of Niigata University (http://www.niigata-u.ac.jp/en/university/access/ikarashi.html)
  - Oral presentation: Library Hall
  - Poster presentation: Library Gallery
- Place Address (not contact address): Central Library, Niigata University 8050 Ikarashi 2-no-cho, Nishi-Ku, Niigata City, Niigata Prefecture 950-2181, JAPAN

—26/Oct (Thu) & 27/Oct (Fri)—

- Lecture Room, Multi-purpose Space and Meeting Room A of "TOKIMATE" (ときめいと), near JR Niigata Station, Niigata Prefecture (English website is unavailable)
  - Oral presentation: Lecture Room
  - Poster presentation: Multi-purpose Space and Meeting Room A
- Place Address (not contact address): "TOKIMATE", Eki-nan Campus of Niigata University PLAKA 1, 1-1, Sasaguchi, Chuo-ku, Niigata City, Niigata Prefecture 950-0911, JAPAN

—Access to Ikarashi Campus from Niigata Station—



Transportation from Niigata Sta. to Niigata Univ.

1: Shuttel bus for InterRad (50 min., once in morning, free)
2: Route bus (50 min., 4 times/hour, 470 JPY/one way)
  Bus stop no. 6: W2 Nishi-kobari Line [西小針線],
  W21 for Niigata Univ. via Nishi-kobari [西小針経由 新潟大学] or
  W21 for Uchino Depot. via. Nishi-kobari, Niigata UNiv. [西小針・新潟大学経由 内野営業所]
  Bus stop Shindai seimon [新大正門], Shindai nakamon [新大中門] or Shindai nishimon [新大西門]
3: Train (25 min. for train and 15 min. for walk, 3 times/hour, 240 JPY/one way)
  Echigo Line [越後線]: for Yoshida [吉田] or for Uchino [内野]
  Niigatadaigakumae Sta. [新潟大学前駅] or Uchino Sta. [内野駅]
4: Taxi (40 min., 3,000-5,000 JPY/one way)

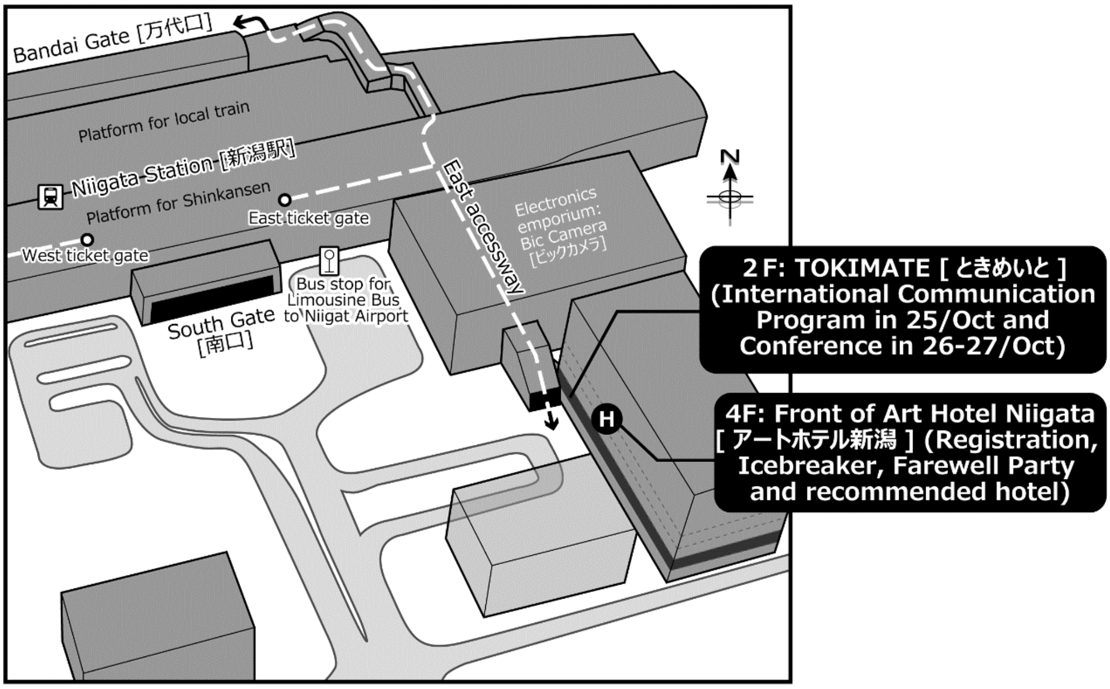
PROGRAM: 22/Oct (Sun)

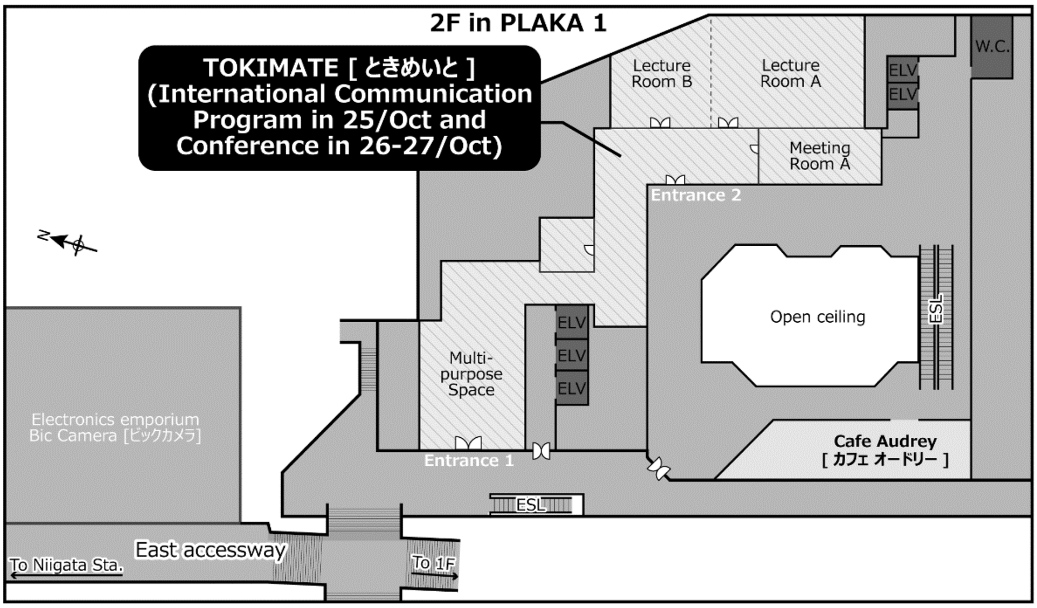
Outreach Program: What's rad??
(Café Space in JUNKUDO Bookstore Niigata)

15:30–17:00

Icebreaker Party
(Art Hotel Niigata)

18:00–20:00





PROGRAM: 23/Oct (Mon)

Opening Ceremony
(Library Hall in Ikarashi Campus)

9:00–10:40

Special Symposium I
(Library Hall in Ikarashi Campus)

11:00–16:20

Session 1 Paleoceanography of Tethys and Panthalassa

O01-01	11:00–11:20 (Keynote)	Ikeda, M. et al.	Astronomical pacing of the global silica cycle recorded in Mesozoic radiolarian cherts
O01-02	11:20–11:40 (Keynote)	Baumgartner, P.O. et al.	Panthalassa and Neotethys - two siliceous giants facing the break-up of Pangea
O01-03	11:40–11:55	Muto, S. et al.	Three episodes of black claystone deposition in the pelagic Panthalassa during the Early Triassic
O01-04	11:55–12:10	Onoue, T. et al.	Impact event and radiolarian faunal turnover recorded in the Late Triassic Panthalassa Ocean
O01-05	12:10–12:25	Soda, K. et al.	Spatiotemporal variations of the Middle Triassic (Anisian) Oceanic Anoxic Events in low latitudinal Panthalassa
O01-06	12:25–12:40	Nishi, H. et al.	Age calibrations of the integrated stratigraphy of planktic forminifera, radiolaria, carbon isotope in the mid-Cretaceous sequences in northern Japan

Lunch & Poster Core Time

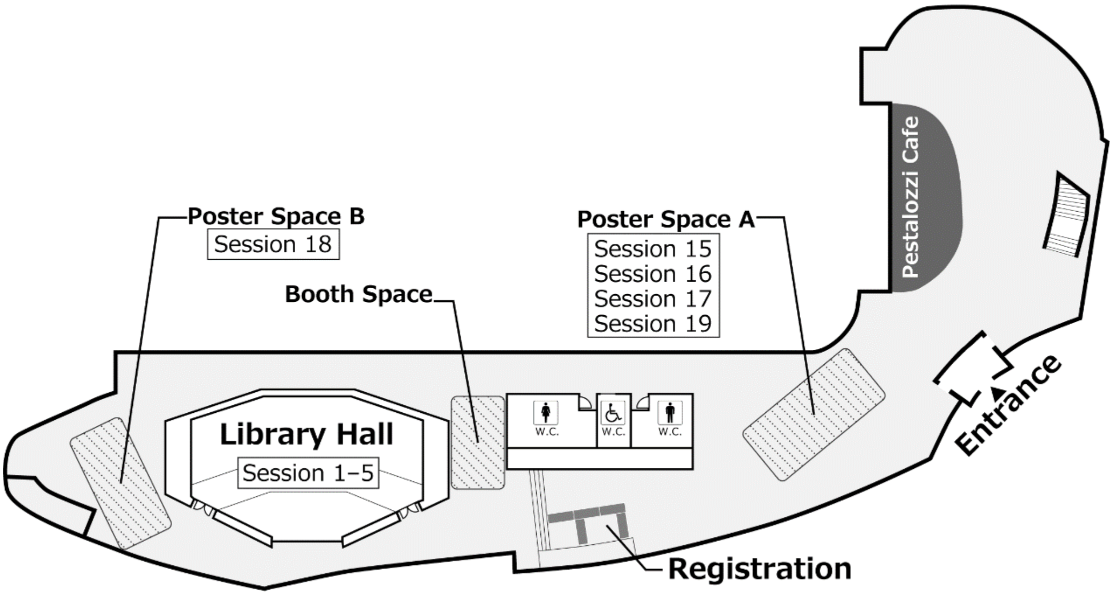
Session 2 Cenozoic Paleoceanography of Marginal Seas

O02-01	14:40–14:55	Itaki, T.	Does global warming deteriorate deep sea environments in the Japan Sea? Insight from deep dwelling radiolarians during the past warm period
O02-02	14:55–15:10	Takata, H. et al.	Correlation between faunal change in deep-sea benthic foraminiferal assemblages and ballasting of particulate organic matter by siliceous plankton
O02-03	15:10–15:25	Abe, M. et al. (Presenter: Jordan, R.W.)	Palaeoenvironmental reconstruction of the Japan Sea during the Mid-Brunhes Event using fossil diatoms
O02-04	15:25–15:45 (Keynote)	Yamada, K. & Irizuki, T.	Paleoceanographic shifts during the late Pliocene in the Sea of Japan based on assemblage and shell chemistry of ostracodes

O02-05	15:45–16:00	Matsuzaki, K.M. et al.	Paleoceanography of the northern East China Sea over the past 400 kyr based on radiolarians (IODP Exp. 346, Site U1429)
O02-06	16:00–16:20 (Keynote)	Lo, L. et al.	CO_2 threshold for precessional variability of sea ice in the Okhotsk Sea during the past 180,000 years

Welcome Party (ANA Crowne Plaza Niigata)
18:30–21:00

—Floor map of Central Library in Ikarashi Campus, Niigata University—



PROGRAM: 24/Oct (Tue)

Special Symposium II (Library Hall in Ikarashi Campus)

9:00–16:55

Session 3 Biology and Paleobiology of Shelled Protista

O03-01	9:00–9:20 (Keynote)	Not, F.	Morpho-molecular approaches to investigate the diversity and ecology of skeleton bearing protist
O03-02	9:20–9:35	Sandin, M.M. et al.	Time calibrated morpho-molecular classification of Polycystine Nassellaria (Radiolaria)
O03-03	9:35–9:55 (Keynote)	Nakamura, Y. et al.	Ultrafine structure and molecular phylogeny of living radiolarians—with a view to clarifying the fossil phylogeny—
O03-04	9:55–10:10	Ishitani, Y. et al.	Speciation and dispersal pattern of marine protists in the vertical dimension
		Coffee break	
O03-05	10:30–10:45	Ito, T.	Dimorphism of Permian Albaillellaria: Reproductive strategy and its development of fossil radiolaria
O03-06	10:45–11:00	Ichinohe, R. et al.	Homeostatic spatial behaviour of nassellarian radiolarians: a likely feeding strategy
O03-07	11:00–11:15	Ikenoue, T. et al.	A new approach to partition the biogenic silica production using Microfocus X-ray CT: radiolarian silica flux in the Chukchi Borderland

Lunch & Poster Core Time

Session 4 Forms: An Interface between Function and Evolution

O04-01	13:15–13:35 (Keynote)	Saito-Kato, M. et al.	Morphological evolution of lacustrine diatoms in Lake Biwa, Japan from a 300 kyr fossil record
O04-02	13:35–13:50	Tokuda, Y.	Adaptive evolution of micro skeletal structures in deep-sea solitary scleractinian corals
O04-03	13:50–14:10 (Keynote)	Kishimoto, N.	Mechanical analysis of Radiolarian skeleton based on three dimensional information using micro X-ray CT
O04-04	14:10–14:25	Asatryan, G.M. et al.	A new methodology of studying radiolarians using 3D X-ray micro-CT imaging and Avizo software
		Coffee break	
O04-05	14:45–15:00	Shiino, Y.	Hydrodynamic functionalisation of brachiopod shells: insights into evolutionary morphology

O04-06	15:00–15:15	Yoshino, T. & Matsuoka, A.	Retraction Force of Axial Projection of Multi-segmented Nassellarian *Eucyrtidium hexastichum* (Haeckel)
O04-07	15:15–15:30	Marquez, E.J. et al.	Automated Identification of Radiolarians using RaDSS
		Coffee break	
		Session 5 Jurassic–Cretaceous Boundary	
O05-01	15:50–16:10 (Keynote)	Sano, S.	The Tetori Group in northern Central Japan provides the clues for recognizing the biotic and environmental changes at the Jurassic/Cretaceous transition in East Asia
O05-02	16:10–16:25	Li, G. & Matsuoka, A.	Late Jurassic radiolarians from Nadanhada Range of eastern Heilongjiang Province, NE China
O05-03	16:25–16:40	Kashiwagi, K.	Radiolarians from the continental shelf sediments of the Tetori Group (Middle Jurassic–Lower Cretaceous) in Central Japan
O05-04	16:40–16:55	Matsuoka, A.	Phylitic analysis of radiolarians for defining the Jurassic/Cretaceous boundary in the western Pacific and eastern Tethys

Entrance of Central Library in Ikarashi Campus, Niigata University

PROGRAM: 25/Oct (Wed)

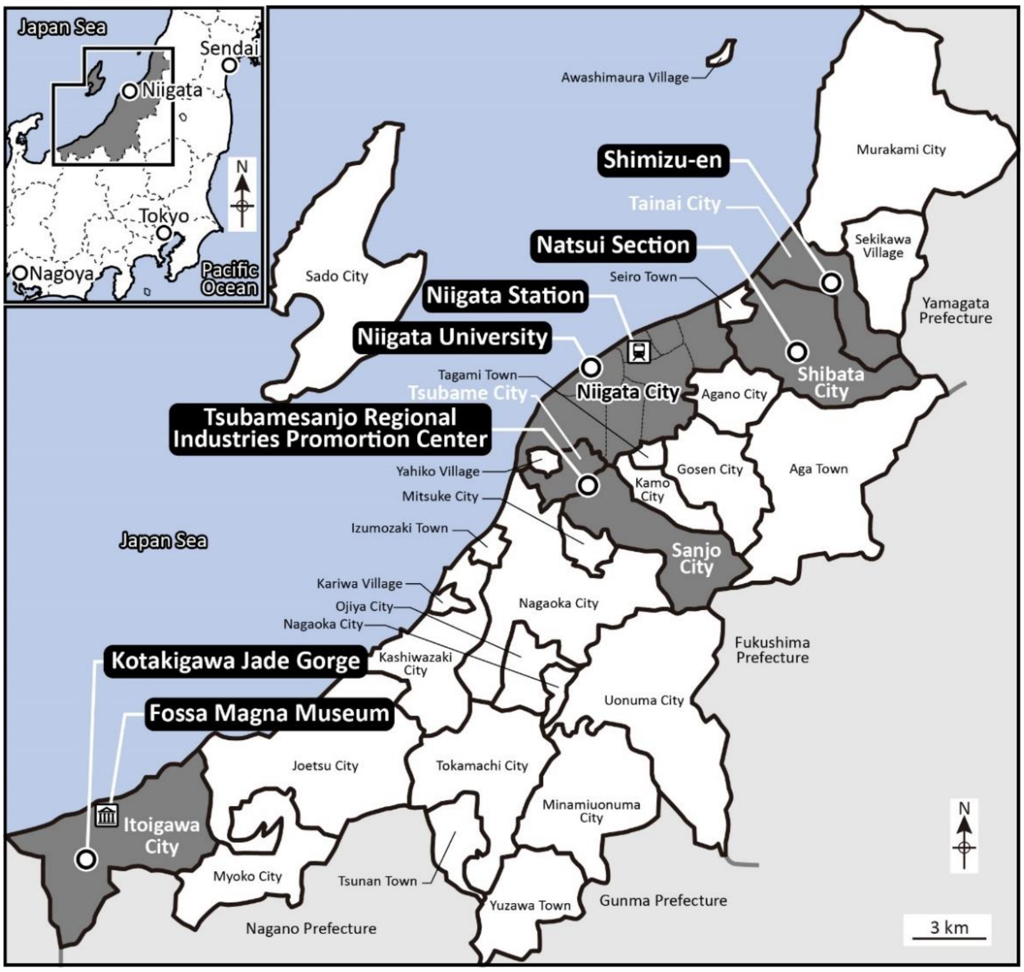
Mid-day Excursion	
C (Itoigawa)	*D (Tai'nai)*
8:00–18:00	**8:30–17:00**

International Communication Program [Session 6]
(Multi-purpose Space of TOKIMATE)

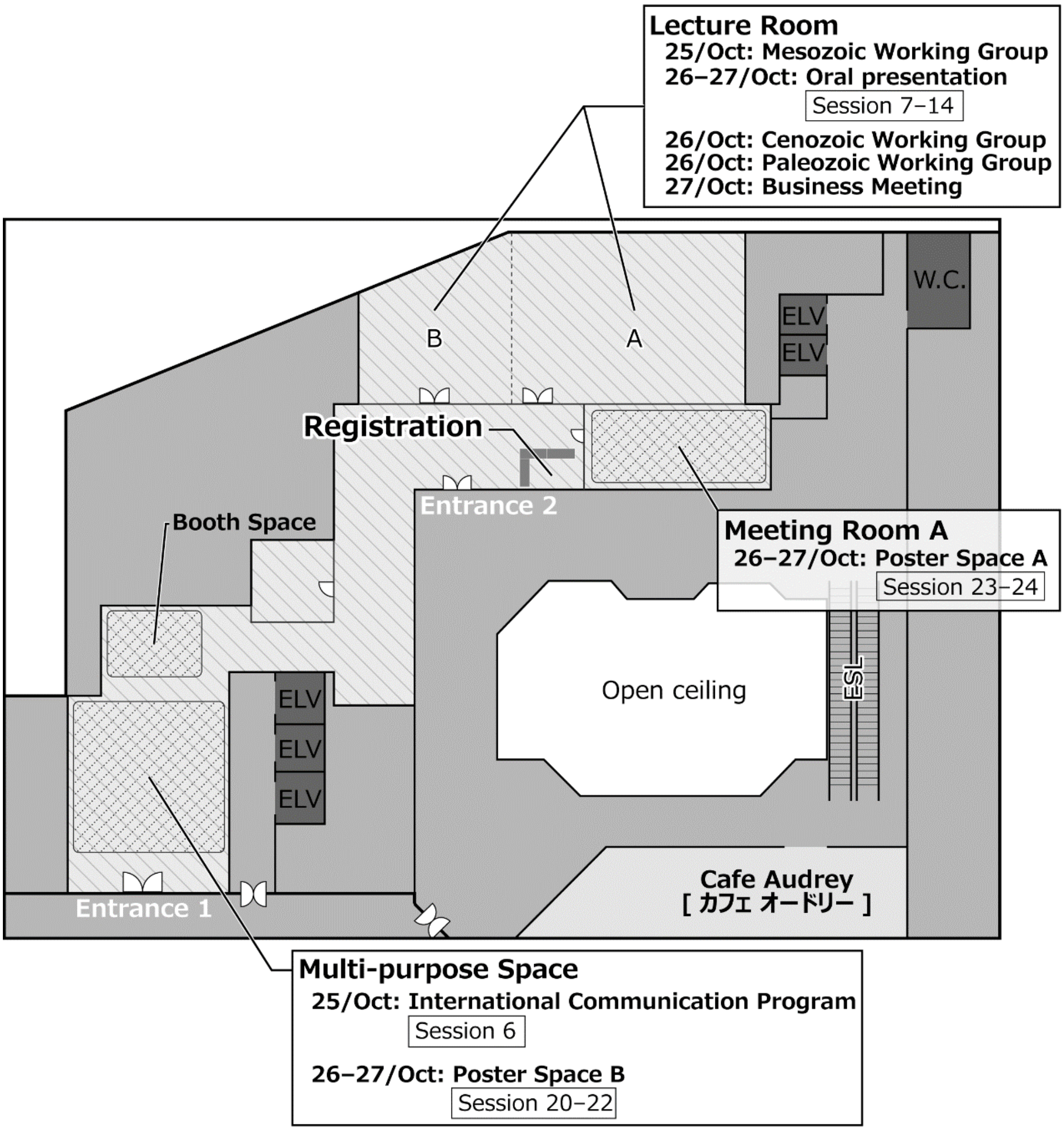
O06-01	19:00–20:00	Baumgartner, P.O. et al.	Radiolarite versus pelagic carbonate sedimentation during the Jurassic-Cretaceous transition, Panthalassa-Tethys-Atlantic-Protocaribbean – paleofertility and ocean circulation

Mesozoic Working Group
(Lecture Room A of TOKIMATE)
20:00–21:00

—Major stops of mid-day excursions—



—Floor map of TOKIMATE in Eki-nan Campus, Niigata University in PLAKA 1—



PROGRAM: 26/Oct (Thu)

General Symposium I (Lecture Room of TOKIMATE)

9:00–16:45

Session 7 Insightful Studies for Radiolarians			
O07-01	9:00–9:15	Ogane, K.	JREC-IN Portal: the career support portal site for all researchers and research staff who are pioneering innovation
O07-02	9:15–9:30	Hori, R.S. et al.	A growth model and strategy of forming siliceous skeletons of living Spumellaria (Radiolaria)
O07-03	9:30–9:45	Kachovich, S. & Aitchison, J.C.	Capturing initial skeletal growth in Paleozoic radiolarians
O07-04	9:45–10:05 (Highlight)	Okazaki Y. et al.	Online oxygen isotope analysis of biogenic opal using the inductive high-temperature carbon reduction method with continuous flow isotope ratio mass spectrometry
O07-05	10:05–10:20	Takahashi, K.	Four decades of research on radiolarians and other siliceous microplankton/fossils
Coffee break			
Session 8 Biosiliceous Records			
O08-01	10:40–10:55	Khan, M.Z. & Feng, Q.L.	Biogenic Silica: Relationship to Paleo-productivity and TOC from Late Ordovician-Early Silurian Organic Rich Shales of Chongqing Area, South China
O08-02	10:55–11:10	Kakuwa, Y.	Significance of trace fossils in radiolarian chert during the Phanerozoic: with special reference to red chert problem
O08-03	11:10–11:25	Aita, Y. et al.	Biosiliceous facies and flux change of the Early Triassic bedded chert from Arrow Rocks, New Zealand, Panthalassa ocean
O08-04	11:25–11:45 (Highlight)	Renaudie, J. et al.	Testing the vital effect on silicon isotope measurements in Late Eocene Pacific radiolarians
O08-05	11:45–12:00	Suzuki, H. & Maung Maung	Mesozoic radiolarian localities and their ages in Myanmar

Lunch & Poster Core Time

Session 9 Modern Oceanography			
O09-01	14:00–14:15	Munir, S. et al.	Paleoenvironmental proxies and their impacts on the distribution of siliceous planktonic radiolarian community in the Eastern Indian Ocean
O09-02	14:15–14:30	Rogers, J.	Is SST the most ecologically important determinant of radiolarian species diversity?
O09-03	14:30–14:45	Suzuki, N. & Zhang, L.L.	How to identify *Tetrapyle* and its related taxa for oceanographic studies
O09-04	14:45–15:05 (Highlight)	Zhang, L.L. et al.	Modern shallow water radiolarians with photosynthetic microbiota in the western North Pacific

Coffee break

Session 10 Paleobiogeography			
O10-01	15:25–15:40	Obut, O. & Danelian, T.	New discoveries of Early Cambrian radiolarians from the Gorny Altai (South of western Siberia)
O10-02	15:40–15:55	He, W.H. et al.	Upper Changhsingian Radiolarian fauna of northern Yangtze basin, South China
O10-03	15:55–16:15 (Highlight)	Xiao, Y.F. et al.	New study on vertical water depths of the latest Permian radiolarians by using correspondence analysis
O10-04	16:15–16:30	Yamakita, S. et al.	Early Triassic conodont provincialism and its implication for the paleoceanography of Tethys and Panthalassa
O10-05	16:30–16:45	Munasri & Putra, A.M.	First evidence of Middle to Late Triassic radiolarians in the Garba mountains, South Sumatra, Indonesia

Coffee break

Paleozoic Working Group (Lecture Room A of TOKIMATE)	**Cenozoic Working Group (Lecture Room B of TOKIMATE)**
17:05–18:05	

PROGRAM: 27/Oct (Fri)

General Symposium II (Lecture Room of TOKIMATE)

8:45–16:00

Session 11 Evolution and Diversity

O11-01	8:45–9:00	Zhang, Y. & Feng, Q.L.	Presence of Radiolarians from Early Terreneuvian in Liuchapo Formation, South China
O11-02	9:00–9:15	Zhang, K. & Feng, Q.L.	Cambrian radiolarians from the Niujiaohe Formation in South China
O11-03	9:15–9:30	Ma, Q.F. et al.	Discovery and significance of radiolarian from lower Qiongzhusinian Stage (Series 2, Stage 3) Shuijingtuo Formation of the Three Gorges area, South China
O11-04	9:30–9:50 (Highlight)	Danelian, T. et al.	Biodiversity patterns of Ordovician and Silurian radiolarians

Coffee break

Session 12 Biostratigraphy

O12-01	10:10–10:30 (Highlight)	Yamashita, D. et al.	Intercalibrated radiolarian–conodont biostratigraphy and magnetostratigraphy of the Upper Triassic succession, Inuyama area, Japan
O12-02	10:30–10:45	Kuwahara, K. & Sano, H.	Upper Capitanian to lower Wuchiapingian (Permian) latentifistularian interval zones and the phylogeny of their nominal species
O12-03	10:45–11:00	Adachi, M.	*Guexella nudata* coexisted with *Choffatia* (*Subgrossouvria*) sp. of upper Bathonian to lowest Oxfordian age; fossil evidence from Inuyama, Mino terrane of central Japan
O12-04	11:00–11:15	Kukoc, D. et al.	Discovery of the oldest fossils of Panama: Early Cretaceous radiolarians from Miocene conglomerate in the Canal Zone
O12-05	11:15–11:30	Motoyama, I. & Eguchi, N.	Radiolarian biostratigraphy of IODP Exp. 343 drill site C0019, Tohoku-Oki earthquake rupture area

Lunch & Poster Core Time

Session 13 Tibetan Tectonics

O13-01	13:00–13:20 (Highlight)	Luo, H. & Liu, S.J.	New discovery of Paleogene Radiolarians from the Yamdrok mélange near Yongla Pass of Gyantse, Southern Tibet and its geological significance

O13-02	13:20–13:35	Liu, S.J. et al.	Lower Cretaceous radiolarian fauna from Zouxue, Zedong, southern Tibet, China and its geological significance
O13-03	13:35–13:50	Li, X. et al.	Radiolarian-based oceanic plate stratigraphy of the melanges and subduction-accretion processes in the western sector of the Yarlung–Tsangpo suture zone, southern Tibet
O13-04	13:50–14:05	Xu, B. et al.	New discovery of Early Jurassic radiolarians from Luoqu, Xigaze, southern Tibet and its geological significance
O13-05	14:05–14:20	Chen, D.S. et al.	Discovery of the oldest (late Anisian) radiolarian assemblage from the Yarlung-Tsangpo Suture Zone in the Jinlu area, Zetang, southern Tibet: indication of the origin of the Neotethys Ocean
		Coffee break	
		Session 14 European Tectonics	
O14-01	14:40–15:00 (Highlight)	Chiari, M. et al.	Radiolarian biostratigraphy and geochemistry of the ophiolites from the Coloured Mélange Complex (North Makran, SE Iran)
O14-02	15:00–15:15	Tekin, U.K. et al.	New evidence of Middle Triassic (late Anisian to late Ladinian) radiolarians from blocks of pelagic volcano-sedimentary successions in the Mersin Mélange, southern Turkey: Implications for the evolution of Neotethyan Izmir-Ankara-Ocean
O14-03	15:15–15:30	Cifer, T. et al.	Pliensbachian (Early Jurassic) radiolarians from Mt. Rettenstein, Northern Calcareous Alps, Austria
O14-04	15:30–15:45	Bertinelli, A. et al.	Middle Triassic radiolarian assemblages from the Monte Facito Formation (Lagonegro succession, Southern Apennines, Italy)
O14-05	15:45–16:00	Goričan, Š. et al.	Jurassic and Cretaceous radiolarian biostratigraphy of the Al Aridh Group (Hawasina Nappes, Oman Mountains)
		Coffee break	
		Business Meeting & Closing Ceremony (Lecture Room of TOKIMATE)	
		16:20–17:20	

Farewell Party
(Art Hotel Niigata)
18:00–20:00

POSTER PRESENTATION TITLES: 23–24/Oct

Poster Core Time (inc. lunch): 23/Oct, 12:40–14:40; 24/Oct, 11:15–13:15

Special Symposium I (Library Gallery in Ikarashi Campus)		
Session 15 Paleoceanography of Tethys and Panthalassa		
P15-01	Baumgartner, P.O. et al.	Evolution of Late Cretaceous Radiolaria - in relation with the Caribbean Large Igneous Province and carbon isotope shifts
P15-02	Bole, M. et al.	Secular variations of oxygen and silicon isotopes in Mesozoic radiolarites from Panthalassa and Tethys - proxies for paleotemperature and paleoproductivity
P15-03	Ibaraki, Y. et al.	Late Silurian radiolarians from a conglomerate of a float block in Kotaki, Itoigawa, central Japan: Oldest fossil record in Niigata Prefecture
P15-04	Ito, T. et al.	Radiolarian research in geological maps of the Quadrangle Series (1:50,000) published by the Geological Survey of Japan, AIST
P15-05	Kamata, Y.	Paleozoic and Mesozoic Back-Arc basin chert of the Paleo-Tethys in Thailand (preliminary report)
P15-06	Muto, S. et al.	Conodont biostratigraphy of Lower Triassic pelagic deep-sea sedimentary rocks in Japan
P15-07	Nakagawa, T.	Permian *Pseudoalbaillella* from manganese carbonate rocks of Akiyoshi accretionary complex, Southwest Japan
P15-08	Paleozoic Genera Working Group (Presenter: Suzuki, N.)	Paleozoic genera and the history of their study
P15-09	Tomimatsu, Y. & Onoue, T.	Radiolarian age constraints of Triassic-Jurassic stratiform manganese deposits in the Chichibu Belt, Southwest Japan
P15-10	Uchino, T. & Suzuki, N.	Deposition ages of clastic rocks in the Northern Chichibu Belt, eastern Kii Peninsula, Southwest Japan
Session 16 Cenozoic Paleoceanography of Marginal Seas		
P16-01	Matsuzaki, K.M. et al.	Paleoceanography of Japan Sea over the past 9.5 Myr based on radiolarians (IODP Exp. 346, Site U1425)
P16-02	Zhang, K.X. et al.	Late Paleocene radiolarian fauna from the Yarlung Zangbo Suture Zone of Tibet, and its geological implications

Poster Core Time (inc. lunch): 23/Oct, 12:40–14:40; 24/Oct, 11:15–13:15

Special Symposium II (Library Gallery in Ikarashi Campus)		
Session 17 Biology and Paleobiology of Shelled Protista		
P17-01	Fujii, M. et al.	A study on chemical composition of living acantharian (Radiolaria) shell
P17-02	Ichinohe, R. et al.	Planktonic capability of discoid spumellarian radiolarians
P17-03	Nakamura, Y. et al.	Cell division of phaeodarians—the first step to clarify the life cycle—
P17-04	Toyofuku, T. & Nagai, Y.	Various imaging approaches revealing the secrets of foraminiferal calcification process
P17-05	Yuasa, T. & Takahashi, O.	Observations of the reproductive swarmer cells of polycystine and acantharian radiolarians in the east China Sea
Session 18 Forms: An Interface between Function and Evolution		
P18-01	Aita, Y. et al.	Diversity and newly revealed internal morphology of Middle Triassic Radiolaria *Glomeropyle* species
P18-02	Niimura, K. et al.	Detailed internal structures of Middle Triassic *Glomeropyle galagala*? and unnamed *Glomeropyle* sp. with the use of X-ray micro-CT
P18-03	Teshima, Y. et al.	Development of Enlarged Skeleton Models of Radiolaria (with Hands-on Exhibition)
P18-04	Teshima, Y. et al.	Development of Enlarged Skeleton Models of Foraminifera (with Hands-on Exhibition)
P18-05	Yoshino, T. et al.	Origami Representation of the Cortical Shell Structures of radiolarian *Pantanellium* (with Hands-on Exhibition)
P18-06	Ishida, N. & Kishimoto, N.	Submicron order three-dimensional imaging for polycystine radiolarians using X-ray micro-computed tomography
P18-07	Shiino, Y. et al.	Head or tail? Morphological analysis of the discoid spumellarian radiolarian *Dictyocoryne*
P18-08	Uetake, Y. et al.	Analysis of internal structure of Eocene *Lithochytris vespertilio* by Cross section Polisher method using a broad Ar^+ ion beam

Poster Core Time (inc. lunch): 23/Oct, 12:40–14:40; 24/Oct, 11:15–13:15

General Symposium (Library Gallery in Ikarashi Campus)		
Session 19 Jurassic and Cretaceous Stratigraphy		
P19-01	Bortolotti, V. et al.	The Jurassic-Early Cretaceous basalt-chert association in the ophiolites of the Ankara Mélange east of Ankara, Turkey: age and geochemistry
P19-02	Kamimura, M. & Hoyanagi, K.	Possibility for Jurassic/Cretaceous boundary identified from carbon-isotope stratigraphy of the Tetori Group in Shokawa, Gifu Prefecture, central Japan
P19-03	Li, X. et al.	Phylogeny and spatial distribution of the early Cretaceous radiolarian *Turbocapsula*
P19-04	Matsumoto, K. & Matsuoka, A.	Newly discovered marine beds in the Lower Jurassic Kuruma Group in the Otari Village, Nagano Prefecture, Central Japan
P19-05	Nishizono, Y. & Yonemitsu, I.	Jurassic radiolarians from Toyora Group, Southwest Japan
P19-06	O'Dogherty, L. et al.	Radiolarian stratigraphy from the proposed GSSP for the base of the Aptian Stage (Gorgo Cerbara, Umbria-Marche Apennines, Italy)
P19-07	Sakai, Y. et al.	The Early Cretaceous fossil plants from the Itsuki and Nochino formations of the Tetori Group in the Kuzuryu area, central Japan and their paleoclimatic implications
P19-08	Sakata, R. & Matsuoka, A.	Lithostratigraphy and bivalve associations of the Lower Jurassic Niranohama Formation in the Hashiura area, South Kitakami Belt, Miyagi Prefecture, Northeast Japan
P19-09	Taketani, Y.	Lowermost Cretaceous radiolarian assemblage from the South Kitakami Terrane, Northeast Japan
P19-10	Tamura, T. et al.	Lithostratigraphy and biostratigraphy of the Tomizawa and Koyamada Formations in the Somanakamura Group, Northeast Japan — Jurassic–Cretaceous transition beds in the eastern margin of Asia
P19-11	Yoshino, K. et al.	Integrated mega- and micro- biostratigraphy of the Campanian–Maastrichtian Izumi Group, Southwest Japan –Application to the Songliao Basin–

POSTER PRESENTATION TITLES: 26–27/Oct

Poster Core Time (inc. lunch): 26/Oct, 12:00–14:00; 27/Oct, 11:30–13:00

General Symposium (Multi-purpose Space of TOKIMATE)		
Session 20 Application and Outreach		
P20-01	Nagai, H. & Shiraki, K.	Japanese radiolarian study and education in the 19th century
P20-02	Matsuoka, A.	How to present diversity of geologic entities? – Proposal of Radiolarian age Diversity IndeX (RADIX)
P20-03	Trubovitz, S. et al.	How good are we at inventorying the biodiversity of radiolarian species?
Session 21 Oceanography		
P21-01	Bole, M. et al.	Oxygen isotopes and trace element stratigraphy of the Middle Jurassic radiolarite section at Colle di Sogno, Lombardy Basin, N-Italy
P21-02	Kamikuri, S. & Moore, T.C.	Reconstruction of oceanic circulation patterns in the tropical Pacific across the early/middle Miocene boundary as inferred from radiolarian assemblages
P21-03	Rogers, J.	A new species of *Spongodiscus* (Radiolaria: Spongodiscidae): its description and occurrence
P21-04	Umeda, M.	Devonian and Carboniferous Radiolarians from the Deep-Sea Pelagic cherts of the New England Fold Belt, Eastern Australia
Session 22 Biogeography		
P22-01	Ito, Y. et al.	Transitions in the Cretaceous radiolarian assemblages of the Yezo Group in the Niikappu area, Hokkaido, Japan: age constraints from U–Pb zircon dating of tuffaceous rocks
P22-02	Manchuk, N. et al.	Late Devonian radiolarians from the Hebukehe Formation, Northwestern Xinjiang, China
P22-03	Sashida, K. et al.	Upper Permian to Middle Triassic radiolarians from bedded cherts distributed in the Nong Prue area, western Thailand

Poster Core Time (inc. lunch): 26/Oct, 12:00–14:00; 27/Oct, 11:30–13:00

General Symposium (Meeting Room A of TOKIMATE)		
Session 23 Evolution and Stratigraphy		
P23-01	Ariunchimeg, Y. & Uugantsetseg, B.	Devonian fossils of Mongolia and their stratigraphical significance
P23-02	Caulet, J.P. et al. (Presenter: O'Dogherty, L.)	An up-to-date catalogue of Cenozoic radiolarian genera and families: a review with illustrations of type species
P23-03	Hollis, C.J. et al. (Presenter: Kamikuri, S.)	Towards an integrated cross-latitude event stratigraphy for Paleogene radiolarians
P23-04	Hori, R.S. et al.	Triassic-Jurassic boundary of a bedded chert sequence from the Chichibu Belt, Shikoku, Japan
P23-05	Matsuda, M. et al.	Early Jurassic radiolarian fauna from a carbonate nodule in Northern Chichibu Belt, Shikoku, Southwest Japan
P23-06	Nakae, S.	Boundary age of the *Dictyomitra koslovae* and the *Amphipyndax tylotus* zones (Campanian radiolarian zones) constrained by detrital zircon U–Pb dating: an example of the Matoya Group (Shimanto belt) in Kii Peninsula, Southwest Japan
P23-07	Suzuki, H. & Gawlick, H.J.	Radiolarians from the lower–middle Oxfordian section in the Northern Calcareous Alps (Fludergraben, Austria)
P23-08	Takemura, A. & Takemura, S.	Radiolarian faunas from the Tanba Belt in Kita-Harima District, Hyogo Prefecture, Southwest Japan
P23-09	Toshiro, G. et al.	The ages of Early-Middle Jurassic radiolarians from the Tamba Terrane, central Japan
P23-10	Zhang, Z. et al.	Radiolarian faunas in Wufeng Formation from Yi Chang, Hubei Province and Lun Shan, Jiangsu Province, China
Session 24 Tectonics		
P24-01	Hara, K. & Kuriahra, T. (Presenter: Kurihara, T.)	Radiolarian biostratigraphy of Late Cretaceous pelagic sediments within the Suhaylah and Zabyat formations of the Oman Ophiolite in the Wadi Jizzi area, northern Oman Mountains
P24-02	Sharav, D. et al.	Radiolarians from the Khooltiin davaa area, eastern Mongolia
P24-03	Sugamori, Y.	Radiolarian biostratigraphy studies of the Permian strata in the Tanto area, southeastern part of Hyogo Prefecture, Southwest Japan
P24-04	Yamagata, T.	Gravity-flow deposits on the slope to the foot of the Permian seamount in the Deadman Bay terrane, the San Juan Island, Washington State, USA

ABSTRACTS (ORAL)

■ MEMO ■

SPECIAL SYMPOSIUM I
SESSION 1

Paleoceanography of Tethys and Panthalassa

Conveners: **Satoshi TAKAHASHI** and **Peter O. BAUMGARTNER**

23/Oct (Mon), 11:00–12:40

Library Hall of Ikarashi Campus, Niigata Univ.

O01-01	11:00–11:20 (Keynote)	Ikeda, M. et al.	Astronomical pacing of the global silica cycle recorded in Mesozoic radiolarian cherts
O01-02	11:20–11:40 (Keynote)	Baumgartner, P.O. et al.	Panthalassa and Neotethys - two siliceous giants facing the break-up of Pangea
O01-03	11:40–11:55	Muto, S. et al.	Three episodes of black claystone deposition in the pelagic Panthalassa during the Early Triassic
O01-04	11:55–12:10	Onoue, T. et al.	Impact event and radiolarian faunal turnover recorded in the Late Triassic Panthalassa Ocean
O01-05	12:10–12:25	Soda, K. et al.	Spatiotemporal variations of the Middle Triassic (Anisian) Oceanic Anoxic Events in low latitudinal Panthalassa
O01-06	12:25–12:40	Nishi, H. et al.	Age calibrations of the integrated stratigraphy of planktic forminifera, radiolaria, carbon isotope in the mid-Cretaceous sequences in northern Japan

■ MEMO ■

Astronomical pacing of the global silica cycle recorded in Mesozoic radiolarian cherts

Masayuki IKEDA[1], Ryuji TADA[2] & Kazumi OZAKI[3]

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The global silica cycle is an important component of the long-term climate system, yet its controlling factors are largely uncertain due to poorly contrained proxy records. Here we present a ~70 Myr-long record of early Mesozoic radiolarian biogenic silica (BSi) flux from radiolarian chert in Japan. Average low-mid-latitude radiolarian BSi burial flux in the superocean Panthalassa is ~90% of that of the modern global ocean and relative amplitude varied by ~20–50% over the 100 kyr to 30 Myr orbital cycles during the early Mesozoic. We hypothesize that radiolarian BSi in chert was a major sink for oceanic dissolved silica (DSi), with fluctuations proportional to DSi input from chemical weathering over timescales longer than ~100 kyr. Chemical weathering rates estimated by the modified GEOCARBSULFvolc model (Berner, 2009) support these hypothesises, excluding the volcanism-driven oceanic anoxic events of the Early-Middle Triassic and Toarcian that exceed model limits.

We propose that the Mega-monsoon of the supercontinent Pangea non-linearly amplified the orbitally-paced chemical weathering that drove radiolarian BSi burial during the early Mesozoic greenhouse world.

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Keywords: Radiolaria chert, astronomical cycle, silica cycle, monsoon

Panthalassa and Neotethys - two siliceous giants facing the break-up of Pangea

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Radiolarites and other radiolarian-rich siliceous deposits are the dominant sediments produced in the world oceans over much of the Phanerozoic (Ordovician to Early Cretaceous, Baumgartner 2013, Hori et al. 1993), as documented in Circum-Pacific and Alpine-Himalayan oceanic terranes.

The break-up of the supercontinent Pangea began during the early Mesozoic with the opening of Neotethys (Fig. 1) within Gondwana, probably as a consequence of back-arc spreading related to the subduction of Paleotethys (Stampfli et al. 2003) Hence, Gondwanian terranes merged Eurasia, leaving of Paleotethys nothing but a suture. During the Late Triassic and Jurassic, Gondwana separated from Eurasia by the progression of Neotethyan ocean basins from east to west. N-America and Eurasia separated from Africa by the formation of the Central Atlantic and the Alpine Tethys since the Early Middle Jurassic. While radiolarite sedimentation continued in Neotethyan basins, this sediment never formed neither in the early Central Atlantic, nor in the Late Jurassic - early Cretaceous Proto-Caribbean. Here, Middle Jurassic clay-rich sediments gave way to the first planktonic carbonates since the Late Jurassic. These "Intra-Pangean" nannofossil carbonates were dominated by *Nannoconus* during the latest Jurassic and Early Cretaceous (Busson & Noël 1991). This nannofossil group was virtually absent from E-Tethys and Panthalassa. During the Late Cretaceous, planktonic carbonates became widespread and radiolarite deposition became episodic, mostly restricted to times of oceanic anoxic events.

The main paleo-oceanographic interpretation of this sedimentation pattern is the late onset of a circum-global equatorial current system. In our opinion, it was only effective during the middle-late Cretaceous, when high eustatic sea level and the emplacement of the Caribbean Large Igneous Province created a large marine passage between the Americas.

Mesozoic and, in particular, Jurassic radiolarites in Western Tethys have often been interpreted as the result of equatorial or monsoonal upwelling. We have modeled Middle-Late Jurassic global current systems with a global coupled ocean -atmosphere model (Brunetti et al. 2015). We could not detect any major westward flow of water in the trans-Pangean seaway, both with open and closed variants of the Central American gateway. The young Central Atlantic had a lagoonal circulation with a stratified water column implying low surface fertility during the Jurassic and earliest Cretaceous.

Upwelling alone cannot explain Mesozoic radiolarite occurrences throughout circum-Pacific terranes now exposed in Japan, Western North and Central America and New Zealand. Si and O stable isotope (Bôle et al. herein) data seem to indicate that the Mesozoic world oceans were less under-saturated in silicic acid than the modern oceans, resulting in better preservation of radiolarians and not necessarily in a higher productivity. This is especially true for the Jurassic and can be explained by more warm/humid continental climates brought about by the Pangea beak-up, resulting in increased continental weathering, producing a higher input of silicic acid to the ocean.

During the Late Cretaceous, planktonic foraminifera began to compete with radiolarians for food, and diatoms were more efficient in extracting silica from sea water, resulting in a quantitative decline of radiolarites.

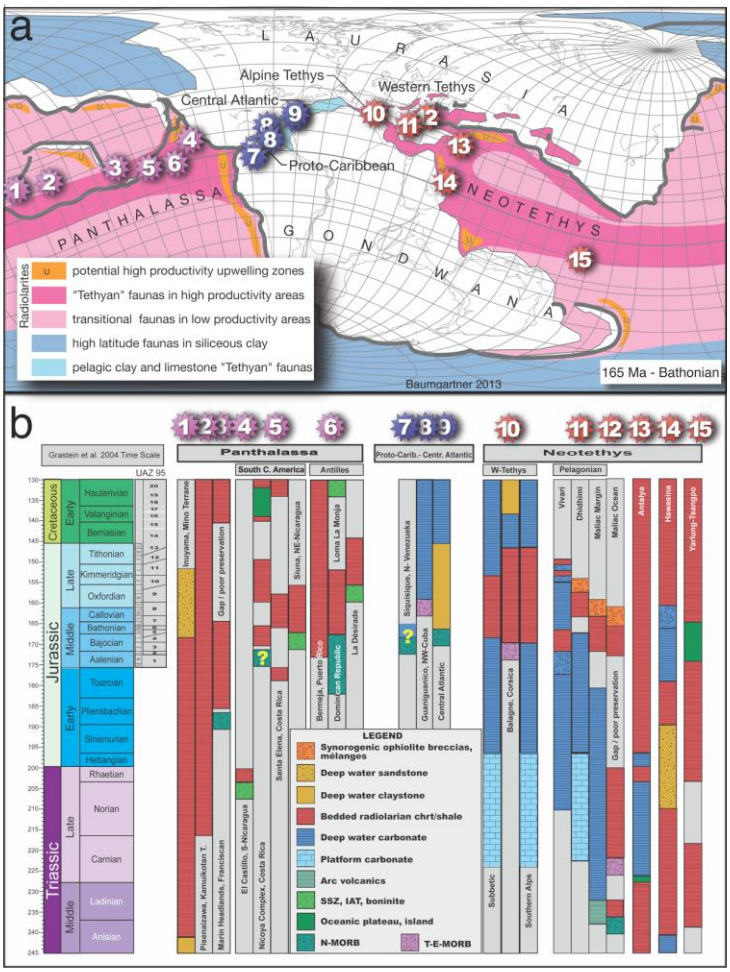

Figure 1. a. Middle Jurassic (Bathonian) world distribution of radiolarian faunal realms and radiolarian-rich sediments with the hypothetical location of key sections. **b**. Key sections of Mesozoic oceanic basins with basement and sediment lithologies.

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Keywords: Pangea breakup, Panthalassa, Tethys, radiolarites, planktonic carbonates, trans-Pangean current system.

Three episodes of black claystone deposition in the pelagic Panthalassa during the Early Triassic

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The end-Permian mass extinction (ca. 252 Ma) was the largest extinction event during the Phanerozoic, and the succeeding ecosystem recovery took around 5 million years until the end of the Early Triassic. Continued or repeated environmental stresses are thought to have delayed ecosystem recovery during the Early Triassic (e.g., Chen & Benton, 2012). One factor that is thought to have contributed to the delay of marine ecosystem recovery is oceanic anoxia (e.g., Wignall & Twitchett, 1996). The occurrence of carbonaceous black claystone in deep-sea sediments deposited in the pelagic Panthalassa has been regarded as evidence of global-scale oceanic anoxia (Isozaki, 1997). Detailed geochemical investigation of pelagic deep-sea black claystone in the Akkamori section in northeast Japan revealed that sulfidic and anoxic (euxinic) conditions occurred in the pelagic Panthalassa during the end Permian (late Changhsingian) to earliest Triassic (early Griesbachian) time (Takahashi et al., 2014). This anoxic event started at the end-Permian mass extinction, and it coincides with oceanic anoxia reported from other sedimentary sections from around the world. Such a synchronous and global anoxia was hypothesised to have been caused by enhanced primary production due to increased inputs of nutrients to the oceans under hothouse climatic conditions (Algeo et al., 2011).

On the other hand, black claystone within the Lower Triassic pelagic deep-sea strata are not confined to the Akkamori section. Previously, the age of the Lower Triassic black claystone in pelagic deep-sea sediments were in most cases unknown due to poor fossil occurrence. We conducted conodont biostratigraphic investigations on the deep-sea sedimentary sections with black claystone beds, and have succeeded in determining the age of the black claystone beds. Our results revealed that the age of black claystone beds within the Lower Triassic pelagic deep-sea sedimentary sequence is concentrated in three time intervals: late Changhsingian to Griesbachian, early Spathian (early late Olenekian) and latest Spathian to early Aegean (earliest Anisian). Thus, widespread oceanic anoxia likely occurred three times during the Early Triassic in the pelagic Panthalassa. Using the conodont biostratigraphic framework, we compared these ages to the secular seawater temperature change of the Early Triassic (Sun et al., 2012). The late Changhsingian to Griesbachian corresponds to an episode of global warming, but the early Spathian and latest Spathian to early Aegean are not episodes of global warming. In fact, these two time intervals immediately follow episodes of decreasing seawater temperatures. This finding indicates that the latter two episodes of black claystone deposition were not caused by oceanic anoxia due to global warming such as Algeo et al. (2011) suggested. Therefore, black claystone deposition during the early Spathian and latest Spathian to early Aegean is likely to have been caused by mechanisms different from the oceanic anoxia at the end-Permian mass extinction.

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Keywords: Conodont biostratigraphy, oceanic anoxia, global warming, Panthalassa

Impact event and radiolarian faunal turnover recorded in the Late Triassic Panthalassa Ocean

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During the last 15 Myr of the Triassic, extinctions in major pelagic groups (such as radiolarians and conodonts) occurred in a stepwise fashion. Available biostratigraphic data suggest that prominent faunal groups in the marine realm experienced a three-step extinction in the Late Triassic: at the end of the middle Norian, at the end of the Norian, and at the end of the Rhaetian. Catastrophic processes, such as episodes of anoxia and mantle plume volcanism, in the Central Atlantic Magmatic Province (CAMP) have been proposed to account for the second (end-Norian) and third (end-Rhaetian) extinction events. However, the cause of the initial (end-middle Norian) extinction event has been uncertain.

Here, we show a possible temporal link between the end-middle Norian radiolarian extinction and a bolide impact, at a high level of precision. A Norian impact event has been inferred from anomalous concentrations of platinum group elements (PGEs) and negative Os isotope excursion in a claystone layer in an Upper Triassic bedded chert succession in the Sakahogi section, Japan (Sato et al., 2013, 2016), which accumulated in a deep seafloor environment in an equatorial region of the Panthalassa Ocean. Previous geochemical studies have revealed that the anomalously high PGE abundances resulted from a large chondritic impactor (3.3–7.8 km in diameter).

A biostratigraphic study of the Sakahogi section indicated that extinctions of middle Norian radiolarian species occurred in a stepwise fashion in the ~1 m interval above the ejecta horizon (Onoue et al., 2016). Our high-resolution biostratigraphic and geochemical data also revealed that there are two paleoenvironmental events in the initial phase of the radiolarian faunal turnover interval: (1) the post-impact shutdown of primary productivity within the timespan of 10^4 years, and (2) significant and sustained reduction in the sinking flux of radiolarian silica for ~0.3 Myr after the impact. A sharp reduction in marine primary and secondary productivity, triggered by a large impact, may have also played an important role in the extinction of Norian marine faunas (ammonoids and conodonts) in the Panthalassa Ocean.

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Keywords: Impact, Bedded chert, Late Triassic, Radiolaria, Extinction, Japan

Spatiotemporal variations of the Middle Triassic (Anisian) Oceanic Anoxic Events in low latitudinal Panthalassa

Katsuhito SODA[1], Tetsuji ONOUE[1] & Mitsutaka MIURA[1]

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Permian-Triassic bedded chert sequences in the Jurassic accretionary complex of Japan provide important paleoenvironmental information for the evolutionary history of marine pelagic fauna after the end-Permian mass extinction (Isozaki, 1997). Superanoxia across the Permian-Triassic boundary, which has a long duration from the late Middle Permian to the early Middle Triassic, has been globally recognized and debated well in the context of the end-Permian mass extinction. To explore the spatiotemporal variation and paleoenvironmental background for Middle Triassic (Anisian) oceanic anoxia, multivariate statistical analyses were employed on the Middle Triassic chemostratigraphies of the pelagic deep sea sequences in the Mino and Chichibu belts, southwest Japan.

As a result of the multivariate analysis, three principal components were statistically accepted and captured most of the total variability. These components provide information about continental weathering, clay mineral composition and oceanic redox condition. Positive correlation between the weathering and redox scores suggests that the enhanced weathering drove the oceanic anoxia for the Middle Triassic. The rapid recovery of the redox scores above the black shales is consistent with residence times of iron and manganese (~1 kyr). Remarkable behaviors of redox sensitive elements (e. g. Molybdenum and Uranium) in the Middle Triassic black shales suggest that Anisian oceanic anoxic events developed frequently (Fujisaki et al., 2016). Paleoclimatic and redox records from South China show that Palaeotethys ocean in the mid–Anisian were under similar conditions as well. In addition, previous radiometric datings on the Siberian Traps report possible linkage between OAEs and the Large Igneous Provinces because the ages of the second flood pulse seem to correspond to distinct Anisian marine extinctions. However, precise chronostratigraphic correlations between these sections remain unclear because of large uncertainties of radiometric and biostratigraphic ages. Further conodont bio-magnetostratigraphic correlations would lead to verification of these causal relationships.

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Keywords: Middle Triassic, Oceanic anoxic events, bedded chert, Panthalassa

Age calibrations of the integrated stratigraphy of planktic forminifera, radiolaria, carbon isotope in the mid-Cretaceous sequences in northern Japan

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The Yezo Group, exposed in Hokkaido, Japan, is represented by the mid-Cretaceous—Paleocene marine sequences which were deposited in a fore-arc basin along east of the active Asian continental margin. Since this strata yields abundant marine macro- and microfossils, numerous biostratigraphic studies have long been conducted (e.g., Matsumoto, 1942; Nishi et al., 2003; Kawabe et al., 2003). In the last two decade, the studies of carbon- and osmium- isotopic stratigraphies (e.g., Hasegawa, 1997; Takashima et al., 2010; 2011; DuVivier et al, 2015) and radiometric dating of $^{40}Ar/^{39}Ar$ and U-Pb (e.g., Obradovich et al., 2002; Quidellur et al., 2011; Du Vivier et al., 2015) have greatly improved the resolution of the international stratigraphic correlations between the Yezo Group and the Cretaceous sequences of the Euro-American sections including Global Boundary Stratotype Section and Points (GSSPs). Consequently, the Yezo Group is regarded as the Cretaceous standard stratigraphy of the northwestern Pacific Ocean.

The Yezo Group yields abundant radiolarian fossils, and is appropriate strata for establishing standard radiolarian biostratigraphic scheme in Northwestern Pacific region. In the Yezo Group, 23 radiolarian bio-events and 11 biozones were identified in this study. Of these, six bioevents (FOs of *Sgl. Zamoraensis*, *Psd.*? *pseudomacrocephala* and *Thl.veneta*, the LO of *Tnl. elegantissima, Psd.*? *pseudomacrocephala*, the FO of *Dic. Formosa*) are useful for international stratigraphic correlation, and eight bioevents (LOs of *Psd.*? *thurowi* and *Psd.*? *lanceloti*, FOs of *Crl. sachalinicum* and *Psd.*? nakasekoi, LOs of *Dnp. euganea,* FOs of *Cca. cachensi*, *Avm. superbum* and *Psc.* sp. B.) are correlative between Tethyan strata and the Yezo Group. This study establish age calibrations of above radiolarian bioevents based on the correlations with planktic foraminiferal biostratigraphy, carbon isotope straitgraphy and U-Pb tuff ages of the Yezo Group.

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Keywords: mid-Creatceous, radiolarian bioevent, planktic foraminifera, carbon isotope, U-Pb, Yezo Group

■ MEMO ■

SPECIAL SYMPOSIUM I
SESSION 2

Cenozoic Paleoceanography of Marginal Seas

Conveners: **Takuya ITAKI**, **Yusuke OKAZAKI** and **Richard W. JORDAN**

23/Oct (Mon), 14:40–16:20

Library Hall of Ikarashi Campus, Niigata Univ.

O02-01	14:40–14:55	Itaki, T.	Does global warming deteriorate deep sea environments in the Japan Sea? Insight from deep dwelling radiolarians during the past warm period
O02-02	14:55–15:10	Takata, H. et al.	Correlation between faunal change in deep-sea benthic foraminiferal assemblages and ballasting of particulate organic matter by siliceous plankton
O02-03	15:10–15:25	Abe, M. et al. (Presenter: Jordan, R.W.)	Palaeoenvironmental reconstruction of the Japan Sea during the Mid-Brunhes Event using fossil diatoms
O02-04	15:25–15:45 (Keynote)	Yamada, K. & Irizuki, T.	Paleoceanographic shifts during the late Pliocene in the Sea of Japan based on assemblage and shell chemistry of ostracodes
O02-05	15:45–16:00	Matsuzaki, K.M. et al.	Paleoceanography of the northern East China Sea over the past 400 kyr based on radiolarians (IODP Exp. 346, Site U1429)
O02-06	16:00–16:20 (Keynote)	Lo, L. et al.	CO_2 threshold for precessional variability of sea ice in the Okhotsk Sea during the past 180,000 years

Does global warming deteriorate deep sea environments in the Japan Sea? Insight from deep dwelling radiolarians during the past warm period

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The Japan Sea is a marginal sea in the northwestern Pacific Ocean bounded by the Eurasian continent, the Japanese Islands, and Sakhalin Island. Although this sea has deep basins with depths to 3,700 m, it is connected to adjacent marginal seas and the Pacific Ocean by only four shallow straits, with sill depths of 130 m or less. As a result of such semi-enclosed situation, this sea has its own deep-circulation system, with its deeper parts occupied by cold and highly oxygenated water formed by winter convection in the northwestern part of the sea. However, recent observations revealed that such deep convection has been weakened by global warming, and it is concerned influence on deep sea communities. According to previous paleo-climate studies, it is known that similar warming trend occurred in the past (e.g., mid-Holocene, Marine Isotope Stage: MIS-5e, Late Pliocene). To understand what happened in deep sea environments during these warm periods is help us to understand what will happen by global warming.

Because many radiolarian species are restricted to discrete depth intervals and the depths at which they dwell are closely related to the vertical water structure, their fossils prove to be useful indicators not only in the reconstruction of the surface water conditions, but also for the conditions of deep water depths. In the present Japan Sea, it is known that *Cycladophora davisiana* lives in a depth interval between 1,000 m and 2,000 m (deep layer of JSPW = Japan Sea Proper Water), and *Actinomma boreale* group in depths below 2,000 m (bottom layer of JSPW). High abundances of these species are likely caused by presence of high nutrient and well-oxygenated cold water masses related to deep convection (Fig. 1a). In this presentation, radiolarian fossil records in the Japan Sea and their relation to deep sea environments during past warm periods will be discussed based on new dataset from IODP Exp. 346 together with previously published data (e.g., Itaki, 2003; Itaki et al., 2004; 2007; 2010).

Radiolarian fossils preserved in several sediment cores collected from various depths between 400 m and 3,600 m show that accumulation rate (#/cm^2/kyr) of deep dwelling species *C. davisiana* and *A. boreale* group have largely varied through late Pleistocene to Holocene. During mid-Holocene (7 ka), living depth of *C. davisiana* was shallower than 400 m in water depth and their productivity was slightly higher than that in the present day (core top). On the other hand, productivity of *A. boreale* group was significantly small during this period. These results suggest that the convection depth had shifted from bottom to deep or intermediate layers due to weakening of the convection with surface warming (Fig. 1b). During the last interglacial period (MIS-5e) at 125 ka, both deep dwellers *C. davisiana* and *A. boreale* group rarely occurred, suggesting no deep-water formation through the water column (Fig. 1c). Mid-Holocene and MIS-5e are similar situation to predicted in 2050 and 2100, respectively, according to IPCC report. Therefore, these radiolarian records imply that deep sea assemblages in the Japan Sea are vulnerable to deteriorated environments with slowdown of the deep circulation by global warming.

Although Late Pliocene (2.7-3.5 Ma) is known as another warm period, deep dwelling radiolarians were quite different from those of the Pleistocene warm periods. The assemblage in this period was characterized by species usually recognized in the Pacific deep sea such as *Cornutella profunda*. Such deep-sea fauna was most likely originated from the Pacific Ocean via the northern strait, which had opened deeply and widely at northern Japanese islands (Fig. 1d).

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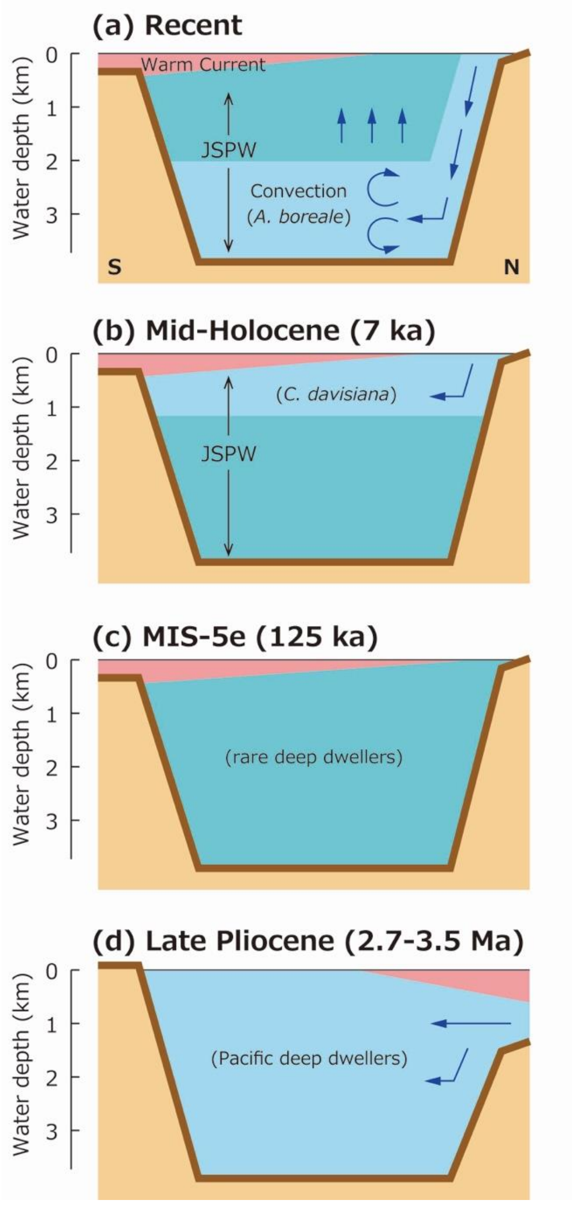

Figure 1. Schematic models showing deep sea circulations in (a) recent and the past warm periods of (b) mid-Holocene, (c) MIS-5e and (d) late Pliocene.

Keywords: Paleoceanography, thermohaline circulation, global warming, Pleistocene, Pliocene

Correlation between faunal change in deep-sea benthic foraminiferal assemblages and ballasting of particulate organic matter by siliceous plankton

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Introduction

Ballasting of particulate organic matter (POM) by biominerals plays an important role in the transfer efficiency of POM from the ocean mixed layer to the deep ocean. For example, Francois et al. (2002) suggested that the presence of carbonate grains (coccoliths, planktonic foraminifera) enhances the transfer efficiency of POM. In contrast, Henson et al. (2012) reported that the presence of biogenic opal grains (radiolaria, diatoms) reduces the transfer efficiency of POM. Such changes to the transfer efficiency of POM may affect benthic organisms, including benthic foraminifera, which depend upon organic matter from photosynthetic primary productivity for food. Studies of the effect of the presence, nature and amount of sinking biogenic minerals on the transfer efficiency of POM may provide insights into paleoceanographic events, as e.g., considered in the potential effects of the loss of calcareous calcifyers across the Cretaceous–Paleogene boundary (Alegret et al., 2012), and assist in predicting effects of future ocean acidification (Hoffman and Schellnhuber, 2009). In this study, we show two examples of correlation between deep-sea benthic foraminiferal assemblages and ballasting of POM with planktonic biominerals.

late Quaternary in the eastern Equatorial Pacific

We investigated upper Quaternary benthic foraminifera over the last ~520 kyrs from sediment cores PC5101 (N2º00.86’, W131º34.32’, 4425 m deep) near the equator in the eastern Equatorial Pacific Ocean, using multivariate statistical analysis (Multi-Dimensional Scaling, MDS). For data from this core, there is a statistically significant correlation between MDS axis 1 and biogenic opal-MAR from MIS 7 through MIS 1, whereas correlation was significant between MDS axis 1 and $CaCO_3$-MAR from MIS 13 through MIS 10. This observation suggests that the dominant factor controlling the food flux to benthic foraminifera switched from carbonate ballasting material (MIS 13 to MIS 10) to opal-ballasting material (MIS 7 to MIS 1) through a transitional period (MIS 9 to MIS 8).

Many scientists have pointed out linkages between paleoceanographic changes in the surface and deep oceans during the mid-Brunhes dissolution interval from MIS 13 to MIS 7 (Farrell and Prell, 1989; Barker et al., 2006). Our results suggest that changes in dominant ballasting of POM by biominerals may have been an important factor affecting the functioning of the biological pump, and such changes the biological pump may have contributed to the correlation between paleoceanographic changes in surface and deep ocean (bentho-pelagic coupling) over this interval.

Holocene in a marginal sea off the western margin of Japan

We investigated the biotic response of benthic foraminifera to late Quaternary (after ~13 ka) paleoceanographic changes in core GH87-2-308 (N35º57.6’, E134º26.0’, 316 m water depth), off southwestern Japan. MDS axis 1 was negatively correlated with the radiolarian accumulation rate, and with the radiolarian and diatom accumulation rates of core D-GC-6 (N37°04′, E134°42′, 946 m water depth), suggesting that benthic foraminiferal fauna responded to ballasting of POM with siliceous plankton skeletons.

Thus, looking into the influence of ballasting of POM according to the dominant biomineral may help to understand the paleoceanography of mid-latitude marginal seas, where planktonic communities have fluctuated between dominantly calcareous and dominantly siliceous taxa during late Quaternary changes of sea-level.

Summary

The insights provided by studying the ballasting of POM by calcareous/siliceous plankton tests may explain links between changes in the biological pump and in faunal changes of benthic foraminifera during paleoceanographic changes. Faunal analysis of benthic foraminifera, and comparison of these data with data on calcareous/siliceous plankton, may provide useful clues to understanding of paleoceanographic changes not only in the pelagic oceans but also in mid-latitude marginal seas.

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Keywords: transfer efficiency of POM, siliceous planktons, ballasting of POM, benthic foraminifera

Palaeoenvironmental reconstruction of the Japan Sea during the Mid-Brunhes Event using fossil diatoms

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The Mid-Brunhes Event (MBE) occurred approximately 450,000 years ago, coincident with low CO_2 concentrations. MIS11 was the warmest interglacial with a sea level approximately 20 m higher than the present day. A recent deep-sea drilling leg (IODP Expedition 346), with excellent recovery of the MBE, provided an opportunity to investigate what the future Japan Sea would look like if global warming continues. In addition, the sediment cores may contain details about the relationship between sea level rise and Tsushima Current incursions during two deglaciations (MIS14-13 and MIS12-11). Site U1425 contained well-preserved diatoms throughout the MBE, thus fossil diatom abundances and assemblage compositions can be used to reconstruct the palaeoenvironmental conditions during the Mid-Brunhes Event (particularly the interglacials). Our results show that *Thalassionema nitzschioides* was the most common diatom throughout the study interval (about 31%), suggesting high nutrient conditions, possibly associated with episodic upwelling. Significant contributions from *Proboscia curvirostris* (about 16%) during the MBE may be associated with southward transport of cold water masses. While the presence of *Chaetoceros* resting spores (about 15%), *Paralia* and *Cyclotella* spp. (<10%) during MIS11 suggest off-shelf transport possibly associated with increased CO_2 concentrations, precipitation and thus river outflow.

Keywords: diatoms, IODP, Japan Sea, Mid-Brunhes Event

■ MEMO ■

Paleoceanographic shifts during the late Pliocene in the Sea of Japan based on assemblage and shell chemistry of ostracodes

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Ostracodes are microcrustacea that inhabit marine, brackish, and fresh water and can be used to reconstruct paleoenvironments based on assemblage and chemical analyses. The Sea of Japan is an enclosed marginal sea, the oceanography of which has been influenced by surface water currents flowing through the Tsushima and Tsugaru straits. The southern strait became closed at 12 Ma, and opened again during the late Pliocene (Tada et al., 1994; Itaki et al., 2016). However, the timing and extent of paleoceanographic shifts that resulted from the opening of the southern strait remain uncertain. Moreover, ostracode assemblages suggest that temperate intermediate waters existed during the late Pliocene (Irizuki et al., 2007). To clarify paleoenvironmental changes and quantitative temperature gradients in the coastal areas of the Sea of Japan, we therefore determined intermediate water temperatures using the Mg/Ca ratio of ostracode shells.

The Plio-Pleistocene Kuwae Formation exposes along the Tainai River in Niigata Prefecture in central Japan. Mg and Ca concentrations of ostracode shells for the *Krithe* sp. (intermediate water species) were measured by ICP-AES. A total of 81 measurements of ostracode shells from the Kuwae Formation indicated that the intermediate water temperatures in the Sea of Japan during 3.1 and 2.6 Ma ranged from 1 to 10 °C. According to the glacial and interglacial cycles recognized from ostracode assemblages and planktonic foraminifers, the highest temperature was identified during the glacial maximum. However, three patterns in bottom water temperature variations during the interglacial period were recognized: the highest temperatures occurred at the interglacial maximum, the lowest temperatures occurred at the interglacial maximum, and temperatures remained stable throughout. These three patterns are thought to have been caused by the existence of temperate intermediate waters and variation in thickness of temperate intermediate waters.

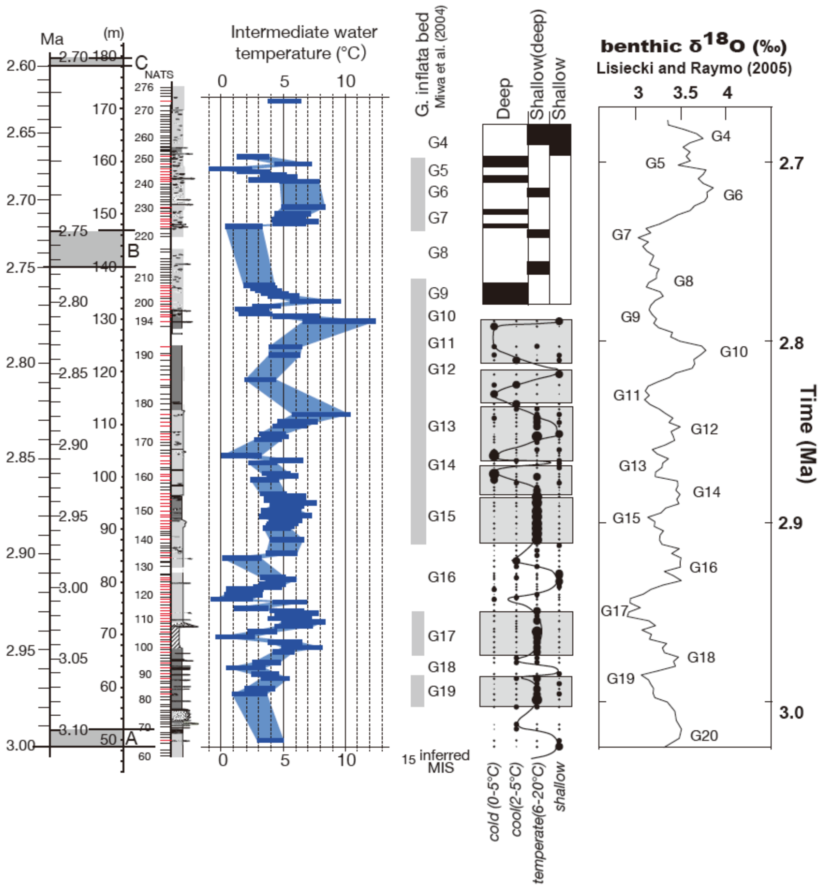

Figure 1. Quantitative intermediate water temperatures in the Sea of Japan between 3.1 and 2.6 Ma based on Mg/Ca of ostracode shells.

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Keywords: Sea of Japan, Pliocene, Pleistocene, Mg/Ca, ostracode

Paleoceanography of the northern East China Sea over the past 400 kyr based on radiolarians (IODP Exp. 346, Site U1429)

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The East China Sea (ECS) is a marginal sea influenced by warm-oligotrophic water of the Kuroshio Current (KC) and discharges of fresh water from the Yangtze River during summer. These two oceanographic features are likely paced by the East Asian summer/winter Monsoon system. On the other hand, this sea lies above a continental shelf. This make the ECS sensible to the sea level changes recorded over the last 500 kyr Glacial/ Interglacial period, where Earth's climate is regulated by 100 kyr eccentricity cycles. Over this time interval, the benthic oxygen isotopes stack of Lisiecki and Raymo (2005) show a variation in $\delta^{18}O$ ca. 1.4 ‰ for the past 500 kyr, which correspond to a $\Delta_{Sea\ level}$ of ca. 120 m (Fairbank and Matthews, 1978). Such variation in sea level would be critical to the ECS because 70 % of this sea has a water depths shallower than 200 m. Numerous studies have documented the paleoceanographic evolution of this area over the past 40 kyr (e.g. Ijiri et al., 2005; Kubota et al., 2010), where a sea surface temperature (SST) drop of ca. 3-5℃ was recorded based on a Alkenone-derived SST method (Ijiri et al., 2005) and plantick foraminifer Mg/Ca SST estimation method (Kubota et al., 2010). However, hydrographical changes in the subsurface to the deeper water were poorly documented at this time, because most of the studies conducted in area were based on assemblages and/or geochemical analysis of calcareous test microfossils (relatively shallow vertical distribution) (e.g. Ijiri et al., 2005; Kubota et al., 2010).

During IODP Expedition 346, cores were retrieved from the ECS (Site U1429), and preliminary data show that radiolarian were abundant and well preserved (Tada et al., 2015). Radiolarians are marine Protista with siliceous tests, widely distributed in the world Ocean characterized by a high sensitivity to changes in sea water ecological/physical properties and, are present from the shallow to deep water. Radiolarians are the unique microfossil group enabling us to monitor hydrographic changes of the subsurface and deep-water masses at this time. Moreover, recently Matsuzaki and Itaki (2017), reviewed the paleoceanographic significance of relevant radiolarian species in the Northwest Pacific and they also propose a method to estimate the intermediate water temperature of this area based on radiolarians.

Therefore, through this study, we propose to reconstruct hydrographic changes of the ECS over the past 400 kyr from the shallow to intermediate water based on recent knowledge on Northwest Pacific radiolarians. First, about 110 samples from IODP Exp. 346 site U1429 were analyzed (full assemblages, where more than 150 distinct species could be identified) for distinguish principal oceanographic features. Then, the climatic terminations were sampled at higher time resolutions for better monitor responses of the Kuroshio Current/Fresh water discharge system to the sea-level rise/fall (50 additional samples). On the other hand, SST and Intermediate water temperature were also reconstructed following Matsuzaki and Itaki (2017). As a brief result, The Summer SST of the interglacials were close to modern SST, and intermediate water temperature were likely colder for the time interval between the MIS 6 to MIS 11 (ca. 190-400 kyr). The most important results are that we can see that the increase in Kuroshio Current taxa, suggesting influences of the KC near our studied site do not occur just at the sea level rise during the termination but likely few kyr later.

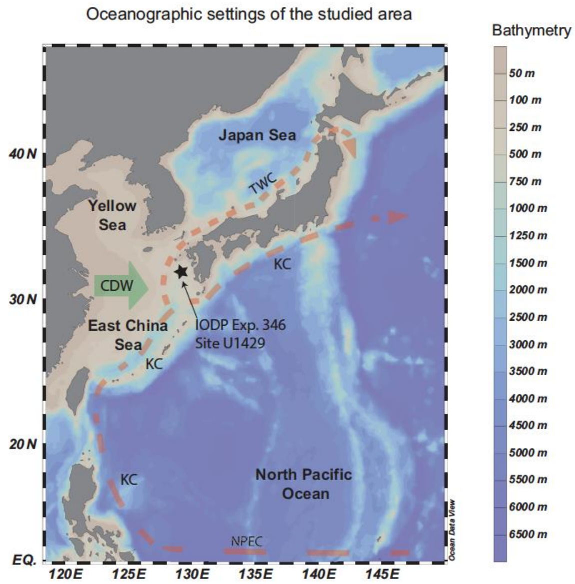

Figure 1. Location of the studied site (IODP Exp. 346 Site U1429)

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Keywords: East China Sea, Paleoceanography, Sea level changes, radiolarians

CO_2 threshold for precessional variability of sea ice in the Okhotsk Sea during the past 180,000 years

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Recent reductions in high-latitude sea ice extent demonstrate that sea ice is highly sensitive to external and internal radiative forcings. Here we reconstructed the changes in sea ice extent and summer sea surface temperature over the past 180,000 years in the central Okhotsk Sea using novel organic geochemical proxies and transient Earth system model simulation. The sea ice extent exhibited strong insolation cycles, which were caused by local autumn insolation changes during intervals of CO_2 concentrations from 190-260 ppm. The transient simulation and sensitivity tests showed that the central Okhotsk Sea was ice-free during the Holocene and throughout the penultimate interglacial when atmospheric CO_2 >260 ppm threshold. Our results demonstrate that past sea ice conditions in the central Okhotsk Sea were strongly modulated by both orbital-driven insolation and CO_2-induced radiative forcing during the past two glacial/interglacial cycles.

Keywords: Okhotsk Sea, Sea ice, CO_2, Orbital forcing

■ MEMO ■

SPECIAL SYMPOSIUM II
SESSION 3

Biology and Paleobiology of Shelled Protista

Conveners: **Katsunori KIMOTO** and **Fabrice NOT**

24/Oct (Tue), 9:00–10:10, 10:30–11:15

Library Hall of Ikarashi Campus, Niigata Univ.

O03-01	9:00–9:20 (Keynote)	Not, F.	Morpho-molecular approaches to investigate the diversity and ecology of skeleton bearing protist
O03-02	9:20–9:35	Sandin, M.M. et al.	Time calibrated morpho-molecular classification of Polycystine Nassellaria (Radiolaria)
O03-03	9:35–9:55 (Keynote)	Nakamura, Y. et al.	Ultrafine structure and molecular phylogeny of living radiolarians—with a view to clarifying the fossil phylogeny—
O03-04	9:55–10:10	Ishitani, Y. et al.	Speciation and dispersal pattern of marine protists in the vertical dimension
O03-05	10:30–10:45	Ito, T.	Dimorphism of Permian Albaillellaria: Reproductive strategy and its development of fossil radiolaria
O03-06	10:45–11:00	Ichinohe, R. et al.	Homeostatic spatial behaviour of nassellarian radiolarians: a likely feeding strategy
O03-07	11:00–11:15	Ikenoue, T. et al.	A new approach to partition the biogenic silica production using Microfocus X-ray CT: radiolarian silica flux in the Chukchi Borderland

Morpho-molecular approaches to investigate the diversity and ecology of skeleton bearing protists

Fabrice NOT

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Marine protists (i.e. unicellular eukaryotes) encompass a rich diversity of taxa across the tree of eukaryotic life. A number of marine protists exhibit mineral skeleton made of calcium carbonate (e.g. Coccolithophores, Foraminifera) or Silica (e.g. diatoms, polycystines). The classification and ecology of these groups are largely based on their morphological features and how these morpho-species distributes in environmental samples. Such approaches require an extensive, tedious to acquire, taxonomic knowledge and time consuming data acquisition time for ecological studies. With the advent of molecular biology, taxonomic marker genes (i.e. barcodes) have been used to reconstruct molecular phylogenies but also to perform molecular ecology directly from environmental samples.

Here I'm presenting an overview of an ongoing effort we are conducting, focusing on Radiolaria, to match single cell morphology to relevant molecular gene used as taxonomic barcodes in order to produce a reference morpho-molecular framework. Combining molecular barcodes sequences with optical microscopy and scanning electron microscopy for single specimens, this work allowed contributing to provide new perspectives on Acantharia and Collodaria taxonomy (Decelle et al. 2012, Biard et al. 2015) and the work is ongoing for Nassellaria and Spumellaria (Mendez-Sandin et al. in prep.). With respect to radiolarian ecology, most ecological patterns are derived from morphology based studies so far (Boltovskoy, D. & Correa, N. 2016). Recent studies demonstrated that some radiolarian taxa contribute largely to plankton biomass (Biard et al 2016) and are also extremely well represented in environmental molecular data (Keeling, P.J. & Campo, J. del. 2017). Therefore, such taxonomic framework is also critical to perform detailed molecular ecology investigation as recently exemplified in the case of Collodaria (Decelle et al. 2013, Biard et al. 2017).

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Keywords: Protists, Marine, Radiolaria, Molecular, Barcode

Time calibrated morpho-molecular classification of Polycystine Nassellaria (Radiolaria)

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Nassellaria are marine radiolarian protists belonging to the Rhizaria lineage. Their skeleton, made of opaline silica (biosilica; SiO_2 nH_2O), allows them to exhibit an excellent fossil record. Consequently, this radiolarian taxa is largely used in micropaleontological studies and proved to be extremely valuable for paleoenvironmental reconstruction. Nassellaria, along with other radiolarian taxa, play some important roles in oceanic ecosystems as they are active predators, living at various depth, and some Nassellaria species can host endosymbiotic algae. Yet, to date very little is known about their diversity and ecology in contemporary oceans, and most of it is inferred from their fossil record. Taxonomic classification of Nassellaria is challenging and only few attempts so far have dug into their genetic diversity. Here we present an integrative classification of Nassellaria based on the 18S and partial 28S ribosomal DNA taxonomic marker genes, compared with the current morphological classification and time calibrated with the fossil record. Our phylogenetic analyses distinguished 10 main morpho-molecular clades. Eucyrtidioidea was considered as the most basal clade. Artostrobioidea, Acropyramioidea and Acanthodesmoidea were closely related. Cannobotryoidea was emended in Plagiacanthoidea and highly supported as sister clade of the group that covers the undetermined family Theopiliidae, Pterocorythoidea and Lychnocanidae. The undetermined family Bekomidae was scattered among Lychnocanidae, showing no phylogenetic differences. A single clade encompassed two species (*Artostrobus* and *Eucecryphalus*) considered morphologically to belong to two different superfamilies. The last clade corresponds to Archipiliidae with doubted phylogenetic relationships. The molecular clock dates the origin of living Nassellaria in between 260 and 220 Ma, agreeing with the first appearance of multisegmented nassellarians in the fossil record (Middle Triassic). Thereafter three main diversification events gave birth to the actual diversity of Nassellaria, these turn out to match with the appearance of new oceanic currents, a series of Oceanic Anoxic Events and the Cooling of the Earth Poles. These observations highlight the importance of an integrative view for both the classification and the understanding of the diversity of living Nassellaria, and strengthen the need of further molecular analyses. Thanks to the NGS techniques, this morpho-molecular classification provides the basis for molecular ecology survey to refine ecology, and eventually, address questions otherwise challenging, such as bipolarity distribution or specificity to certain environments.

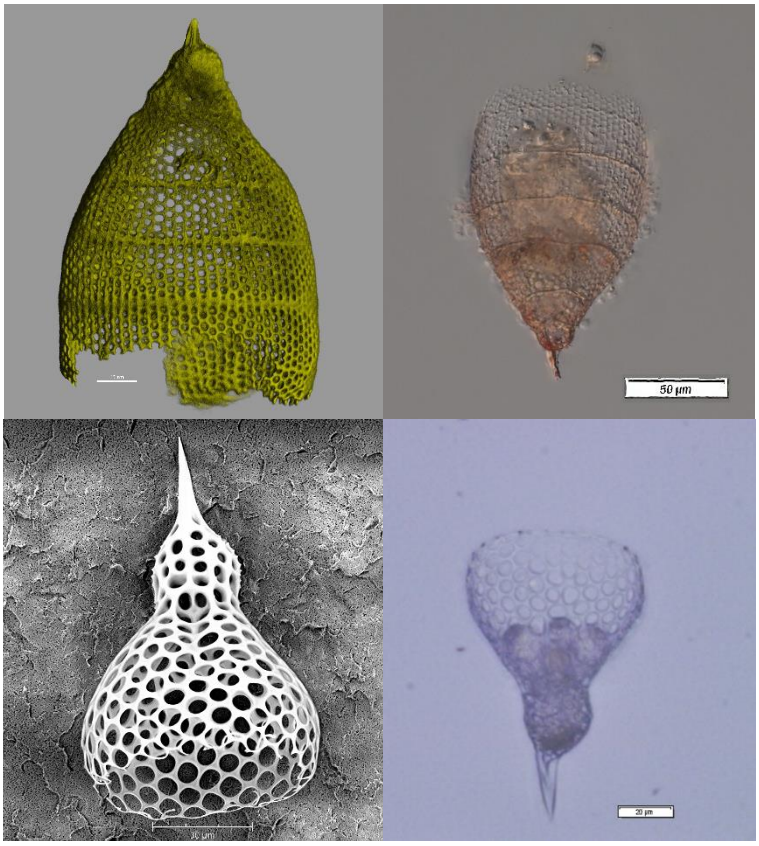

Figure 1. Scanning electronic microscopy (bottom left), confocal microscopy (top right) and light microscopy (right) images of individuals used for this study (Vil496 top row, Vil444 bottom row).

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Keywords: Nassellaria, integrative taxonomy, molecular phylogeny, opaline silica, polycystine, Radiolaria, Rhizaria, single-cell

Ultrafine structure and molecular phylogeny of living radiolarians—with a view to clarifying the fossil phylogeny—

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Radiolarians are a group of marine siliceous zooplankton, and their fossils have a great importance from the viewpoints of paleontology and geology (Suzuki & Not 2015). Phaeodaria have long been treated as members of Radiolaria. Molecular studies, however, revealed that phaeodarians and radiolarians are phylogenetically different (Polet et al. 2004, Nikolaev et al. 2004), and the former is now classified as a subclass of the phylum Cercozoa (Adl et al. 2012). The morphological differences among these two groups have not been well clarified, but the information about the structure of the skeleton is especially needed for the identification of fossil species. This study examined the fine structure of the skeleton including the elemental distribution and partly clarified the structural differences between the two groups.

Living radiolarians and phaeodarians were sampled by plankton net at ca. 20 stations in the Northern hemisphere in 2011–2016. The samples were individually preserved in 99.5% ethanol and stocked at 4ºC. Before and after the fixation, each sample was identified by careful observation under the inverted microscope. The *18S* and *28S* rDNA sequences of the samples were determined by single-cell PCR method presented by Nakamura et al. (2015). From a part of the samples, thin sections of 70–200 nm were also prepared by an ultramicrotome (UM-sections) and by a Focused Ion Beam (FIB) thinning system (FIB-sections). Both types of thin sections were observed by using a Field-Emission Transmission Electron Microscope (FE-TEM). The elemental distribution of each section was also analyzed with the Energy Dispersive Spectroscopy (EDS) system equipped on the FE-TEM, and the chemical composition of each section was estimated.

The analyses on FIB- and UM-sections revealed that the skeletons of radiolarians and phaeodarians are structurally different. The radiolarian skeletons were solid without porous structure, and the distribution of chemical components was homogenous. On the other hand, chamber-like or hollow structures were observed in phaeodarian skeletons, and elemental distribution was inhomogeneous. The rDNA analysis clarified that two living entactinarians belong to different groups. According to the branching pattern of the phylogenetic tree, Thalassothamnidae and Orosphaeridae entactinarians are phylogenetically related to phaeodarians and collodarians, respectively. The skeletal structure of Thalassothamnidae was similar to that of phaeodarians. In contrast, the skeleton of Orosphaeridae was solid, and its elemental distribution was homogeneous like the case in radiolarians. Consequently, the information from FIB- and UM-sectioning supports the results of molecular analysis. The ultrafine structure of the skeleton would reflect the phylogenetic relationship, and it could be a good marker to clarify the phylogeny of fossil species.

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Keywords: biogenic silica, Cercozoa, EDS, Entactinaria, FIB, Phaeodaria, Radiolaria, Rhizaria

Speciation and dispersal pattern of marine protists in the vertical dimension

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How do organisms disperse over a wide area? What is a trigger for the diversification of species? Phylogeographic studies could provide new insights into these fundamental questions. Radiolarians are one of the good candidates to study biodiversity of marine protists, because they have vertically and geographically wide distributions in the world oceans and their large body–size are easy to identify individuals. However, less molecular information of radiolarians impedes us to test this dispersal pattern and speciation process. Hence, the phylogeographic study of radiolarians is an urgent task for understanding their evolutionary processes. Here, we demonstrated two important subjects for radiolarian speciation and ecology — ecological partitioning and wide vertical dispersal — by using molecular techniques.

Spongotrochus glacialis, a symbiotic radiolarian, dwells in the warm surface water and can distribute in deeper water than chlorophyll maximum depth. We collected individuals of this radiolarian morphospecies at different depth along the water column in the North Pacific Subtropical Water. Our phylogenetic analyses of the small subunit (SSU) rDNA, internal transcribed spacer (ITS) regions of rDNA, 5.8S rDNA, and large subunit (LSU) rDNA showed that S. glacialis is composed of two genetic types with morphological differences and these two genetic types were vertically segregated from each other, bounded by chlorophyll maxima. With respect to morphological significance and different distribution pattern, we propose here these two genetic types are genetically isolated sibling species. The distribution pattern associated with environmental features of habitats suggests that two sister species can survive on different food resources: one in oligotrophic surface waters by using nutrients from photosynthetic symbionts, and the other at deeper depths by depending on both heterotrophic and symbiotic nutrition. Moreover, molecular clock analyses showed that the two sister species were diverged during the period of oligotrophic surface-water development in the Pacific Ocean. Thus, the genetic isolation in vertical dimensions occurs through ecological partitioning without any physical barriers in the pelagic oceans.

The morphospecies, Larcopyle buestchlii, is mainly distributed in surface waters (above 200 m in water depth). However, only in the Japan Sea, this species can be found in deeper water exceeding around 1,000 m in depth. We analyzed genetic structure of this morphospecies from surface to deep waters in the Japan Sea based on the ITS rDNA genes. We found that multiple ITS variants from each individual and these polymorphisms show no geographic structure. These high polymorphic ITSs possibly indicate a strictly clonal mode of reproduction because such clonal reproduction cannot reduce the genetic variation by genetic recombination. Our finding suggests that the strictly clonal mode of reproduction produces high polymorphisms

and leads fast dispersal of radiolarians toward deep water.

Keywords: sibling species, speciation, dispersal, compensatory base change

Dimorphism of Permian Albaillellaria: Reproductive strategy and its development of fossil radiolaria

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An organism reproduces therefore extinct fossil organisms must have reproduced. However, it is very difficult to speculate the reproduction of extinct fossil organisms because of lack of several information during fossilization. Consequently, we have to discuss comprehensively on reproductive strategy of fossil organisms.

Dimorphic pairs of living foraminifera are known, and are supposed to be generative dimorphism (Dettmering et al., 1998). In living Phaeodaria and Permian fusulinid, same phenomena also have been reported (e.g. Dunbar et al., 1935; Kling, 1978).

Albaillellaria, known as a major index radiolarian order in the late Paleozoic, take on dimorphic in some genera, with normal- and swollen-types (Ishiga, 1991). As its name suggests, the swollen-type has a swollen apical portion. On the basis of the above-mentioned cases, Ishiga (1991) suggested the possibility that the dimorphic pairs reflect alternating generations. The Albaillellaria dimorphism therefore might indicate reproductive strategy of Permian radiolaria, fossil holoplanktonic protozoa.

Since the preliminary study by Ishiga (1991), a few studies have focused on the occurrence of the dimorphic pairs of Albaillellaria. This study compiles the occurrences of the swollen type in previous studies and describes its distribution in the lineage.

In Albaillellaria, *Pseudoalbaillella* Holdsworth & Jones and *Follicucullus* Ormiston & Babcock and related genera have been generally assigned to the Family Follicucullidae Ormiston & Babcock whereas *Albaillella* Deflandre and related genera have been assigned to the Family Albaillellidae Deflandre (e.g. De Wever et al., 2001). This study uses genera of the Albaillellaria proposed by Kozur & Mostler (1989), although the taxonomy has been debated. According to Kozur & Mostler (1989), *Pseudoalbaillella* evolved from *Curvalbaillella* Kozur & Mostler; *Foremanconus* Kozur & Mostler also evolved from *Curvalbaillella* and into *Parafollicucullus* Holdsworth & Jones; *Parafollicucullus* evolved into *Follicucullus*; *Follicucullus* evolved into *Ishigaconus* Kozur & Mostler. In addition, *Spinodeflandrella* Kozur and *Imotoella* Kozur & Mostler were separated from *Albaillella* Deflandre (Kozur & Mostler, 1989).

In *Foremanconus*, only one figure of *For. sakmarensis* Ishiga and Imoto was shown (Ishiga & Imoto, 1980). Swollen type specimens of *Parafollicucullus* have been described in several species, such as *Pa. lomentarius* (Ishiga & Imoto) and *Pa. ornatus* (Ishiga & Imoto) (e.g. Ishiga & Imoto, 1980; Ishiga, 1991). In *Follicucullus*, only one figure of *Fol. porrectus* Rudenko was imaged (Ujiié & Ohba, 1991). Swollen type specimen of *Longtanella* Sheng & Wang and *Ishigaconus* Kozur & Mostler has not been discovered so far. Certain occurrence of swollen type of *Pseudoalbaillella* is not known yet.

In *Spinodeflandrella*, the occurrence of swollen type has been reported in *S. sinuata* (Ishiga & Watase) and *S. asymmetrica* (Ishiga & Imoto) (e.g. Ujiié & Ohba, 1991; Ito & Matsuoka, 2015). In *Neoalbaillella* Takemura & Nakaseko, swollen type has been discovered in several species, such as *N. optima* Ishiga, Kito & Imoto and *N. pseudogrypa* Sashida & Tonishi (e.g. Kuwahara & Yao, 1998; Wu et al., 2010). In spite of the exhaustive study of *Imotoella* (e.g. Kuwahara & Yao, 1998), swollen type of this genus has never been discovered.

On the basis of the compilation, the dimorphism seemed to appear in *Foremanconus* and to become common in *Parafollicucullus* in the Follicucullidae lineage. In the Albaillellidae lineage, the dimorphic pairs are seemingly common in *Spinodeflandrella* and *Neoalbaillella*. Consequently, the dimorphism developed on the different lineage, suggesting that this is common phenomenon beyond the families of Albaillellaria. In contrast, *Imotoella* and *Neoalbaillella* co-appears in the Lopingian (upper Permian) but no dimorphic pairs have been recognized in the former. These results imply that the development and subsidence of the dimorphism differ by the genera within the same families. From morphological standpoint, Albaillellaria genera with no or rare swollen-type, such as *Imotoella*, *Follicucullus*, *Longtanella* and *Pseudoalbaillella*, apparently has simpler shell than other genera with dimorphic pairs.

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Keywords: Albaillellaria, paleobiology, dimorphism, alternating generation, reproductive strategy

Homeostatic spatial behaviour of nassellarian radiolarians: a likely feeding strategy

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Ventilation of ambient fluids is one of the prime requisites for planktonic organisms, which involves in feeding, respiration and nutrient exchange during lifetime. In the case of radiolarians, sinking due to heavier siliceous shell (Takahashi & Honjo, 1983) and uplifting with the aid of specialised floating organelles (Anderson, 1983) have been routinely adopted to understand a spatial behaviour as a representative of the ventilation. In addition, radiolarians could obtain a biomechanical, hydrodynamic property with each change in morphology. When considering the axial symmetry in nassellarian radiolarians, it would be expected that the ambient fluids alter and change the animals to be a unique life posture whereby efficiency of biological performances is optimised under the condition of fluidic environment. To elucidate the hydrodynamic properties of the sinking of nassellarians under a static condition as a representation of passive spatial behaviour, we performed sinking experiments using living nassellarian radiolarians.

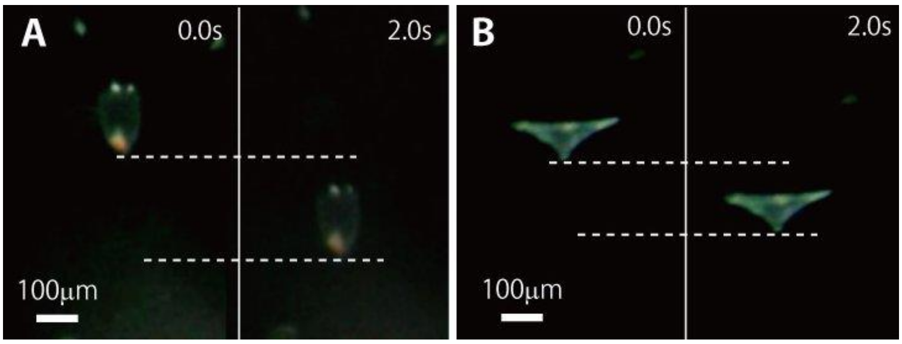

Figure 1. Selected microscopic photographs of sinking experiments for nassellarians. (A) Living *Eucyrtidium* sp. (B) Shell of *Eucecryphalus sestrodiscus*.

The experimental results showed that the sinking posture of nassellarians was stable with a cephalis-down orientation (Fig. 1), and the sinking speed was considerably slower than that of *Dictyocoryne* spp. as a control experiment. The sinking posture of *Eucyrtidium* with a higher height of the conical shell was stable, while that of *Eucecryphalus* with a wide conical shell was unstable.

Nassellarian radiolarians have conical shell with one side, equivalent to the base of conical shepe, is opened to project long, thick pseudopodia (e.g., Sugiyama et al., 2008; Suzuki & Aita, 2011). According to previous studies, these pseudopodia have a role in capturing organic matter smaller than the diameter of the aperture, subsequently drawing the organic matter in as a food particle (Sugiyama et al., 2008). Given the capabilities of posture and movement in the water column, the present results of characteristic spatial behviour closely related to feeding efficiency in the seawater column. In this work, we discussed feeding model of living nassellarians on the basis of hydrodynamic properties of morphology.

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Keywords: Nassellaria, functional morphology, biomechanics, adaptive strategy

A new approach to partition the biogenic silica production using Microfocus X-ray CT: radiolarian silica flux in the Chukchi Borderland

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We studied time-series fluxes of radiolarian particles collected by two sediment traps deployed in the Chukchi Borderland from 4th October 2012 to 18th September 2013. In order to elucidate the contribution of radiolarians to the biogenic silica production, three-dimensional imaging technique using Microfocus X-ray was applied to radiolarian siliceous skeletons. We measured volumes of individual radiolarian skeletons accurately by the three-dimensional model of them, thereby estimating the weight of silica for each radiolarian species. The time-series fluxes of radiolarian abundance were combined with the weights of radiolarian silica, and were transformed to fluxes of radiolarian silica. As a result, we found that *Amphimelissa setosa* and *Spongotrochus glacialis* were the highest contributors to radiolarian silica flux in the Chukchi Borderland. The radiolarian silica flux was usually higher in the eastern side of the Chukchi Borderland than that in the western side of the Chukchi Borderland. The contribution of radiolarian silica flux to biogenic silica flux was less than 10 weight percent in general during the sampling duration, but occasionally reached 40 weight percent during open water season.

Keywords: Sinking particles, Sediment trap, Chukchi Sea, Arctic Ocean, biogenic silica, Microfocus X-ray CT

SPECIAL SYMPOSIUM II
SESSION 4

Forms: An Interface between Function and Evolution

Conveners: **Yuki TOKUDA** and **Yuta SHIINO**

24/Oct (Tue), 13:15–14:25, 14:45–15:30

Library Hall of Ikarashi Campus, Niigata Univ.

O04-01	13:15–13:35 (Keynote)	Saito-Kato, M. et al.	Morphological evolution of lacustrine diatoms in Lake Biwa, Japan from a 300 kyr fossil record
O04-02	13:35–13:50	Tokuda, Y.	Adaptive evolution of micro skeletal structures in deep-sea solitary scleractinian corals
O04-03	13:50–14:10 (Keynote)	Kishimoto, N.	Mechanical analysis of Radiolarian skeleton based on three dimensional information using micro X-ray CT
O04-04	14:10–14:25	Asatryan, G.M. et al.	A new methodology of studying radiolarians using 3D X-ray micro-CT imaging and Avizo software
O04-05	14:45–15:00	Shiino, Y.	Hydrodynamic functionalisation of brachiopod shells: insights into evolutionary morphology
O04-06	15:00–15:15	Yoshino, T. & Matsuoka, A.	Retraction Force of Axial Projection of Multi-segmented Nassellarian *Eucyrtidium hexastichum* (Haeckel)
O04-07	15:15–15:30	Marquez, E.J. et al.	Automated Identification of Radiolarians using RaDSS

Morphological evolution of lacustrine diatoms in Lake Biwa, Japan from a 300 kyr fossil record

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Many endemic diatom species have been reported from extant lakes and lacustrine deposits, but are rarly reported from oceans and marine sediments. The sporadic geographic distribution of lakes is one factor contributing to the origin of endemics. Morphological variability in lacustrine diatoms presents an obstacle to those attempting taxonomic classification, but, in contrast, has also attracted the research interest of phylogeneticists and evolutionarybiologists. The evolutionary history of an endemic diatom species in Lake Biwa was elucidated and will be presented in this symposium.

Lake Biwa is the oldest lake in Japan.　Its age, basin morphology, and chemistry create a unique escosystem that has supported many endemic diatom species. Among the endemics, *Stephanodiscus suzukii* (original description in Tuji & Kociolek, 2000; emendation of taxonomy in Kato et al., 2003) and *Aulacoseira nipponica* (Tuji, 2002) constitute significant diatom productivity. We will give a talk about evolutionary history of one of the endemics, *S. suzukii*, recorded in the “200-m core” from Saito-Kato et al.’s (2015) investigation. The 200-m-long core used in this study is legendary and represents the earliest lake drilling efforts in Japan (Horie, 1972) and is curated by the National Museum of Nature and Science, Japan.

Evolutionary tempo and mode of morphological changes in *S. suzukii* and its ancestors were identified by paleoTS, a statistical test proposed by Hunt (2006). The results discovered with this test were: 1) long modes of morphological stasis with small evolutionary rates were most common over time, 2) directional evolution modes with relatively fast evolutionary rates appeared intermittently, 3) directional evolution in specific morphological features occurred at specific times, 4) these directional evolution events occurred in synchrony with abrupt climatological changes.

These results suggest diatom valve morphology is modified by natural selection. If the natural selection is altering valve morphology, the morphological modifications should provide improved fitness in species bearing these modifications. If this increase in fitness can be demonstrated these morphological features can be designated as adaptive. This is a goal we will pursue and hope others will contribute to as well.

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Keywords: Lake Biwa, diatoms, evolutionary rate, morphological evolution, paleoTS

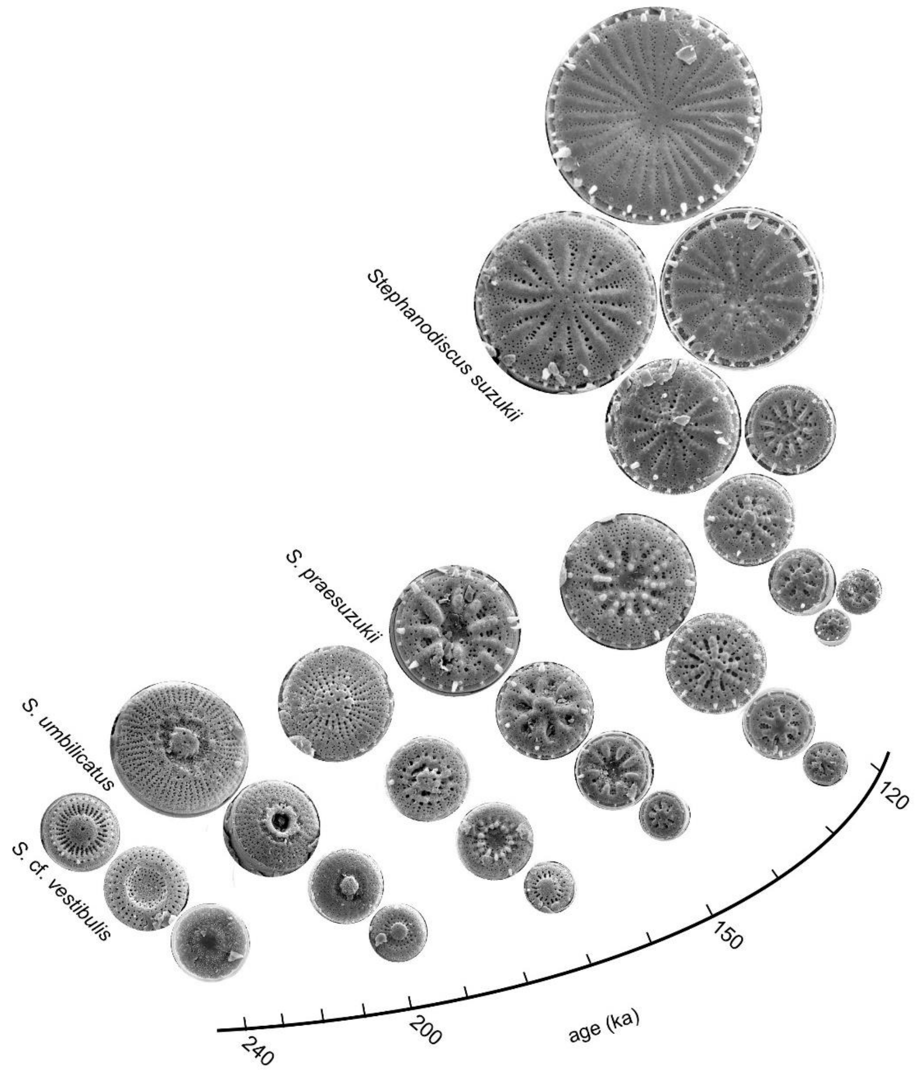

Figure 1. Lake Biwa endemic Stephanodiscus species and the ancestors:
SEM images of *Stephanodiscus suzukii*, *S. praesuzukii*, *S. umbilicatus* and *S.* cf. *vestibulis* are schematically arranged. Each population includes morphological variation in valves, such as large and small, concave and convex.

Adaptive evolution of micro skeletal structures in deep-sea solitary scleractinian corals

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Sessile organisms are greatly influenced by their substrate conditions, and their adaptive strategies are the key to understanding of their morphologic traits and evolution of life history. Micro-skeletal structures have been investigated to define and delimit a new set of morphological characters, which is clearly reflected in the molecular phylogenies. In addition, the roles of microstructures are tried to elucidate the formations of macro-morphologies and the adaptation to various substrates conditions.

The family Flabellidae (Cnidaria: Scleractinia) is the typical azooxanthellate solitary corals that live on both soft and hard substrates by using various adaptive strategies. However, their detailed phylogenetic relationships and morphological evolution are not yet fully understood. Genus *Flabellum* (Family Flabellidae) is characterized by its free-living flabellate corallum. *Flabellum* are divided into two subgenera, *Flabellum* (*Flabellum*) and *F.* (*Ulocyathus*). In addition to marked differences in macro morphologies, micro skeletal characteristics also are different from each other. In light of geographic distribution, *F.* (*Ulocyathus*) is widespread into far deeper-water environments. In microscopic skeletal level, *F.* (*Ulocyathus*) is mainly constructed of shingle-like thickening deposits consisting of spherical aragonite crystal. Each shingle-like deposit is enclosed with an organic matter which is recognized as pigmented layers in cross section. The micro skeletal structure of *F.* (*Ulocyathus*) is therefore indispensable to protect itself from mechanical destruction and chemical corrosion of the thinner calcareous skeleton. In conclusion, flabellids have developed varied modes of life and adaptive strategies by changing not only corallum shapes but also micro skeletal structures, according to the secular fluctuations in substrate conditions during the course of their evolution.

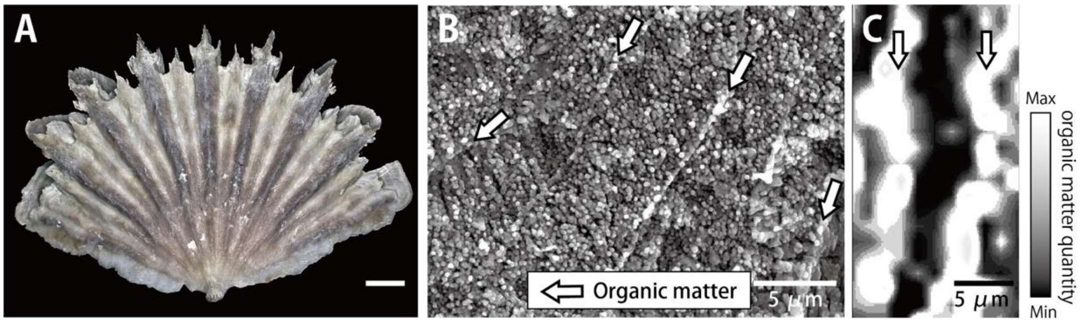

Figure 1. (Times New Roman, 10.5 pt., Bold) Macro and micro skeletal structures of *Flabellum* (*Ulocyathus*). A, lateral view of a corallum. B, scanning electron photomicrograph of shingle-like thickening deposits in etched transverse section. C, organic matter quantity in shingle-like thickening deposit by raman spectroscopy technique.

Keywords: form, aragonite, deep-sea, free-living

■ MEMO ■

Mechanical analysis of Radiolarian skeleton based on three dimensional information using micro X-ray CT

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In order to investigate what structures are optimized and adapted under microgravity conditions, we focus on shapes of marine plankton with calcareous or silicate skeletons because they float in water like under microgravity owing to buoyant forces. Various shapes of fossils and modern species also proved that they have varied their shapes to fit to environmental changes in their evolution process for over several hundred million years. Usually details of skeleton structures should be observed by an electron microscope and we cannot easily observe their internal structure. In previous study, it has become possible to acquire three dimensional information of the whole structures using a micro X-ray CT and to evaluate their geometric features (Ishida et al., 2015; Matsuoka et al., 2012; Yoshino et al., 2012; Yoshino et al., 2014).

In this study, we show some mechanical analysis results which indicate adaptability of the skeleton structures. We can construct a voxel finite element model base on acquired 3D information and calculate mechanical stress distribution of plankton skeleton under some appropriate boundary conditions. Figure 1 shows computer graphic image of *Didymocyrtis tetrathalamus* (Haeckel), its STL format image and constructed voxel finite element model based on the STL format image. This voxel model has 460458 rectangular voxels. However larger number of voxels allows accurate modeling and analysis, it increases computational costs.

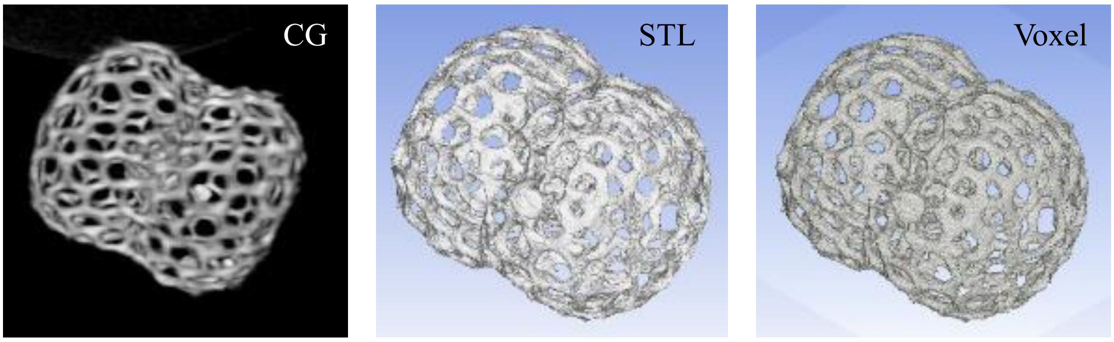

Figure 1. Images and voxel finite element model of *Didymocyrtis tetrathalamus* (Haeckel)

Table 1. Analysis condition on voxel finite element models

Material	Silica glass (Quartz)
Young’s modulus	74GPa
Poisson’s ratio	0.18
Boundary condition	Free-free
Loading condition	Simulated water pressure (depth of water : ~1m)
Analysis software	VOXELCON 2010

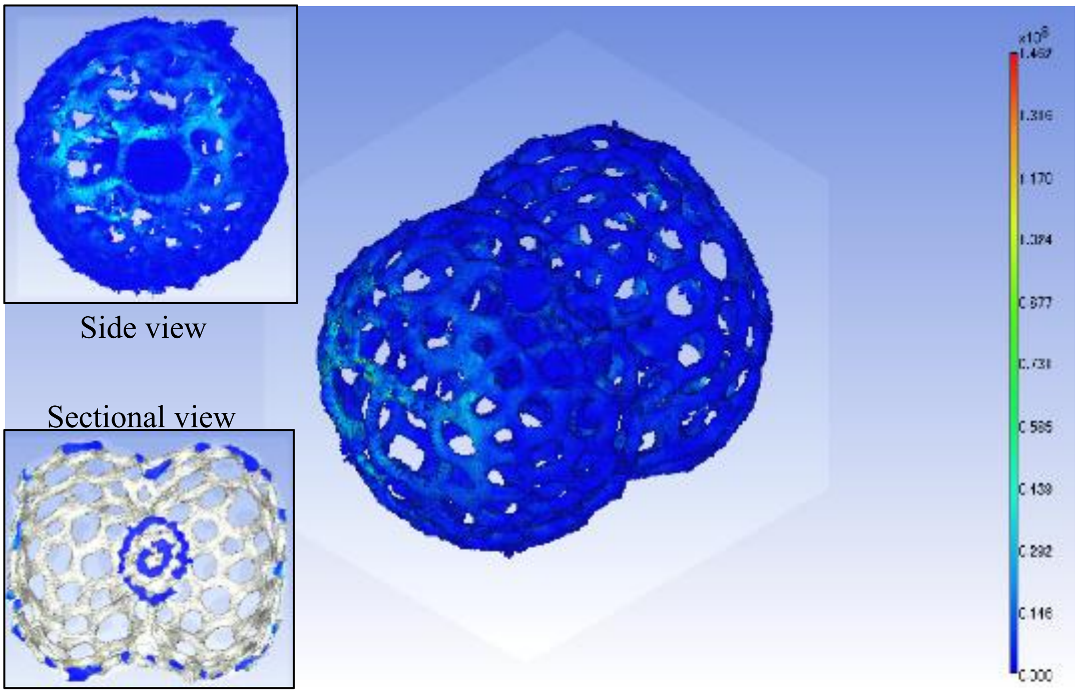

Figure 2. Stress distribution (Von Mises stress) of the skeleton

Table 1 shows analysis condition on voxel finite element model as shown in Fig.1. Considering they float in the water, we adopt simulated water pressure around it. Figure 2 shows stress distribution result of the *Didymocyrtis tetrathalamus* (Haeckel) skeleton structure. This result indicates that no stress concentration is occurred, which means the skeleton structure is some kind of optimized structures in engineering sense.

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Keywords: micro X-ray CT, mechanical property

A new methodology of studying radiolarians using 3D X-ray micro-CT imaging and Avizo software

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Ordovician radiolarians have been reported from the Mallongulli Formation of central New South Wales, Australia. The rich and relatively well-preserved assemblage has been studied using scanning electron microscopy and is assigned to the Katian (Webby and Bloom, 1986, Noble and Webby, 2009). It is dominated by *B. subulata* (Webby and Blom), *H. spongium* (Renz), *I. complanata* (Nazarov), *K. maculosa* Webby and Blom and *P. octaramosum* Renz.

The application of micro computed tomography (micro-CT) in micropaleontology is a relatively new method, and few publications describing radiolarians exist (e.g. Matsuoka et al., 2012, Yoshino et al., 2014, Yoshino et al., 2015, Ishida et al., 2015, Wagner et al., 2015). When this method of imaging is combined with high-resolution image development using the Avizo 3D program it permits the first analysis of detailed internal structures simultaneously with the study of external features of 26 Ordovician radiolarian specimens from the Mallongulli Formation. Such detail was previously inaccessible using other techniques without physically damaging the specimens.

Selected well-preserved radiolarian specimens were first mounted on micro-CT suitable plastic solid stubs fixed using Norland Optical Adhesive. The stubs were placed on a turntable, which can rotate through 360° and X-Ray micro tomographs were taken for each angular step. The micro-CT apparatus is composed of an X-ray source that generates X-rays, which penetrate the object and are captured by an X-ray detector panel where they are recorded as 2D radiography representing the two-dimensional projection of the radiolarian onto the panel. Depending on the size of the specimen, different combinations of source-sample and sample-detector distances were used to fit the entire region of interest in the field-of-view. Each of the specimens was scanned in the CT lab over a period of around 6 to 9 hours using a Zeiss Versa Xradia 500 instrument, and around 600 to 1000 micro tomographs were taken for each specimen. Images were reconstructed first with the volume reconstruction software integrated with the Xradia 500 instrument then saved in TIFF format for processing using Avizo software. This program assisted with visualization and the development of high-resolution X-ray micro-CT images of the radiolarians. The 3D program is replete with abundant tools for processing, exploration, and analysis of Micro-CT image data. The first step in processing the 2D radiographs was segmentation. This was followed by generation of surfaces, a process similar to volume rendering. This give the 3D volume of the radiolarians and finally allows imaging of internal architecture (Fig. 1) by using different tools and cutting, slicing or zooming to the most internal parts. By cleaning the specimen to isolate and remove glue and rock particles study of the tiniest internal details was possible. Resolution to size of a few microns revealed detail that is otherwise physically impossible to observe. It is also possible to calculate angles between internal spicules, etc.

When combined with the use of the Avizo 3D program for image processing the micro-CT imaging generated precise numerical data for the skeletal architecture of the 26 specimens we analysed. Such detail may lead to a new understanding of their taxonomy and systematics. The new method that we used allowed us to simultaneously study and measure external features as well as tiny internal details and investigate at a scale of a few microns, which is not readily accessible by SEM or other techniques. This method also allowed us to retain irreplaceable specimens after study, without physically damaging them.

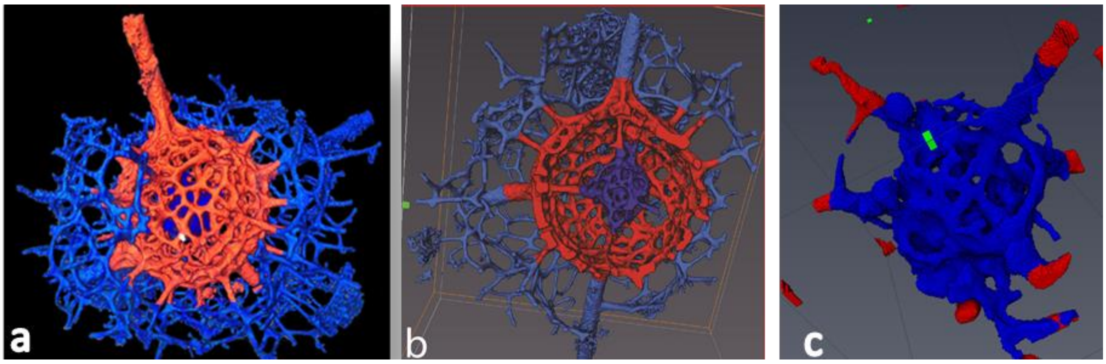

Figure 1. *K. maculosa* studied by micro-CT and Avizo software (a-outer and b-c inner spheres).

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Keywords: Radiolarians, micro-CT, Avizo, Malongulli Formation, Ordovician.

Hydrodynamic functionalisation of brachiopod shells: insights into evolutionary morphology

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As macroevolution involves the change of adaptive strategies, it has long been recognised that an understanding of autecology for extinct animals may lead to deeper insight into the evolutionary process. However, there are no reliable methods to test the biological aspects of fossils, most of which are only preserved as hard skeletal parts, without any soft tissues.

The Brachiopoda are marine invertebrates with bi-valved shell in which food-capturing tentaculate organ, the so called lophophore, is completely encapsulated. For the capture of food particles, feeding flows are generated both by the cilia on tentacles of lophphore and by the passive secondary flows through the shell gape in the fluidic environments (LaBarbera, 1981).

In contrast to the modern decline and simplification, the brachiopod morphology has diversified dramatically through the Palaeozoic time (Fig. 1). Because the generation of passive flows are closely related to the shell form, it would be hypothesised that the morphological disparity lead to a variety of passive feeding strategies, and different functionalities contributed to the brachiopod diversification under various environmental conditions. The present work exemplified hydrodynamic functionalisation of the extinct brachiopods (Fig. 2), providing a fundamental framework to find morpho-evolutionary dynamic.

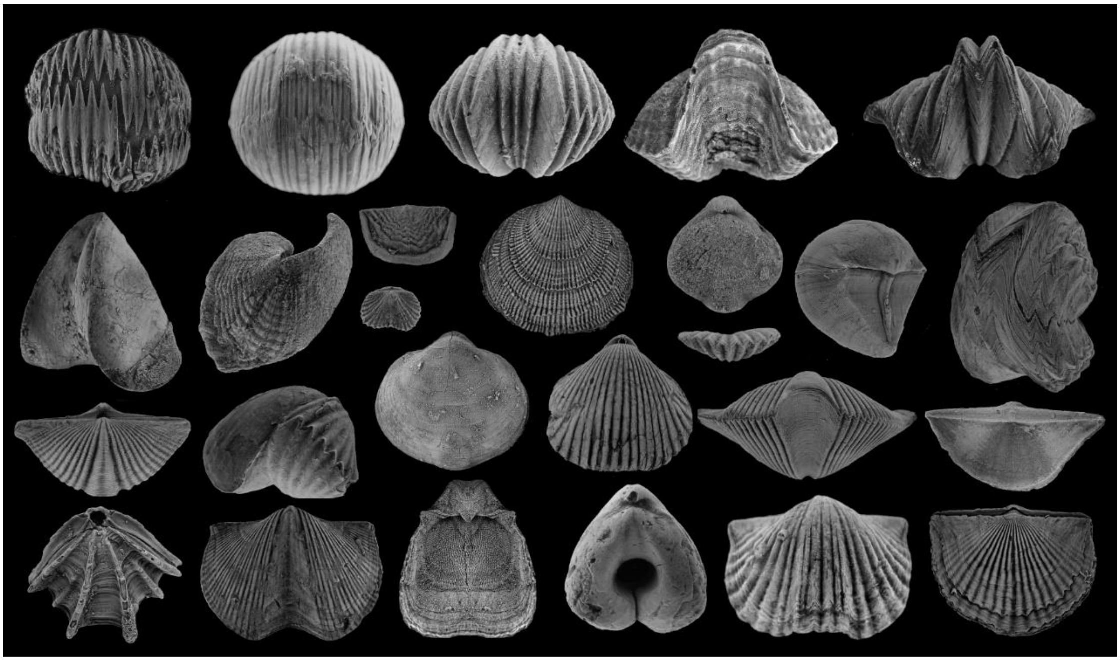

Figure 1. Morphology of fossil brachiopods. There are great variety of shell shape through the Phanaerozoic. Not scale.

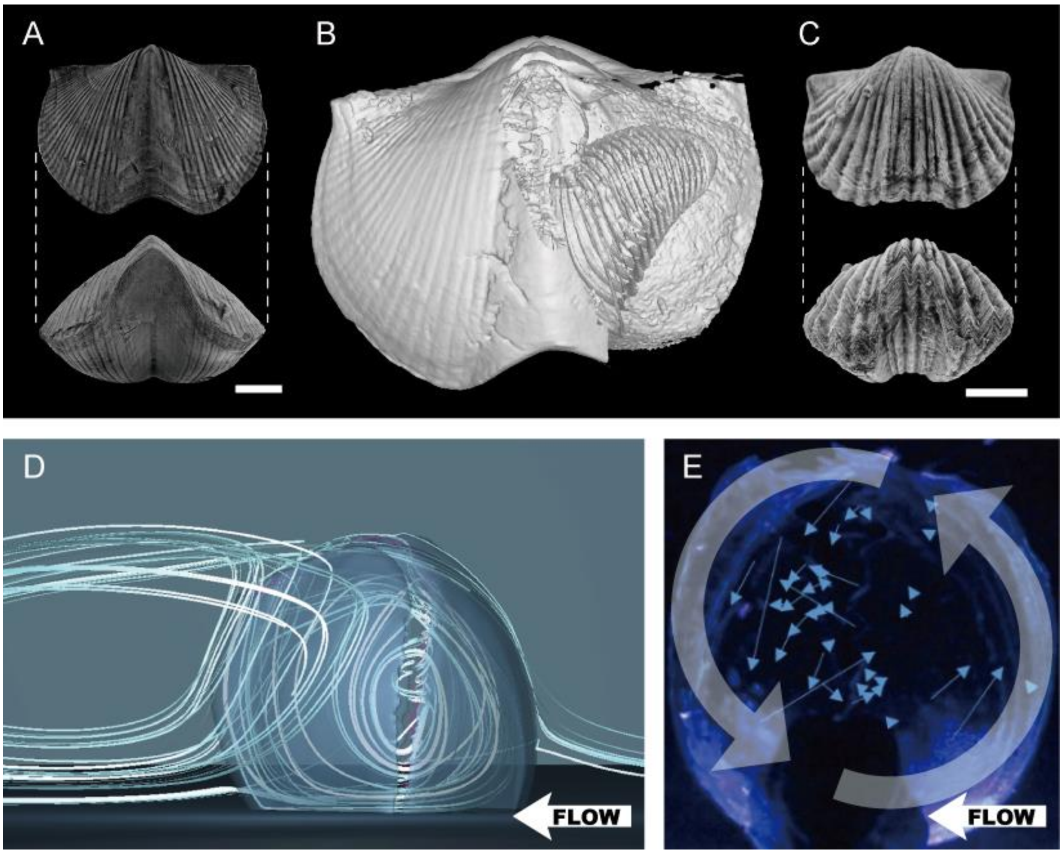

Figure 2. Examples of brachiopod morphology and function. (A) Devonian spiriferid *Paraspirifer bownockeri*. (B) 3D reconstruction of internal structure, showing spiral lophophore, brachidium (Shiino et al., 2010). (C) Ordovician orthide *Vinlandstrophia ponderosa*. (D) Computational fluid dynamics simulation on spiriferid *Paraspirifer* revealed that the shell form has a role to generate passive spiral flows for feeding (Shiino et al., 2009; Shiino & Kuwazuru, 2010). It is a synergic performance between the shell and lophophore, enhancing feeding efficiency. (E) Flow experimental result of the orthide *Vinlandostrophia*. Spiral flows similar to those of *Paraspirifer* suggest the morpho-functional convergence to generate effective feeding flows.

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Keywords: biomechanics, evolution, adaptation, homoplacy

Retraction Force of Axial Projection of Multi-segmented Nassellarian *Eucyrtidium hexastichum* (Haeckel)

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We estimated the retraction force of the axial projection (Sugiyama et al., 2008) of multi-segmented nassellarian *Eucyrtidium hexastichum* (Haeckel) based on the movie, which records the ecology of the specimen. The fluid dynamical consideration is required to discuss the mechanism of the expansion and contraction of axial projection quantitatively and to discuss the evolution of the skeletal structure of radiolarians. This is because the shapes of radiolarian test can reflect their feeding strategies (Matsuoka, 2007). Multi-segmented nassellarians use their axial projection for taking prey.

The movie used in this study records the slow expansions and quick retractions of the axial projection of the specimen of *E. hexastichum*. We used the part of the movie in which the tip of the axial projection was fixed to the bottom of the container. In this case, the body was dragged during the retraction of the axial projection. This movie enabled us to estimate the magnitude of the retraction force of the axial projection. The procedure of the estimation consists of three parts: estimation of the velocity of the movement during the retraction, extraction of the outline of the specimen, and the numerical simulation of fluid flow around the specimen.

The estimated value of the average speed of the movement is approximately 2.88×10^{-4} m/s. Figure 1 shows a part of the capture images used for the estimation. The length of the specimen is approximately 160 μm and its maximum diameter of the section is approximately 92.6 μm. The angle of tilt from horizontal plane was estimated from the aspect ratio of the ellipse at the section denoted in Fig. 1. We estimated the distance of the movement using the difference in the two sequential images captured from the movie. The duration time of the movement was obtained by the product of the number of frames and the time per one frame (1/30 Sec.). As the results, we finally obtained the average speed mentioned above. The estimated Reynolds number is approximately 2.67×10^{-5} so that the flow around the specimen can be regarded as the low Reynolds number flow (Happel & Brenner, 2012).

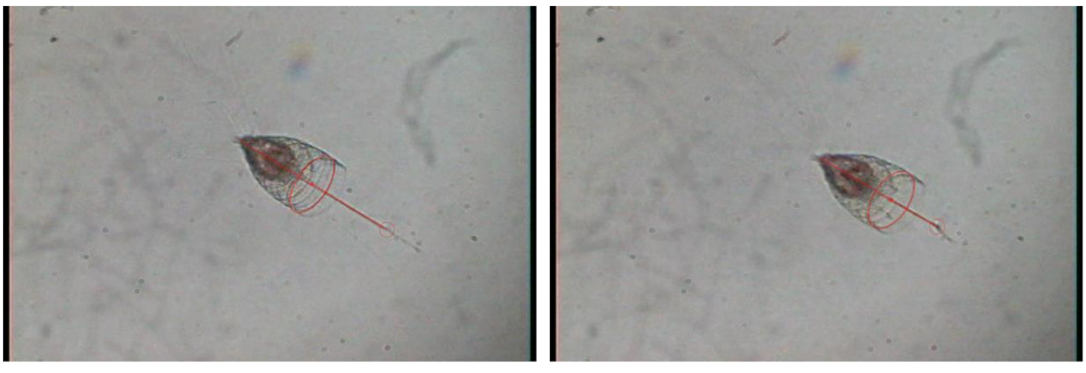

Figure 1. Examples of the captured images during the contraction of the axial projection. The tip of the axial projection was fixed to the bottom and the body of the specimen was moved.

We approximated the shape of the specimen to the seventh order polynomials. We determined two approximated polynomials because the shape of the specimen was divided into two parts; upper and lower ones. We selected the image of the specimen which can be considered to be lying horizontally. After removing its background, we binarized the images using the method of morphological binarization. We selected outermost pixels as the points denoting the outlines and determined the coefficients of the approximated polynomials from first order to ninth one. We chose the seventh order polynomial as the most suitable equation for representing the shape of the specimen.

The estimated value of the drag force is approximately 2.22×10^{-10} N. Figure 2 shows the example of the part of the results of the simulation. We used OpenFOAM (OpenCFD Ltd, 2016) for the numerical simulation. We approximated the shape of the specimen to axisymmetric and simulated the fluid flow under the assumption of axisymmetric flow as shown in Fig. 2. We allocated the obstacle, whose shape is almost same with the upper or lower shape of the specimen, in a uniform flow. The velocity of the uniform flow is opposite to the movement of the specimen. Therefore, the fluid flows from right to left in Fig. 2. We monitored the viscous resistance force applied to the obstacle and estimated the stable value. The estimated value of the magnitude of the viscous force is 2.09×10^{-10} N for upper boundary and 2.34×10^{-10} N for lower boundary, respectively. We chose the averaged of the two values as the estimated one.

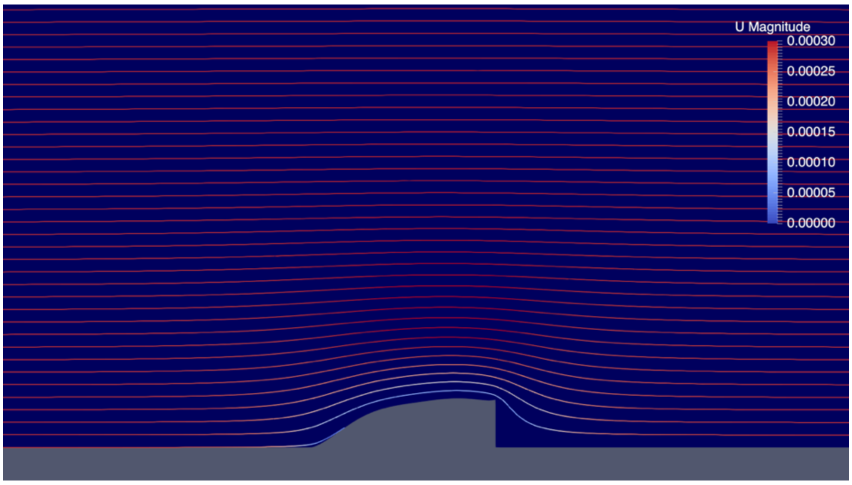

Figure 2. An example of the results of numerical simulation. The color denotes the magnitude of fluid velocity. References

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Keywords: drag force, axial projection, fluid dynamics, multi-segmented nassellaria

Automated Identification of Radiolarians using RaDSS

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Radiolarian identification is currently done by comparing microphotographs of radiolarians with published images. Text-based identification is time consuming and requires availability of reference materials. This study created RaDSS, a classifier application that will help in the identification of radiolarians. RaDSS allows users to identify radiolarians by using support vector machines (SVM), a machine learning algorithm. Machine learning gives computers the ability to learn without being programmed explicitly. This type of artificial intelligence is a supervised learning wherein a ground truth is available, in this case, image of the type species or correct identification of the species is available. It also allows itself to adjust, through training, when exposed to new data sets. For this study, four radiolarian species were used for SVM classification. The species were chosen based on their frequency in the available data set. A 95% classification accuracy was obtained when Haralick texture descriptors with six principal components were used.

Keywords: RaDSS, machine learning, support vector machines, classifier application

SPECIAL SYMPOSIUM II
SESSION 5

Jurassic–Cretaceous Boundary

Conveners: **Atsushi MATSUOKA** and **Gang LI**

24/Oct (Tue), 15:50–16:55

Library Hall of Ikarashi Campus, Niigata Univ.

O05-01	15:50–16:10 (Keynote)	Sano, S.	The Tetori Group in northern Central Japan provides the clues for recognizing the biotic and environmental changes at the Jurassic/Cretaceous transition in East Asia
O05-02	16:10–16:25	Li, G. & Matsuoka, A.	Late Jurassic radiolarians from Nadanhada Range of eastern Heilongjiang Province, NE China
O05-03	16:25–16:40	Kashiwagi, K.	Radiolarians from the continental shelf sediments of the Tetori Group (Middle Jurassic–Lower Cretaceous) in Central Japan
O05-04	16:40–16:55	Matsuoka, A.	Phylitic analysis of radiolarians for defining the Jurassic/Cretaceous boundary in the western Pacific and eastern Tethys

The Tetori Group in northern Central Japan provides the clues for recognizing the biotic and environmental changes at the Jurassic/Cretaceous transition in East Asia

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The Tetori Group is a thick siliciclastic sequence of mainly Early Cretaceous age, and sporadically distributed in the Hida Belt, northern Central Japan, which was considered to be a fragment of continental block (possibly a part of the North China Block) before the Miocene opening of the Japan Sea (e.g., Sano, 2015; Sano and Yabe, 2017). In the lower part of the Tetori Group (= depositional stage (DS) 2 of Sano (2015)), the brackish environment is dominant with intercalation of shallow marine environment in some horizons, which were usually assigned to the Berriasian or the late Hauterivian in age. The Mitarai Formation of the Tetori Group is a shallow marine stratum in the Shokawa area, which is famous for rich bivalve and other invertebrate fossils. Although it was previously considered as the Middle Jurassic in age, recent discoveries of ammonoids including *Neocosmoceras* sp. (Sato et al., 2008) and belemnites: *Arctoteuthis tehamaensis* and *Cylindroteuthis* sp. nov. (Sano et al., 2015, 2017) suggest its age assignment to the Berriasian. It should be noted that *A*. *tehamaensis* is one of the key taxa for the discussion and correlation of the Jurassic/Cretaceous boundary in Siberia and northern California, indicating the possible correlation among the sequences in the Tetori Region, the Boreal Realm and Northeast Pacific (e.g., Dzyuba, 2012). Considering the stratigraphic sequence (several hundred meters thick) showing mainly brackish depositional environment underlies the Mitarai Formation, the Jurassic/Cretaceous boundary is supposed to be present within this sequence of the Tetori Group, though its exact horizon cannot be determined at present.

The marine stratigraphical sequences around the Jurassic/Cretaceous boundary have been recognized in several regions in East Asia: (1) northern Sikhote-Alin in Russian Far East (Urman et al., 2014), (2) eastern Heilongjiang in China (Sha et al., 2008), (3) southern Sikhote-Alin (Sey and Kalacheva, 1999), and (4) South Kitakami Region in northeastern Japan (Sano et al., 2015). They are characterized by rich occurrences of *Buchia*, a typical Boreal bivalve genus (1, 2, 3), ammonoids of Tethys–Pacific affinity (3, 4), and Tethyan belemnites (4). In addition, ammonoids of Tethys–Pacific affinity and boreal belemnites have been known from the Tetori Group. Thus the ecotone between the Boreal and Tethys realms is possibly located in the areas around southern Sikhote-Alin and the Tetori Region at that time.

On the other hand, tectonic setting of these sequences is still controversial. Some were supposed to be deposited in fore-arc basin(s) or a trench (1, 2?), and the others on small continental blocks (3, 4) (e.g., Kemkin et al., 2016). Consequently, paleogeographical reconstruction (e.g., paleolatitude) of these regions are highly debatable. However, since the Hida Belt, where the Tetori Group was deposited, possibly represents the easternmost part of the North China Block, namely a “core” of the Asian Continent at that time, the paleontological record of the Tetori Group can be used as a kind of a “fixed point” for the marine paleo(bio)geographical reconstruction in the Northwest Pacific at mid-latitudes.

Furthermore, as mentioned in Li and Matsuoka (2015), the Jurassic/Cretaceous boundary level is probably also present within non-marine sequences in northeastern

China, and its correlation with marine sequences in the Heilongjiang Region has been frequently discussed. However, both Liaoning and Tetori regions are located in the almost same latitudes within the same North China Block, the comparison of stratigraphical records, and paleoenvironmental and biotic changes between both regions may be more suitable. Further studies of the Tetori Group and its biota probably provide the clues for recognizing biotic, paleogeographical and paleoenviromental changes at the Jurassic/Cretaceous transition, and also the evolution of Late Mesozoic terrestrial and marine ecosystem in East Asia and Northwest Pacific.

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Keywords: Tetori Group, Jurassic, Cretaceous, Central Japan, East Asia

Late Jurassic radiolarians from Nadanhada Range of eastern Heilongjiang Province, NE China

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The early geological study on the Nadanhada Range began in 1930s by Japanese geologists (Yabe & Ohki, 1957). In 1957 Chinese and Russian scientists made a joint geological research in the Ussuri River region, and confirmed the occurrence of Upper Triassic, Lower and Middle Jurassic rocks according to fossil evidence (Wang, 1959), and they came to the conclusion that the Mesozoic mobile belt developed in a geosyncline in the northeastern continental margin of East Asia.

Based on fossil records of Late Palaeozoic fusulinids the Nadanhada Range was considered as a Palaeozoic geosyncline that has extended from the northeast Sikhote-Alin region (Li et al., 1979). But the sporadically and irregularly distributed rocks yield various age fossils, such as Carboniferous and Permian fusulinids in limestone, Triassic conodonts in bedded chert (Wang et al., 1986; Buryi, 1996), Triassic, Early and Middle Jurassic radiolarians in bedded chert and siliceous shale (Yang et al., 1993) and Late Jurassic to Early Cretaceous *Buchia* bivalves in mudstone (Sha & Fürsich, 1993). These strongly suggest the melange geological characters of the Nadanhada Range, which together with the Mino and Western Sikhote-Alin terranes formed a single superterrane before the opening of the Japan Sea (Kojima, 1989).

Recent studies showed that the Dajiashan Formation, cropping out in the Zhenbaodao–Dajiashan area, southern Nadanhada Terrane, yields a middle-late Early Cretaceous *Aucellina* Fauna (Sha, 2002). Furthermore, the purported Early Jurassic ammonites of the Dajiashan Formation (Li, 1996) are also similar to those of the *Pseudohoploceras* ammonite fauna from the Lower Cretaceous Longzhaogou Group. All these sparked an interest in restudying the palaeontology and biostratigraphy of the Dajiashan Formation and its underlying deposits.

Well preserved Middle–Late Jurassic radiolarian faunas were encountered in four samples from the black mudstone of the Dalingqiao Formation, which had been originally assigned to Late Triassic–Early Jurassic by the Geological Survey of Heilongjiang Province of China. These radiolarian faunas consist of 45 species and subspecies in 28 genera and are assignable to two radiolarian zones, i.e. a Middle Jurassic (middle Bathonian to middle Callovian) *Striatojaponocapsa conexa* zone and the Late Jurassic (Kimmeridgian) *Hsuum maxwelli* zone of Matsuoka (1995). The new fossil record of Late Jurassic radiolarians makes it possible to reconstruct the geological history of the Nadanhada Range in northeastern China.

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Keywords: radiolarian, Late Jurassic, Nadanhada, estern Heilongjiang, northeastern China

Radiolarians from the continental shelf sediments of the Tetori Group (Middle Jurassic–Lower Cretaceous) in Central Japan

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The Tetori Group, the Middle Jurassic to Late Early Cretaceous in age, is subdivided into the Kuzuryu, Itoshiro, and Akaiwa subgroups, and it consists mainly of terrigenous and brackish sediments with some intercalations of the continental shelf sediments (Maeda, 1961; Fujita, 2003). Most of the continental shelf sediments yield abundant marine invertebrate macrofossils: ammonoids, belemnites, bivalves, and gastropods (e.g., Sato and Westermann, 1991; Sano et al., 2010), and high-diversified microfauna: radiolarians, foraminifers, sponge spicules, prodissoconchs of bivalves and gastropods, echinoderm fragments, and carapaces of ostracods (e.g., Hirasawa et al., 2010; Kashiwagi and Hirasawa, 2010, 2015; Kashiwagi et al., 2016). Radiolaria-bearing rocks are calcareous nodules and trace fossils within sandy siltstone matrices except for one example. Careful observations of hydrofluoric residues under a stereoscopic microscope and rock thin sections under a polarizing light microscope demonstrate that the radiolarian tests are only scattered in nodules and trace fossils, and never be in their surrounding matrices.

Radiolarian occurrences from the Tetori Group are as below: middle Middle Jurassic Kaizara Formation of the Kuzuryu Subgroup in Fukui Prefecture (Kashiwagi and Hirasawa, 2015), early Late Jurassic Kiritani Formation of the Kuzuryu Subgroup in Toyama Prefecture (Kashiwagi and Hirasawa, 2010; Sano and Kashiwagi, 2013), early Late Jurassic Arimine Formation of the Kuzuryu Subgroup in Toyama Prefecture (Hirasawa et al., 2010), late Late Jurassic Kamihambara Formation of the Itoshiro Subgroup in Fukui Prefecture, and middle Early Cretaceous Kuwajima Formation of the Itoshiro Subgroup in Ishikawa Prefecture (Kashiwagi et al., 2016). Although the radiolarian tests are poorly to moderately preserved, they show spumellarian-dominated radiolarian assemblages. Spumellarian compositions form the Tetori Group are characterized by common orbiculiformids including *Orbiculiforma*, which is one of the characteristics for the Northern Boreal Province sensu Kiessling 1999 in the Tithonian time. Thus, I suggest the probable hypothesis on the basis of radiolarian occurrences that the palaeobiogeographic location of the Tetori sedimentary had been within and/or around the Boreal Province.

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Keywords: Tetori Group, Jurassic, Cretaceous, Central Japan

Phylitic analysis of radiolarians for defining the Jurassic/Cretaceous boundary in the western Pacific and eastern Tethys

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The Global Boundary Stratotype Section and Point (GSSP) of the Jurassic/ Cretaceous (J/K) boundary is the last among the GSSPs in the Phanerozoic. It is defined as the base of the Berriasian Stage. The formal definition was made in 2016 to use the base of the *Calpionella alpina* Subzone as the primary marker by the Berriasian Working Group in the International Subcommission on Cretaceous Stratigraphy. The definition is satisfactorily applicable for shallow marine deposits within the western Tethys and central Atlantic. Unfortunately, the primary marker taxon cannot be found in the Pacific and circum-Pacific regions since the distribution of *Calpionella* is limited to the western Tethys and central Atlantic. To determine the base of the Berriasian outside of these regions, alternative markers are needed.

Radiolarians are good candidates for defining the J/K boundary because they are wide spread and can be found both shallow and deep sedimentary facies. Pelagic sequences across the J/K boundary have been reported in ODP/IODP sites in the western Pacific and land sections in Japan, the Philippines, southern Tibet, Iran and others. Evolutionary series of several radiolarian lineages across the J/K boundary are reviewed and suitable bioevents, which are approximate to the J/K boundary, are presented. These lineages include the radiolarian genera *Archaeodictyomitra, Cinguloturris, Eucyrtidiellum, Hemicryptocapsa, Hsuum, Loopus, Mirifusus, Neorelumbra, Ristola, Podocapsa, Pseudodictyomitra*, *Tethysetta*, *Thanarla*, and *Vallupus*.

Matsuoka (1995) proposed a radiolarian zonal scheme for the entire Jurassic and lower Cretaceous. In defining zones evolutionary first appearance biohorizons (EFABs) are selected as much as possible. The J/K boundary is located within the *Pseudodictyomitra carpatica* Zone, of which base is defined by the EFAB of *Pseudodictyomitra carpatica* and of which top is defined the EFAB of *Cecrops septemporatus*. Our current research revealed that important lineages for defining the J/K boundary are *Cinguloturris, Eucyrtidiellum, Podocapsa,* and *Vallupus*.

The most complete section across the J/K boundary in the Pacific is ODP Site 801. The core was studied by Matsuoka (1992) and the results were utilized in establishing a zonal scheme in Matsuoka (1995). The core was re-studied by Yang and Matsuoka (1997). Extremely well-preserved Berriasian radiolarians were recovered from the Mariana Trench (Matsuoka, 1998). Further re-investigation on these materials is in progress.

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Keywords: Jurassic/Cretaceous boundary, GSSP, radiolarians, phylogeny, zonation, ODP Site 801

■ MEMO ■

INTERNATIONAL COMMUNICATION PROGRAM [SESSION 6]

国際ふれあいトーク

25/Oct (Wed), 19:00–20:00

Multi-purpose Space of TOKIMATE, Eki-nan Campus, Niigata Univ.

O06-01	19:00–20:00	Baumgartner, P.O. et al.	Radiolarite versus pelagic carbonate sedimentation during the Jurassic-Cretaceous transition, Panthalassa-Tethys-Atlantic-Protocaribbean – paleofertility and ocean circulation

Radiolarite versus pelagic carbonate sedimentation during the Jurassic-Cretaceous transition, Panthalassa-Tethys-Atlantic-Protocaribbean – paleofertility and ocean circulation

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Proto-Caribbean, Central Atlantic and Western Tethyan ("intra-pangean") sedimentary records across the Jurassic-Cretaceous transition differ form the radiolarite-dominated series known form Panthalassa: 1. During the Jurassic no radiolarites formed in the Proto-Caribbean, Gulf of Mexico and the Central Atlantic. The fist sediment in these basins is pelagic, often C-rich claystone (DSDP Site 534) or pelagic carbonate since the Oxfordian (Guaniguanico Terrane, NW-Cuba). 2. In Western Tethys, Middle to lower Upper Jurassic ribbon bedded radiolaries progessively grade during the Oxfordian-Kimmeridgian, depending on paleo-geography, into cherty pelagic limestones and pass during the middle-late Tithonian into pure nannofossil limestones with occasional radiolatian-rich chert layers (Maiolica or Biancone Formation).

During the Late Jurassic, calcareous nannofossils became for the first time an important component of the intra-pangean sediments: *Watznaueria* spp. appear first, while *Nannoconus* spp. became dominant during the Tithonian-early Valanginian and declined again in favor of *Watznaueria* during the late Valangnian-early Hauterivian (Erba & Tremolada 2004), Nannoconids came back during late Hauterivian and finally declined during late Barremian. When nannoconids thrived, *Watznaueria* declined in numbers and size (Bornemann et al. 2013). While nannoconids became rock forming in intra-pangean basins and epicontinental seas, this genus has been reported from Panthalassa only in small abundances, mainly from shallow DSDP/ODP sites (e.g. Ongtong-Java, Mid-Pacific Mountains, Erba 1994).

Hyaline calpionellids (*Crassicollaria*, *Calpionella*, *Tintinopsella* , etc.) have a very similar paleogeographic and stratigraphic distribution, in that they appeared and became common in intra-pangean basins during the late Tithonian, evolved quickly and disappeared with the first nannocond crisis at the end of the early Valanginian. Isolated calpionellid occurrenecs have been reported form E-Tethys (Kiogar Nappes of Tibet, Heim & Gansser 1939), but this group in unknown from Panthalassa.

The paleo-ecological affinities of nannoconids have been discussed controversially, including the following interpretations: warm waters; low nutrients; low CO2 concentrations, low terrigenous input and high carbonate productivity. J.M. currently interprets nannoconid blooms as indicating clear waters, barren of mud, reflecting relative warm, arid and low nutrient conditions.

These conditions clearly contrast with conditions generally advocated for the formation of radiolarites, namely increased surface fertility and/or bottom water conditions that favored carbonate dissolution and silica preservation. The distribution of pelagic carbonate vs. radiolarite is critical to the paleo-oceanographic interpretation of the trans-pangean seaway: It supports no east-west directed current (often conceived as a circum-global equatorial system) across this seaway, whether it is open or intermittently closed during the Middle Jurassic-Early Cretaceous (Brunetti et al. 2015). The intra-pangean basins were "Mediterranean" seas, characterized by a sluggish, lagoonal circulation, with stratified water masses and relatively low surface fertility, only poorly connected to the world ocean. The jaw-like opening of Western Tethys during the Middle-Late Jurassic shafted the boundaries between silica and carbonate realms: Radiolarite facies reached nevertheless to the W into Subbethic and the Rif realms adjacent to the Central Atlantic, while the nannoconid carbonate facies reached eastwards to the drowned Arabian Platform, but not to the deep water Hawasina Realm.

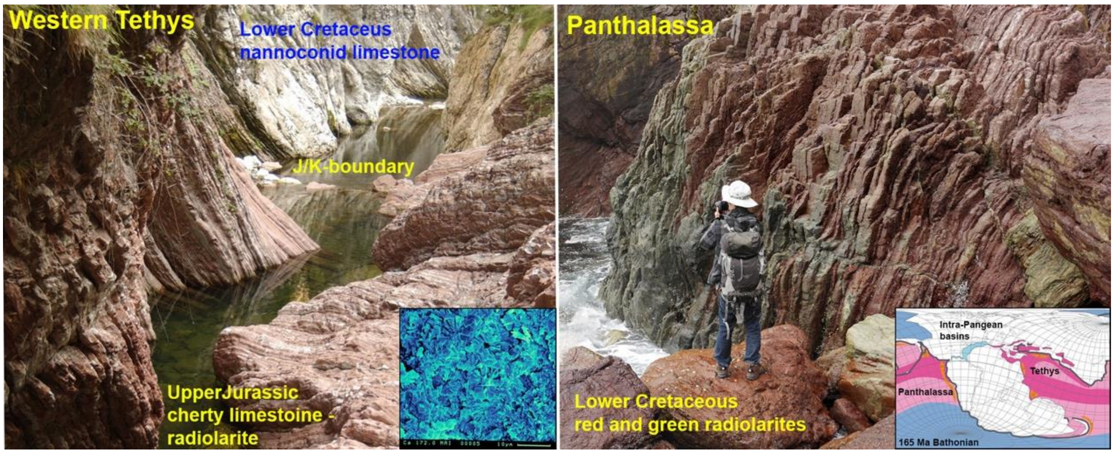

Figure 1. Left: Typical Western Tethyan Jurassic/Cretaceous boundary, Breggia Gorge, S-Switzerland, change from siliceous to nannocinid limestone sedimentation. Inset: SEM image of nannoconids, broken surface, Capriolo Quarry, Lombardy Basin, scale bar = 10µm. Right; Lowe Cretaceous ribbon bedded green and red radiolarian chert, Goshiki section, Shikoku Terrane, Japan, Inset: Bathonian paleogeographic map with Intra-Pangean seas in light blue.

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Keywords: Jurassic-Cretaceous transition, nannoconids, calpinellids, pelagic carbonate vs. radiolarite

■ MEMO ■

GENERAL SYMPOSIUM I
SESSION 7

Insightful Studies for Radiolarians

Convener: **Yoshiaki AITA**

26/Oct (Tue), 9:00–10:20

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O07-01	9:00–9:15	Ogane, K.	JREC-IN Portal: the career support portal site for all researchers and research staff who are pioneering innovation
O07-02	9:15–9:30	Hori, R.S. et al.	A growth model and strategy of forming siliceous skeletons of living Spumellaria (Radiolaria)
O07-03	9:30–9:45	Kachovich, S. & Aitchison, J.C.	Capturing initial skeletal growth in Paleozoic radiolarians
O07-04	9:45–10:05 (Highlight)	Okazaki Y. et al.	Online oxygen isotope analysis of biogenic opal using the inductive high-temperature carbon reduction method with continuous flow isotope ratio mass spectrometry
O07-05	10:05–10:20	Takahashi, K.	Four decades of research on radiolarians and other siliceous microplankton/fossils

■ MEMO ■

JREC-IN Portal: the career support portal site for all researchers and research staff who are pioneering innovation

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JREC-IN Portal (https://jrecin.jst.go.jp/seek/SeekTop?ln=1) is an informative portal site that supports the career development and skill building of researchers, research assistants, technicians and other research-related human resources, which is operated by Japan Science and Technology Agency (JST).

JST is one of the core institutions responsible for the implementation of science and technology policy in Japan including the government's Science and Technology Basic Plan. One of the pillar of this plan is that "Establishing a systemic virtuous cycle of human resources, knowledge, and capital for innovation." For contributing this pillar, JREC-IN Portal provide the information for career development for researchers and research staff.

This website contains a database of information on job postings for research and education positions in industries, academia and the public sector. The job seeking users can search the job information online. This website also provides other contents and information for career development of researchers.

The main service of JREC-IN Portal:

The following services can be used by anyone if they agree to the "Usage notice".

1) View job postings

This website provides the job postings. These job postings are submitted by the registered recruiting institutions. The job seeking researchers and research stuff can search online of job information on website. Most of the job information is submitted by universities, public research institute, and private companies.

2) View contents

This website provides contents such as helpful articles on human resources utilization. But they are written only in Japanese.

3) View events and other information

This website provides information on the career path of research-related human resources, such as events and grants.

Only registered users can use the following services.

4) Matching e-mail

Registered users can receive e-mail alerts for new jobs posted on JREC-IN Portal that match their desired conditions. Registered user must be set desired conditions to use matching e-mail.

5) Tools for Application

Registered users can create your own application form or achievements and activities by entering the prescribed information.

6) Web application

Registered users can apply to job postings online. They can also check the status and details of a web application on website.

Keywords: career development, job information, online service, job seeking

A growth model and strategy of forming siliceous skeletons of living Spumellaria (Radiolaria)

Rie S. HORI[1], Takenobu SHINKI[1*], Akihiro IWAKIRI[1*], Atsushi MATSUOKA[2], Noritoshi SUZUKI[3], Kaoru OGANE[3*] & Akihiro TUJI[4]

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**: former affinities graduated*

Culturing experimental studies of living Radiolarian are difficult because living radiolarian individuals are too sensitive to live long-duration under artificial environments. We have studied and improved experimental works for culturing living radiolarian cells, and succeeded to detect newly-formed parts of siliceous skeletons labeled using fluorescent markers such as PDMPO and HCK-123 (ex. Ogane et al. 2010). In this study, we will introduce one of our recent results from our culturing studies on living radiolarian cells.

Spumellaria usually shows high-diversity in shell morphology, for example, they have shells of concentric and spherical, those with extremely long spines, or discoidal and other forms. Spumellarian cells can live usually longer than nassellarian ones under artificial environments, we therefore performed experimental studies on living spumellarians to clarify how does spumellaria make its skeleton. Living samples were obtained from surface sweater of Kuroshio Current offshore Okinawa Is. and Kashiwajima Is, Kochi, Japan, and separated individually into a small dish for laboratory works. The sample cells had been settled under stable temperature conditions (27 Celsius) with blue and white LED lights. After addition of fluorescent marker solutions, we have cultured them during 12 hours, 24hours and 48hours. Through these procedures, the following results were obtained.

Spumellarians having discoidal shells such as specimens belonging to the genera *Dictyocoryne, Euchitonia* and *Spongaster* change the new forming skeletal part depending on the growth stage. The skeletal growth has been operated by alternation of rapid growth stage and stable one without remarkable growth. For the case of *Spongaster tetras tetras,* we recognized 2 types of skeletal growth steps, 1) rapid growth on the outermost shell with enlargement of shell-size, 2) inter growth without shell-size change. After the shell achieved around 300μm in size, there is no skeletal growth on the shell surface. It reveals that *S. tetras tetras* has a strategy to keep skeletal shape in adult stage.

Spongosphaera streptacantha having a spherical shell with several extremely long spines shows these 2 types growing stages and also a special growth way for extending spines. We have found patched spots of the new siliceous additions within the blade part along the long axis. This is a good way to growth for extending of spine in one direction without width change.

The facts obtained from these culturing studies suggest that Spumellaria keeps and controls its shell shape result from change the newly formed parts depending on the growth stages.

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Keywords: Spumellaria, Culturing, HCK-123, Siliceous skeleton

Capturing initial skeletal growth in Paleozoic radiolarians

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This project investigates the development of 3D X-ray micro-computed tomography (μ-CT) as a diagnostic tool for taxonomic assignment of Early Paleozoic radiolarians. Understanding Early Paleozoic radiolarian faunas remains problematic as understanding the majority of natural relations between higher-level taxonomy relies on our ability to observe complete structural details that are not often revealed due to the typical state of preservation. Rarely, when preservation is exceptional, external morphologies of early radiolarians reveal spongy, densely latticed and multiple shells, which typically obscure important internal details when using classical methodologies. Here we demonstrate that μ-CT techniques can obtain information about primary morphological characteristics and provide a basis for valid systematic classifications relating to functionality of the organism as well as constraining later mature skeletal growth. This research is necessary because taxonomy based on genuine morphological characteristics (homologies rather than homoplasies) is a prerequisite for any significant systematic and bistratigraphic work.

Early Paleozoic lagerstätten with a predominance of pelagic assemblages are well known from western Newfoundland. Thirteen samples were systematically collected from the top of the Table Cove Formation at the Piccadilly Quarry, Newfoundland where rhythmically interstratified, organic rich beds of peloidal limestone are exposed. The quarry is a well-known graptolite and sponge spicule locality, but accompanying radiolarian faunas have never been examined in any detail. Age diagnostic conodonts and diverse assemblages of disarticulated sponge spicules were recovered along with the radiolarians and help facilitate consistent stratigraphic interpretation and usefulness of Palaeozoic radiolarian faunas for biostratigraphy. Based on recognition of important age-diagnostic pectiniform taxa such as *Histiodella kristinae* and *Polonodus* sp., an Ordovician (mid-Darriwillian) assignment is made within the *Haplentactinia juncta–Inanigutta unica* assemblage (Nazarov & Popov 1980).

The acquisition of μ-CT images was accomplished using a Zeiss Xradia 500 instrument. Scans revealed unexpected diversity and preservation equivalent to assemblages from the Shundy Formation (Pouille et al., 2014) and the Bestomak Formation (Nazarov & Popov 1980), Kazakhstan. The radiolarian assemblage is dominated by members of the family Inaniguttidae, represented by five genera (*Triplococcus, Inanihella, Inanigutta, Inanibigutta* and *Kalimnasphaera*), accompanied by less common Haplentactiniids (*Haplentactinia, Haplotaeniatum)* and Entactiniids.

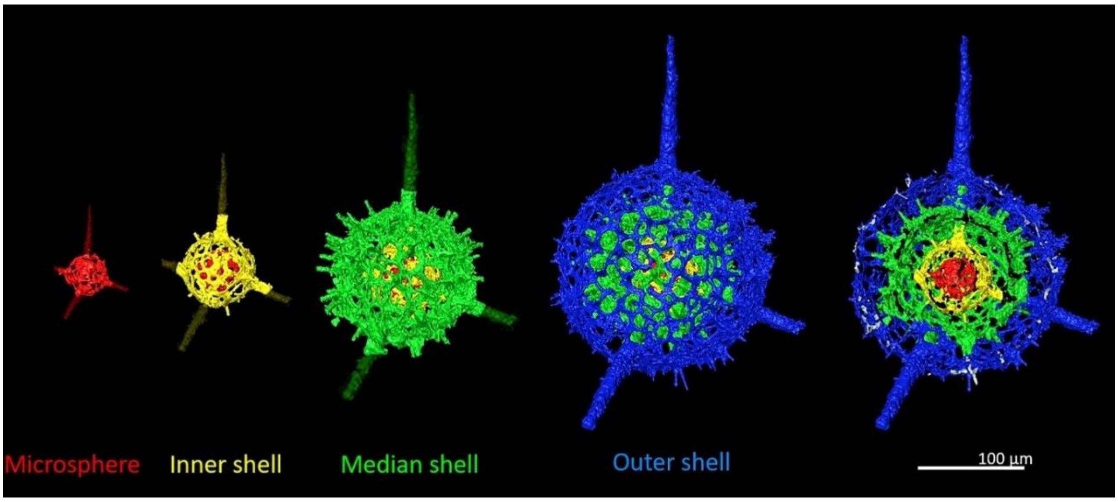

Figure 1. Isolated µ-CT segmentations of a *Triplococcus acanthicus* shell, from the Piccadilly Quarry, western Newfoundland, demonstrating ontogenetic position of skeletal elements and morphological variation between each element growth stage.

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Keywords: Ordovician, Micro-CT, Taxonomy, Newfoundland

Online oxygen isotope analysis of biogenic opal using the inductive high-temperature carbon reduction method with continuous flow isotope ratio mass spectrometry

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Biogenic opal is produced by amorphous silicate produced by radiolarians, diatoms and sponges. Oxygen isotope ratio of biogenic opal has a potential to be a quantitative paleo-proxy likewise the oxygen isotope ratio of foraminiferal shell (calcium carbonate). Here we present a method for determining sub-milligram quantities of biogenic opal (Ijiri et al., 2014). The method employs the inductive high-temperature carbon reduction method for dehydration of opal and reduction of silica, and a continuous-flow isotope ratio mass spectrometry system for direct analysis of the oxygen isotope ratio in the evolved carbon monoxide. The accuracy and precision of the online analytical system were evaluated by isotopic analysis of various quantities of standard SiO_2 in the range 40–538 μg. The time required to analyze a single sample was ~50 min. hence, our method is suitable for routine analysis for paleoenvironmental studies that require large amounts of time-series data. The method was validated for samples in the sub-milligram range and can be applied to oxygen isotope analysis of various types of biogenic opal. We applied our method to the first oxygen isotope analysis of monospecific radiolarian skeletons: (1) *Schizodiscus* spp. in the Bering Sea sediment (Holocene and LGM) and (2) *Spongotrochus glacialis* in the Plio-Pleistocene sediments from the Antarctic Wilkes Land margin. 40 to 110 specimens (>200 μg) of the radiolarian species were picked up and washed in an ultrasonic bath with Milli-Q water, and then dried at 40 °C in an oven. For Bering Sea case, a bulk diatom sample from the same sediment sample was also analyzed for comparison. The average $\delta^{18}O$ value for *Schizodiscus* spp. (~40.4‰ VSMOW) was ^{18}O-enriched by 0.7‰ compared with that for the diatom sample (~39.7‰ VSMOW). However, $\delta^{18}O$ value for *Schizodiscus* spp. (~36.7‰ VSMOW) was lighter than that of Holocene value. In addition, $\delta^{18}O$ changes in *S. glacialis* from the Antarctic Wilkes Land margin samples exhibited no systematic trend related to the global cooling during Plio-Pleistocene.

References

Ijiri, A., M. Yamane, M. Ikehara, Y. Yokoyama & Y. Okazaki, Online oxygen isotope analysis of sub-milligram quantities of biogenic opal using the inductive high temperature carbon reduction method coupled with continuous-flow isotope ratio mass spectrometry, Journal of Quaternary Science 29, 455-462, 2014.

Keywords: oxygen isotope ratio, biogenic opal, radiolarian skeleton, diatom frustule

■ MEMO ■

Four decades of research on radiolarians and other siliceous microplankton/fossils

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One of the unique research topics in the late 1970th was to quantify what could be captured by deploying sediment traps (traps hereafter) in the midst of water column in the deep oceans. The methodologies were quite exploratory and thus hard to develop because of no prior study. For instance, no flux of shelled microplankton such as radiolarians, diatoms, and coccolithophores was ever properly quantified and thus our knowledge concerning biogenic opal (opal hereafter) or calcium carbonate flux was quite meager. The flux work on tropical radiolarians from the four depth-series traps was performed at the Demerara Basin of the western equatorial Atlantic, revealing something unexpected. That is, loss due to dissolution en route to sea-floor was tribual and vertical fluxes did not change much throughout the water column (Takahashi & Honjo, 1981). Thus, an earlier hypothesis of "99% opal dissolution occurs in water column" (e.g., Lisitzin, 1972; Kennett, 1982) was clearly rejected. In fact, increases of some deep dwelling radiolarian fluxes with depth were observed, which was attributed to deep production (Takahashi, 1981). Such a finding of radiolarian opal conservation en route to sea-floor was also confirmed on diatoms (Takahashi, 1986) and silicoflagellates (Takahashi, 1987a). This led to understanding of opal dissolution mainly on the sea-floor upon flux arrival but prior to burial.

Phaeodarian skeletons were quite different in terms of dissolution due to their constituents (e.g., water contents) and porous morphology (Takahashi et al., 1983). They can be lost during sinking or dissolved on the sea-floor. Because of such rapid dissolution and often massive shell size such as mm to cm in diameter their depth transport and redistribution of opal can be quite significant (Takahashi, 1987b).

Time-series work on radiolarians received a push by winds with innovative automated rotating traps. In the Gulf of Alaska, where many other oceanographic data had been accumulated for decades, seasonality of closely linked paired radiolarian taxa such as *Pterocanium korotonevi* & *P. diplotriaena* as well as *Euphysetta staurocodon* & *E. elegans* (phaeodarians) (1987b) were clarified. Differences in specific environmental preferences were discussed. In the equatorial Pacific where the behavior of the Western Pacific Warm Pool (WPWP) governs biological productivity. Significant changes in radiolarian species composition became clear as you move from the WPWP to the east (upwelling area) (Yamashita et al., 2002; Okazaki et al., 2008). One of the highlights in radiolarian time-series works is on the fifteen-year long observation at Stations SA in the subarctic Pacific and Station AB in the Bering Sea (Ikenoue et al., 2012). Twenty-year long sediment trap deployments in the subarctic (Takahashi et al., 2012) offered such an exceptionally detailed work.

Paleoceanographic works were application of the knowledge obtained through the trap and plankton tow works. The Bering and Okhotsk Seas were the important targets of this because of "polar amplification". The works on *Cycladophora davisiana* represented by Okazaki et al. (2006) showed reconstructed glacial environmental conditions of the Okhotsk Sea. Changes in time-sliced contribution extent of the Bering and Okhotsk Seas to the formation of the North Pacific Intermediate Water were investigated in detail (Tanaka & Takahashi, 2005). Pliocene-Pleistocene radiolarian biostratigraphy and paleoceanography in the Bering Sea was recently discussed (Ikenoue et al., 2016). This was among many paleoceanographic studies presented for the IODP Expedition 323 "Bering paleoceanography" volume (Takahashi et al., 2016).

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Keywords: sediment traps, flux, biogenic opal dissolution, seasonality, Bering Sea

■ MEMO ■

GENERAL SYMPOSIUM I
SESSION 8

Biosiliceous Records

Convener: **John ROGERS**

26/Oct (Thu), 10:40–12:00

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O08-01	10:40–10:55	Khan, M.Z. & Feng, Q.L.	Biogenic Silica: Relationship to Paleo-productivity and TOC from Late Ordovician-Early Silurian Organic Rich Shales of Chongqing Area, South China
O08-02	10:55–11:10	Kakuwa, Y.	Significance of trace fossils in radiolarian chert during the Phanerozoic: with special reference to red chert problem
O08-03	11:10–11:25	Aita, Y. et al.	Biosiliceous facies and flux change of the Early Triassic bedded chert from Arrow Rocks, New Zealand, Panthalassa ocean
O08-04	11:25–11:45 (Highlight)	Renaudie, J. et al.	Testing the vital effect on silicon isotope measurements in Late Eocene Pacific radiolarians
O08-05	11:45–12:00	Suzuki, H. & Maung Maung	Mesozoic radiolarian localities and their ages in Myanmar

Biogenic Silica: Relationship to Paleo-productivity and TOC from Late Ordovician-Early Silurian Organic Rich Shales of Chongqing Area, South China

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Recently, Paleozoic marine strata have been the centre of attraction as a potential resource in oil and gas exploration. In China, most marine hydrocarbon source rocks are largely associated with siliceous rocks and radiolarian (Xiang et al., 2013; Li et al., 2017).

Siliceous microfossils, particularly radiolarian and sponge spicules, can be used as proxies of palaeoceanic environments in sedimentology. Silica which originated from these organisms (Biogenic Silica) is a chemically determined proxy measuring the amorphous Si content of sediments (Conley & Schelske, 2001).

Therefore, radiolarian bearing strata deposited in Sichuan Basin can be used to help understand the relationship between biogenic silica (BSi) and paleo-productivity in Late Ordovician and Early Silurian. For instance, Xiang Yu and Feng Qinglai (2013) studied Changhsingian radiolarian fauna to explore their possible relationship to BSi and paleo-productivity in Anshun from Xinmin Section.

In this research, geochemical and paleontological studies have been conducted to investigate the origin of BSi and it's relationship to paleo-productivity and TOC. Although this has been studied in detail in South China related to Paleozoic marine strata of Permian (Xiang et al., 2013), and briefly for Ordovician-Silurian (Zhao et al., 2016); however, to date, no research has revealed the mystifying controlling factors of BSi and it's relation to TOC in Late Ordovician and Early Silurian strata of Upper Yangtze block, or it's paleo-geographic depositional pattern in Chongqing area.

This research aims to confirm the origin of BSi from micro-siliceous organisms associated to the Late Ordovician upper Yangtze sea. Our goal is to study four boreholes; namely Jiaoye A, Jiaoye B, Yanzi and Liye, located from East to West, and an outcrop of Qiliao Section situated in the south eastern area of Chongqing.

The shale succession studied is composed of two lithostratigraphic units; the Upper Ordovician Wufeng Formation and Lower Silurian Longmaxi Formation. The Wufeng Formation comprises the lower Graptolite shale Member (composed of organic rich siliceous shale) with overlying Guanyinqiao Member (composed of black shale intercalated with limestone bearing Hirnantian Fauna). The Lower Longmaxi is composed of black shale dominated by grey silty shale. The organic rich shale facies (TOC >2%) predominantly occur in the Wufeng Formation and the Lower Longmaxi Formation.

A comprehensive review of all geochemical results (with BSi) and radiolarian studies utilizing SEM, optical microscopy and handpicking will be presented; and their interlinking 'linear' relationships, especially with TOC, will be discussed.

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Keywords: BSi, TOC, paleo-productivity, Ordovician-Silurian.

Significance of trace fossils in radiolarian chert during the Phanerozoic: with special reference to red chert problem

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Over 50% of the surface of the Earth is occupied by abyssal ocean deeper than 3000 m (Menard & Smith, 1966), and the information of there is essential to understand the environmental change of the Earth. Trace fossils are one of the important tools to understand the sedimentary environment of the ocean. Those of radiolarian chert are, although, remained unstudied by both ichnologists and sedimentologists. My presentation shows some examples of burrowed cherts and discuss the significance of trace fossils in red chert.

Trace fossils are recognized by their distinct shape that consists of the difference in compositions between trace fossils and host rocks. The most common case is the difference in colors such as black trace fossils in gray chert. The difference in color is due to the content of high organic matter in trace fossils. Either Radiolaria-rich or Radiolaria-absent texture in radiolarian chert, which is identified on HF-etched surfaces, is interpreted as burrow tunnels.

Benthic animals colonized by the late Middle Ordovician (Darriwilian) on the pelagic ocean bottom, and since then trace fossils in radiolarian chert are one of the important tool to read the secular change in oxygenation level of ocean bottom (Kakuwa & Webb, 2007; 2010; Kakuwa & Floyd, 2017). Black and gray radiolarian cherts with pyrite are believed to be an indicator of the anoxic environment, but they are commonly bioturbated instead.

Red radiolarian chert, on the other hand, bears oxidized iron and suggests that the sedimentary environment was reasonably judged as oxic. Trace fossils are, although, rare in red chert (Kakuwa & Floyd, 2017). This is mainly due to the scarcity of foods that is originated from the primary productivity in the photic zone of ocean. I propose the "hyper-aerobic" environment of the ocean bottom for the sedimentation of red radiolarian chert. The environment is so harsh that no or few benthic animals can survive due to the lack of available foods.

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Keywords: trace fossil, red chert, paleoceanography, evolution, pelagic

■ MEMO ■

Biosiliceous facies and flux change of the Early Triassic bedded chert from Arrow Rocks, New Zealand, Panthalassa ocean

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Biogenic bedded chert and siliceous mudstone sequence of the Oruatemanu Formation ranging from Late Permian to Middle Triassic exposed on the Arrow Rocks of the Waipapa terrane, New Zealand is characteristic because the Early Triassic bedded chert has been deposited during the Early Triassic Chert Gap period in the Panthalassa ocean. The enhanced biogenic silica sedimentation during the Induan and Olenekian time is a very rare case and it needs to find out what sort of microfossills or constituents are composed of bedded chert. The current explanation for the chert deposition of the Induan and Olenekian is that the Waipapa terrane was located in the refuge area of marine plankton and the enhanced radiolarian shell production has been continued only in this area of middle latitude of the Panthalassa ocean (Spörli et al., 2007).

The bedded chert section of the Oruatemanu Formation, Arrow Rocks of the Waipapa terrane is comprised of grey, red and orange chert for Unit 2b, black chert and black siliceous mudstone for Unit 3(OAE-β of Hori et al., 2007), and red chert and red siliceous mudstone for Unit 4. Here we present the high-resolution SEM observations on an acid-etched chert slabs to unravel the sedimentary facies and microstructure of the bedded chert. Four microfacies have been recognized within the Unit 2b to Unit 4 sequence of the Oruatemanu Formation. Facies G1-3: pelagic facies comprising biogenic, densely packed with radiolarian shells (>70%), Facies G2: a chert matrix with a high biosiliceous component (30-70%), Facies G3: a chert facies with a few biosiliceous component (10-30%), Facies E1/E2: a siliceous clay matrix with a low content (1-10%) of biosiliceous shells and spicules, and Facies H: facies with abundant spherical objects.

A single chert bed is consisting of a combination of microfacies rather than only a single facies. Pelagic facies with biogenic abundant radiolarian shells (G1+G2+G3) indicates enhanced flux change up to 30-60% within the Unit 2b during the Griesbachian and Dienerian. Biogenic Facies G1-3 ranges 59.3 to 100% in Unit 3 (Dienerian) indicating a high radiolarian shell production. On the other hand, in the lowest to upper part of the Unit 4 (Late Dienerian). biogenic Facies G2+G3 decreased up to 28.9% stepwise upward while pelagic clay Facies E was dominated. In the upper part of Unit 4 (Smithian), biogenic Facies G2+G3 ratio increased temporally to 32.5% but soon decreased to 4.7-7.7% in Unit 4 (early Spathian).

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Keywords: Early Triassic, biosiliceous facies, bedded chert, Arrow Rocks, New Zealand, Panthalassa ocean,

Testing the vital effect on silicon isotope measurements in Late Eocene Pacific radiolarians

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Because of marine diatom primary productivity and of continental weathering, the marine silicon cycle and the global carbon cycle are intrinsically intertwined in the Cenozoic: understanding variations in the marine silicon cycle thus becomes primordial to understanding Cenozoic climate. δ_{30}Si measured on sponge spicules, radiolarians and diatoms has been determined and used in a few studies so far to quantify past marine silicon cycle, specifically the amount of biogenic silica produced and the amount of silicic acid recycled (see Figure 1). Both diatoms and radiolarians are indeed fractionating silicon isotopes either while extracting the silicon from seawater or while depositing it in their shell, therefore δ_{30}Si of dissolved silica (DSi) varies according to biological fractionation, i. e. silicic acid usage. On the other hand variations in δ_{30}Si on sponge spicules seems to be linked to variations in dissolved silicon concentration (Hendry & Robinson, 2012). Measuring the variations of δ_{30}Si(sponge spicules) and δ_{30}Si(diatoms) or δ_{30}Si(radiolarians) thus provides insights on the variations of the coupled system [DSi] / biological fractionation (e. g. Egan et al., 2012; Fontorbe et al., 2016).

This proxy, being relatively new, still needs to be tested, in particular for 'vital effect' as, as it stands so far, δ_{30}Si(radiolarians) is measured on bulk (i. e. undifferenciated) radiolarians. We thus tried here to determine species-specific silicon isotope measurements: we selected 12 abundant species, identifiable on a stereomicroscope, and we picked ca. 20 to 40 specimens (depending on their volume) for each of these species from 16 samples from the late Eocene of leg 199 sites 1217 to 1220, the same material from which silicon isotopes on bulk radiolarians were analyzed in Fontorbe (2016). The selected species consists of nine Nassellarians (*Podocyrtis chalara, Thyrsocyrtis bromia, T. rhizodon, T. lochites, Eusyringium fistuligerum, Calocyclas hispida, Dictyoprora mongolfieri, Dorcadospyris ombros* and *Zealithapium anoectum*) and three Spumellarians (*Periphaena decora, Amphicraspedum prolixum* and *Lithocyclia ocellus*).

We will present here a comparison between those results and the δ_{30}Si measured on bulk radiolarians and thus test the extent of the 'vital effect'. We will also test a variety of possible influencing factors on the various species-level trends observed, such as biogeographic ranges and ecology, with an emphasis on the supposed living depth of the species, as such a differentiation would provide us with an invaluable tool to understand and reconstruct the past marine silicon cycle and more generally the past ocean chemistry.

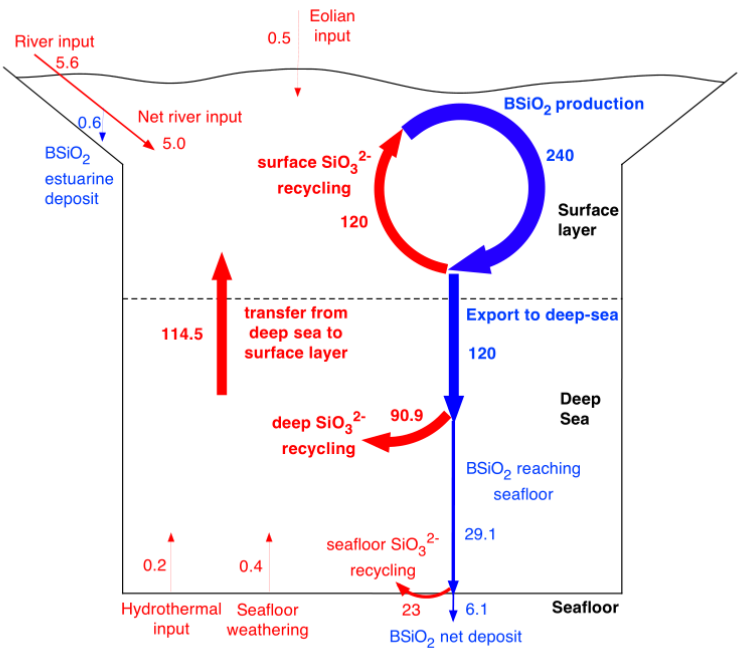

Figure 1. Marine silicon cycle. Modified after Tréguer et al. 1995. In red, silicic acid; in blue, biogenic opal.

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Keywords: Eocene; Isotope Geochemistry; Silicon cycle; Paleoceanography.

Mesozoic radiolarian localities and their ages in Myanmar

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The first report of the Mesozoic radiolarians was made from two radiolarite pebbles of the Eocene Pondaung Formation (Suzuki et al., 2004). Their ages are estimated as Middle to Late Jurassic (Callovian to Kimmeridgian/Tithonian).

After the first report from pebbles of the Cenozoic formation, we have sought radiolarian localities from the Mesozoic sequences that underlie the Cenozoic formation of Myanmar. Until now we have found following localities:

That-tu Bedded Chert in the Tagaung Taung area, north of Mandalay: Early Cretaceous age (Valanginian-Barremian) on the basis of the occurrence of following species: *Hemicryptocapsa capita* TAN, 1927, *Acanthocircus dicranacanthos* (SQUINABOL, 1914), *Archaeodictyomitra vulgaris* PESSAGNO, 1977, *A. apiarium* (RÜST, 1885), *Archaeodictyomitra mitra* DUMITRICA, 1997, *Stylosphaera squinaboli* TAN, 1927 and so on (sample Tagaung CD; Maung Maung et al., 2006).

Another horizon of the That-tu Bedded Chert, we have found another fauna of a late Early Cretaceous age (Barremian/Aptian), including following species: *Xitus elegans* (SQUINABOL, 1903), *Thanarla pulchra* (SQUINABOL, 1904), *Thanarla brouweri* (TAN, 1927), *Loopus nudus* (SCHAAF, 1981), *Pseudodictyomitra carpatica* (LOZYNIAK, 1969) and *Pseudodictyomitra* spp. (sample T-1; unpublished data of authors with sample offer of Prof. Aung Kyaw Thin, Mandalay University).

Red claystone of the Ngapyawdaw Chaung Formation in the Chinghkran area, Kachin state: Latest Jurassic age (Tithonian) on the basis of the occurrence of following species: *Pseudodictyomitra carpatica* (LOZYNIAK, 1969), *Cinguloturris cylindra* KEMKIN & RUDENKO, 1993, *Parvicingula boesii* (PARONA, 1890), *Archaeodictyomitra* cf. *minoensis* (MIZUTANI, 1981), *Tetracapsa accincta* (STEIGER, 1992), *Tetracapsa horokanaiensis* (Kawabata, 1988), *Mirifusus dianae globosus* (STEIGER, 1992), *Ristola altissima* (Rüst, 1885), *Stylosphaera squinaboli* Tan, 1927, *Eucyrtidiellum pyramis* AITA, 1986 and so on (sample KR2; Maung Maung et al., 2011).

Red chert included in the "Triassic Pane Chaung Group", Chin state: Middle Jurassic age (Bajocian-Callovian) on the basis of the occurrence of following species: *Eucyrtidiellum circumperforatum* CHIARI et al., 2002, *Praezhamoidellum* cf. *buekkense* KOZUR, 1984, *Unuma* cf. *gordus* HULL, 1997, *Striatojaponocapsa* sp. and so on (sample 381; unpublished graduate thesis of Mr. J. Higashi, Otani University with sample offer of Dr. Tun Tun Min, Kalay University).

As a result of the present data, stratigraphic distribution of radiolarite and radiolarian claystone can be summarised in table 1. We can recognise radiolaria-bearing rocks from Middle Jurassic to Early Cretaceous in Myanmar. This result indicates the existence of Tethyan ocean floor between Indian and Asian continents in Middle Jurassic to Early Cretaceous time, which had been accreted to Asia and made basement geology of Myanmar.

Table 1. Stratigraphic distribution of the radiolaria-bearing Mesozoic strata in Myanmar.

system	stage	lithology	index taxon
Cretaceous	Barremian-Aptian	Radiolarian chert	*Pseudodictyomitra* spp.
	Valanginian-Barremian	Radiolarian chert	*Hemicryptocapsa capita*
Jurassic	Tithonian	Claystone	*Cinguloturris cylindra*
	Callovian-Kimmeridgian /Tithonian	Chert pebble in Eocene strata	*Williriedellum carpathicum*
	Bajocian/Callovian	Radiolarian chert	*Striatojaponocapsa* sp.

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Keywords: Myanmar, Jurassic, Cretaceous, chert, radiolaria.

■ MEMO ■

GENERAL SYMPOSIUM I
SESSION 9

Modern Biogeography

Convener: **Rie S. HORI**

26/Oct (Thu), 14:00–15:05

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O09-01	14:00–14:15	Munir, S. et al.	Paleoenvironmental proxies and their impacts on the distribution of siliceous planktonic radiolarian community in the Eastern Indian Ocean
O09-02	14:15–14:30	Rogers, J.	Is SST the most ecologically important determinant of radiolarian species diversity?
O09-03	14:30–14:45	Suzuki, N. & Zhang, L.L.	How to identify *Tetrapyle* and its related taxa for oceanographic studies
O09-04	14:45–15:05 (Highlight)	Zhang, L.L. et al.	Modern shallow water radiolarians with photosynthetic microbiota in the western North Pacific

Paleoenvironmental proxies and their impacts on the distribution of siliceous planktonic radiolarian community in the Eastern Indian Ocean

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Abstract

Planktonic Rhizaria were collected with plankton nets at 200m depth in the water column at 44 north-eastern Indian Ocean sites (10^0N-5^0S, 80^0E-95^0E) during the RV. Shiyan I cruise from 10th April to 13th May 2014. The plankton observed comprised Acantharia, Phaeodaria, polycystine Radiolaria, and Taxopodia (monospecific - *Sticholonche zanclea* Hertwig is the only recognised species) so included both celestine-based and siliceous organisms. Cell concentrations ranged from 5 to 5270 specimens per m^{-3} and maximum abundance was dominated by the combined occurrence of Collodaria and Taxopodia, and the lowest population abundances by Nassellaria, Spumellaria, Acantharia and Phaeodaria. During cruise measurements were taken of temperature, salinity, and chlorophyll at various depts. From the surface to 200 m deep in the water column.

Shannon-Wiener's diversity index (H′) (Shannon and Wiener, 1949), Pielou's evenness index (J) (Pielou , 1969), and the dominance index (Y) (Sun and Liu, 2003) were used to analyze community structure. Application of Bray-Curtis similarity matrices and hierarchical single clustering established there were three species assemblages.

Using canonical correspondence analysis (CCA) a number of plankton species were shown to have abundances correlated with ocean environment variables. Redundancy analysis (RDA) was employed to investigate the possible explanation of species distributions by environmental variables and, although no result was obtained for the full species dataset, the samples from the cruise's equatorial transect related strongly to mixed-layer chlorophyll a concentrations and those of a north-south transect to surface silicate concentrations or mixed-layer nitrate or oxygen concentrations which correlated with the silicates.

Highlights

- First comprehensive plankton-net sampling of north-eastern Indian Ocean.
- Apparent dependence of some observed taxa of particular oceanic environmental variables.
- Explanatory environmental variables for plankton abundances in two cruise transects.

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Keywords: North-eastern Indian Ocean; net sampling; Celestine-based and siliceous plankton; canonical ordination analysis; CCA; RDA; ocean temperature; salinity; nutrients; chlorophyll a.

Is SST the most ecologically important determinant of radiolarian species diversity?

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On a global scale it has been found that sea-surface temperature (SST) is the principal determinant of radiolarian species distribution (Boltovskoy and Correa, 2016). However, general considerations of the requirements of living organisms suggest that there is always a number of different environmental factors which must be in balance to allow an organism to thrive or, at least, survive. It is, therefore, likely that, in any given (more local) biome, the abundance or scarcity of one or more of these environmental factors will determine species diversity. This study examines radiolarian abundance datasets from all the major ocean areas to determine the major factors affecting the species diversity in each.

Canonical ordination was applied to the datasets with the World Ocean Atlas 2013 (“WOA13”) (Garcia et al., 2013a; Garcia et al., 2013b; Locarnini et al., 2013; Zweng et al., 2013) data for temperature, salinity, the concentrations of nitrate, phosphate, and silicate, and oxygen (available, dissolved, and saturation) and chlorophyll *a* from NASA Earth Observations (NEO., 2106) as possible environmental factors. Following , the principles of parsimony (Borcard et al., 2011), the selection of potentially ecologically-meaningful factors was achieved by considering the probability of the F statistic derived by analysis of variance and requiring that the ratio of the eigenvalue of the first RDA (constrained) axis to that of the first unconstrained axis be greater than one (Juggins, 2013). Consideration was also given to the correlation between the environmental variables.

The study concludes that, in many geographic regions, that temperature is not the principal determinant of radiolarian species diversity, nutrients such as nitrate and phosphate concentrations frequently being the most likely factors. In some instances it could not be demonstrated that any of the WOA13 data explained the diversity. This might result from:

- environmental variable(s) other than those in the WAO3 being at play; and/or
- the region studied being too small for a significant change in potentially explanatory variables or too large so that different variables affect the diversity in different parts of the region.

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Keywords: Radiolaria as proxies; canonical ordination; SST; nutrients; explanatory environmental factors

How to identify *Tetrapyle* and its related taxa for oceanographic studies

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This presentation focuses on the species of the Pylonioidea (Order Spumellaria, Class Polycystina, Infrakingdom Rhizaria) found in Holocene deposits in the northeastern Indian Ocean. Pylonioid radiolarians show high species diversity in surface sediments of the northeastern Indian Ocean. They can be applied as important oceanographic indices in tropical and subtropical oceans, but taxa of this superfamily have been regarded as particularly difficult to identify for a century because of major change in the appearances of specimens in different orientations. Examination of their internal structures for precise identification has been considered, but this method is not realistic for examining thousands pylonioid specimens embedded on microscopic slides. Therefore, we have developed practical methods for pylonioid radiolarian identification under transmitted light microscopy with mounted slides.

We have found that this difficulty can be resolved with clear recognition of a specimen's orientation in terms of absolute or relative Cartesian coordinates and by improving morphological terminology. This procedure begins with confirming the orientations of specimens with respect to the shadow of the central combination. After orientations were determined under both absolute (Type 1) and relative (Type 2) coordinate systems (Figs. 1 and 2), morphological groups were identified based on differences in appearance. All pylonioid species encountered in the surface samples from the northeastern Indian Ocean have been described with consideration given to ontogenetic morphological changes, intra-species variation, and the similarity of specimens to the holotypes of species. The pylonioids were classified into 10 genera and 34 species/subspecies. Of these, three new genera and 20 new species/subspecies were described.

Based on our taxonomic scheme, commonly recorded taxa such as "*Tetrapyle octacantha*", "*Octopyle stenozona*", "*Schizomma quadrilobum*", "*Larcospira quadrangula*", "*Tholospira cervicornis*" and "*Larcopyle buetschlii*" had been mixed with different species. From our taxonomic work, we conclude that (1) true *T. octacantha* are rare in both the Pacific and Indian oceans, (2) true *Tetrapyle stenozona* was not found in the Indian Ocean so far, (3) "*Schizomma quadrilobum*" is a group of juvenile *Tetrapyle* specimens, (4) true specimens of "*Larcopyle quadrangula*" are rarely illustrated, (5) the current usage of "*Tholospira cervicornis*" is different from the topotypic specimens, and (6) "*Larcopyle buetschlii*" from the Sea of Japan is not found in the Indian Ocean. Several Pylonioid species are absent from the Indian Ocean: *Larcopyle dendrophora* (Haeckel) [= *Tholospira* in the original description], *Pylodiscus dodecantha* (Haeckel) [= *Hexapyle*], *Pylonium scutatum* Chen and Tan, *Pylospira octopyle* Haeckel, *Tetrapyle hexagona* (Tan and Chen) [= *Octopyle*], *Pylozonium polyacanthum* Chen and Tan, *Phorticium clevei* (Jørgensen) [= *Tetrapylonium*], *Phorticium polysytle* (Chen) [= *Octopyle*], *Tetrrapylonium pyrum* Tan and Chen, *Tetrapyle roundospinosa* Tan, and *Tetrapylonium strobilinum* Tan and Chen. This finding suggest that identifying pylonioids at the species level have useful applications for oceanographic and paleoceanographic research. This result will be online an article for *Palaeontologia Electronica* (Zhang & Suzuki, in press).

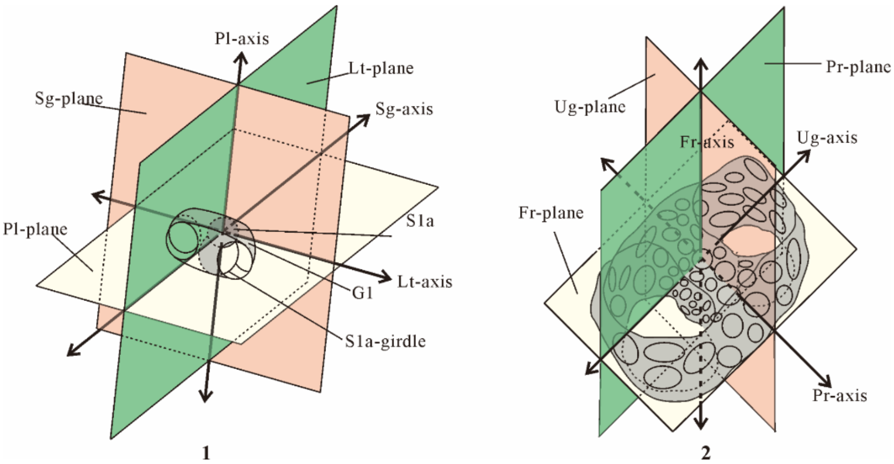

Figure 1. 1.1. Absolute Cartesian coordinates (Type 1). 1.2. Relative Cartesian coordinates (Type 2).

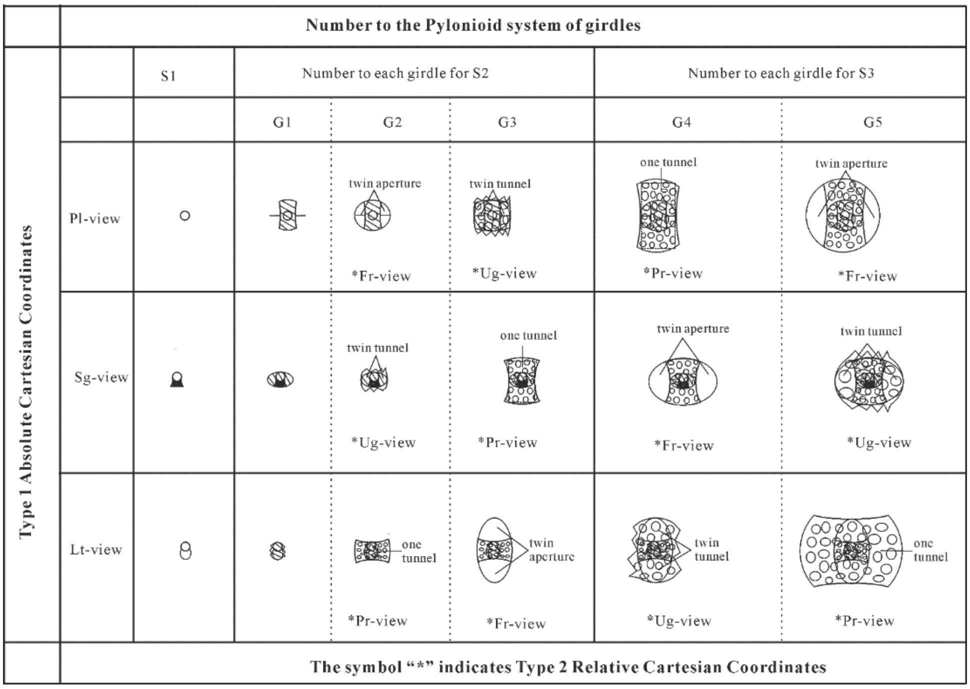

Figure 2. The shape of pylonioids in relation with absolute and relative Cartesian Coordinates

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Keywords: Radiolaria, Pylonioidea, Indian Ocean, Tropical surface sediments, oceanography

Modern shallow water radiolarians with photosynthetic microbiota in the western North Pacific

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To study the photosynthetic associations on modern radiolarians, we analyzed plankton samples from waters shallower than 200 m at 30 stations in the western North Pacific. A total of 328 taxa, including morphotypes, were identified from 2,091 specimens. The fluorescence patterns under a epi-fluorescence microscope were mainly classified into five groups: 1) R&D; 2) R-G; 3) Y-B; 4) Periph-R; and 5) Pale-R. There were 37 species/morphotypes with the R & D pattern in the orders Collodaria, Entactinaria, Nassellaria, and Spumellaria. The R-G and Y-B patterns were confirmed in only four species (*Dictyocoryne profunda*, *D. truncata*, *Spongaster tetras tetras*, *S. tetras irregularis*) of our identified 328 taxa, suggesting a strong species-specific effect on the presence of PE-containing *Synechococcus*-type cyanobacteria. In the Periph-R pattern, red fluorescence is emitted from the peripheral part inside flat spumellarians, suggesting that the source of this pale red fluorescence is photosynthetic organisms digested by radiolarians. In particular, taxa with the R&D pattern can be classified into three groups: 1) obligate associations; 2) facultative association; and 3) non-associations. Many taxa belonging to Acanthodesmiidae and *Lophospyris* have a great number of symbiotic dinoflagellates outside the central capsule. However, Acanthodesmiidae include non-photosynthetic holobionts (*Amphispyris* and *Ceratobotrys borealis*), suggesting different environmental adaptability to some acanthodesmiid species. In contrast with the obligate symbiosis tendency in Acanthodesmiidae, Lophophaenidae tend to have non-photosynthetic holobionts. In Spumellaria, one significant tendency was recognized in *Tetrapyle* and *Phorticium* as obligate dinoflagellate holobionts. Thus, *Tetrapyle* and *Phorticium* are useful for tracing oceanographic conditions in the euphotic zone. *D. truncata* and *D. profunda* are classified into the R-G pattern, whereas *D. muelleri* was grouped into the R&D pattern, indicating that the difference in the photosynthetic association may be closely related to the floating depth. The Q-mode cluster analysis showed that the 30 stations were classified into four clusters: A1, A2, B, and C. The geographical distributions of the four cluster groups are consistent with the climate zone and water masses, suggesting that the species composition of these shallow taxa is influenced by the distribution of water masses. In particular, the Kuroshio Current may play an important role in the migration of shallow living radiolarian species from the subtropical climatic zone to the subarctic climatic zone.

Keywords: Living Radiolaria, fluorescence, latitudinal distribution, water masses, western North Pacific

GENERAL SYMPOSIUM I
SESSION 10

Paleobiogeography

Convener: **Kiyoko KUWAHARA**

26/Oct (Thu), 15:25–16:45

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O10-01	15:25–15:40	Obut, O. & Danelian, T.	New discoveries of Early Cambrian radiolarians from the Gorny Altai (South of western Siberia)
O10-02	15:40–15:55	He, W.H. et al.	Upper Changhsingian Radiolarian fauna of northern Yangtze basin, South China
O10-03	15:55–16:15 (Highlight)	Xiao, Y.F. et al.	New study on vertical water depths of the latest Permian radiolarians by using correspondence analysis
O10-04	16:45–16:30	Yamakita, S. et al.	Early Triassic conodont provincialism and its implication for the paleoceanography of Tethys and Panthalassa
O10-05	16:30–16:45	Munasri & Putra, A.M.	First evidence of Middle to Late Triassic radiolarians in the Garba mountains, South Sumatra, Indonesia

New discoveries of Early Cambrian radiolarians from the Gorny Altai (South of western Siberia)

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New data on the Early Cambrian radiolarians from the central Gorny Altai (Shashkunar Formation) were recovered recently after re-examination of the Ak-Kaya section along the Katun River in the framework of a Russian-French collaboration. The Shashkunar Formation crops out in the Katun zone of Gorny Altai; it is a pelagic sedimentary sequence (siliceous mudstones, cherts and carbonates) deposited above a seamount /ocean island. The Ak-Kaya section is situated in the lower reaches of the Katun River, south of the village Chemal from the top of the Ak-Kaya Gorge down to the river flood plain. First radiolarians as well as diverse siliceous sponge spicules were obtained from siliceous mudstones with the use of dilute hydrofluoric acid (Zybin et al, 2000; Sugai et al., 2004). However, preservation was rather poor and did not allow to observe any internal structures. Three species belonging to 2 genera were described (Obut, Iwata, 2000).

The first results of our new examination confirmed the presence of radiolarians in a 8 m-thick interval of bedded cherts from the upper part of the Shashkunar Formation (Pouille et al., 2011). More importantly, the Botoman trilobites *Calodiscus* and *Serrodiscus* were discovered in a carbonate horizons situated a few tens of meters below the radiolarian-bearing cherts; they allowed to confirm the Botoman age of the mentioned strata (Korovnikov et al., 2013; Sennikov et al., 2017). The radiolarians discussed in this presentation come from two carbonate horizons that delivered trilobites. Radiolarians were revealed from the thin-bedded nodular limestones with intercalations of siliceous mudstones. Microfossils were obtained following application of dilute acetic acid, in which samples were left for several days. In addition to radiolarians various siliceous sponge spicules and SSF *Rhombocorniculum cancellatum* were found. Mentioned SSF species is known from the upper Atdabanian - Lower Botoman interval (=Cambrian stage 3) worldwide (Kouchinsky et al, 2015).

The material obtained is composed of well-preserved specimens (several 10s) that display all characters of the family Archeoentactiniidae (Won and Below, 1999). More specifically, they are characterized by a 6-rayed point-centered internal spicule and a spherical to subspherical shell with an irregular interwoven meshwork. The shell is made of thin, thread-like, delicate elements placed at various angles in such a way to form a complex three-dimensional meshwork. In some specimens, the eccentric position of the central spicule could be observed. Some morphotypes can be clearly assigned to the genus *Archeoentactinia* described by Won and Below (1999) from the Middle Cambrian of Australia. A second morphotype displays numerous arch-shaped fine elements composing the spherical shell. The thin rays of the internal spicule protrude through the shell as the long outer spines. In some specimens more than 6 spines could be observed on the shell wall.

New material was obtained from the siliceous mudstone beds situated in the upper part of the Ak-Kaya section. Those are rather poorly preserved radiolarians with spherical shells that display a fairy thick wall composed of irregularly interwoven threadlike elements. No internal spicule and outer spines are present. The threadlike bars of shell wall are straight and rather thick and short. In some specimens latticed–like shell with angular mesh could be observed. These specimens recall *Parechidnina* Kozur, Mostler and Repetsky, reported also by Won and Below (1999) as *Aitchisonellum* from Middle Cambrian strata.

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Keywords: Cambrian, Botoman, Gorny Altai

Upper Changhsingian Radiolarian fauna of northern Yangtze basin, South China

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Palaeogeographically, the Yangtze Basin was mainly subdivided into a deep-water trough hosting siliceous sediments and a shallow-water carbonate platform during the Permian. Upper Changhsingian (Upper Permian) Radiolarian faunas from Chaohu, Meishan, Rencunping and Hushan sections have been compared in the diversity and taxonomic composition. The Hushan section exposes along the north margin of the northeastern Yangtze Basin, and Chaohu, Meishan and Rencunping sections expose south to the Hushan section (He et al., 2015).

Recently, a number of research reveals that radiolarian diversity, abundance and taxonomic composition mainly vary with water depths (Feng & Ye, 2000; He, 2006; He et al., 2008, 2011), although they could be affected by paleotemperature, palaeosalinity, radiolarian dissolution in water column, ocean upwelling, nutrition and taphonomic factors (Empson-Morin, 1984; De Wever et al., 2001). Most Albaillellaria and Latentifistularian forms occurred in deeper water, commonly in outer shelf to basin and most Entactinarian and Spumellarian forms commonly in shallower water (Xiao et al., in review).

The upper Changhsingian radiolarian fauna includes 24 species in 16 genera at the Hushan section, 15 species in 12 genera at the Chaohu section, 4 species in 3 genera at the Meishan section (He et al., 2015) and 35 species in 20 genera at the Rencunping section (Xiao et al., in review). It can see, therefore, the diversity of upper Changhsingian radiolarian fauna from the Rencunping section is highest among the four sections and that from Hushan takes the second, higher than the diversity from the sections adjacent, south to Hushan.

The Albaillellaria and Latentifistularia forms account for 50% of the fauna in species level in the upper Changhsingian at Hushan section, 30–40% at Chaohu (without Albaillellaria forms), 40% at Meishan, and 41% at Rencunping in taxonomic composition. It can be seen, therefore, the percentage of Albaillellaria and Latentifistularia forms from Hushan is higher than that from the sections south to Hushan. This indicates the water depth was deepening from south to north in the northeastern part of the Yangtze basin during the late Changhsingian, the Eastern Qinling-Dabie deep sea which was located along the northern margin of the northeastern Yangtze Basin, persisted at least until the end of the Palaeozoic, and that the collision between the North China and South China plates had not occurred by the end of the Permian.

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Keywords: Radiolaria, Palaeogeography, Changhsingian, South China.

New study on vertical water depths of the latest Permian radiolarians by using correspondence analysis

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The vertical distribution of radiolarians is one of the important concerns in the field of earth science of the Late Permian. Compared to studies on modern radiolarians that estimate the floating depths based on species level and show no trends to higher taxonomic levels (Matsuzaki et al., 2014; Boltovskoy, 2017; Matsuzaki and Itaki, 2017), reliable depth information in the Permian shows contradicts because of the common usage of shallow Copicyntrinae (subfamily) and deep Albaillellaria (order) (Kuwahara et al., 2005; He et al., 2008, 2011; Noble et al., 2011).

Since previous studies have not applied any objective methods like statistics to determine water depths in radiolarian assemblages, we approached to this contradict issues about vertical water-depth distributions by using a statistic analysis, named correspondence analysis (CA) which has never been used for Permian radiolarian studies so far. CA was applied to multivariate meta-dataset of the Changhsingian Dalong Formation of South China and pelagic deep cherts of Japan since their depositional water depths were well studied with reliable evidences.

CA result indicated that the output Dimension 1 well represents deposition water depths from very shallow (to the positive value) to deep (to the negative value). Following the scores along Dimension 1, the examined nine sections were categorized into five water-depth zones from ‘very shallow’ (Xinmin and Shangsi), ‘shallow’ (Pingdingshan and Hushan), ‘upper intermediate’ (Rencunping), ‘middle intermediate’ (Dongpan), and ‘lower intermediate–pelagic deep’ (Gujo-hachiman, Itsukaichi and Shikoku). This order is roughly agreeable with empirical water-depths with paleontologic and geologic evidence. Based on this water-depth order, 92 species were also categorized into five water-depth zones (14 very shallow water, 18 shallow water, 14 upper intermediate water, 39 middle intermediate water, seven lower intermediate to deep water species). Our data also first statistically proved that Entactinaria and Spumellaria didn’t live in very deep water, and the most Latentifistularia and Albaillellaria species are upper intermediate to deep water species. This result partly supports a usability of water-depth indicators at the taxonomic order level in the Late Permian at least.

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Keywords: Late Permian; Vertical distribution; Correspondence analysis; South China; Japan

Early Triassic conodont provincialism and its implication for the paleoceanography of Tethys and Panthalassa

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As first pointed out by Matsuda (1985), Early Triassic conodonts show provincialism. It is more obvious in taking account the deep sea data rom Japan and New Zealand, originally deposited in central equatorial and southern high-latitudinal Panthalassa, respectively. In Griesbachian, *Hindeodus parvus*, which is the diagnostic species of the base of Triassic, and species deriving from it are common in equatorial Tethys in shallows and central Panthalassa in deeps, while they are rare in Boreal, Peri-Gondowqna Tethys and west coast of Pangea in shallows and southern Panthalassa in deeps. On the other hand, *Neogondolella* is rare in the former province, but common in the latter. In late Dienerian and Snithian, *Neogondolella*, *Scythogondolella*, *Borinella* and *Novispathodus novaeholandiae* group are rare in the former province, but common in the latter. The P_1 element of the former three taxa are segminiplanate (with platform) and that of the latter one is segminate with well-developed mid-lateral rib. On the other hand, taxa with simple segminate (without well-developed mid-lateral rib) P_1 element (e.g. *Neospathodus* and most of *Novispathodus*) are cosmopolitan. Similar provincialism is also recognized in Spathian.

Thus, Genera with elements of segminiplanate or segminate with well developed mid-lateral rib in P_1 position (except for “washboard-type” segminiplanate such as *Eurygnathodus* and *Icriospathodus*) are rare in equatorial Tethys and central Panthalassa in both shallow and deep facies through Early Triassic (Figure 1). Such provincialism is a sharp contrast to the uniform dominance of *Neogondolella* all over the world in Late Permian. The difference between the two provinces does not simply lie on latitudes, because the latter province includes equatorial west coast of Pangea (west US). The deposition of radiolarian cherts was interrupted in Early Triassic in central Panthalassa (Isozaki, 1997), althouth it continued in southern Panthalassa (Spörli et al., 2007). And exceptionally high temperature in Early Triassic is estimated in equatorial Tethys (Sun et al., 2012). We infer that the former province was damaged more severely than the latter in the Early Triassic environmental extreme. We can hypothesize that P_1 elements with platform or well developed mid-lateral rib had less adaptability in poor surroundings.

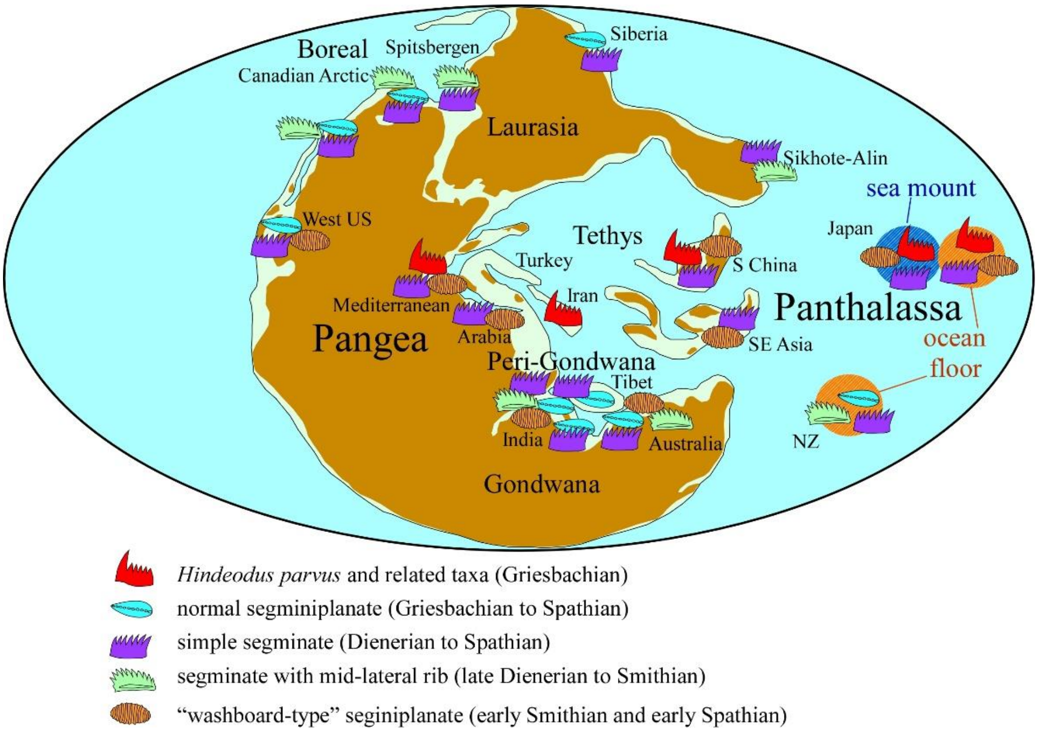

Figure 1. Occurrences of Early Triassic conodonts. Only common occurrences are shown.

The conodont apparatus was a feeding organ. Although functions of each element are not fully clarified, P_1 elements may have played a role in cutting or chewing foods in the final feeding process because of their most caudal position in the apparatus. A wide platform aside, however, a narrow platform or mid-lateral rib is unlikely to participated essentially in such a role, because they might come in little contact with foods. They might be parts to reinforce the blade. Probably, the reason of the less adaptability of platformed or laterally ribbed P_1 elements was a shortage of resources to construct such reinforcing parts. Another disappearance of platformed P_1 elements occurred in Late Triassic (Norian). Rhaetian conodonts have no platformed P_1 elements and finally came to extinction at the end of Triassic. If this hypothesis is valid, we can assume that the environmental deterioration leading to the end-Triassic mass extinction started in Norian.

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Keywords: conodont, provincialism, Tethys, Panthalassa, Boreal, Early Triassic

First evidence of Middle to Late Triassic radiolarians in the Garba mountains, South Sumatra, Indonesia

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Middle to Late Triassic radiolarian fauna was discovered from cherts of the Situlanglang Member of the Late Jurassic – Early Cretaceous Garba Formation. This fauna is characterized by the presence of *Annulotriassocampe sulovensis*, *Triassocampe postdeweveri*, *Spngostylus tortilis*, *Poulpus piabyx*, *Canoptum levis* and others. This evidence may indicate the deposition of the Situlanglang cherts took place simultaneously since after the collision of Sibumasu and East Malaya blocks recorded in the Bentong-Raub Suture in Peninsular Malaysia in Late Permian-Early Triassic times. During the Middle-Late Triassic times in Sumatra and Peninsular Malaysia were formed a submarine horst and graben structures. In Sumatra, a submarine graben: Tuhur basin which its southern boundary was unknown, now it is conceivable that it extended into South Sumatra, to where the Situlanglang cherts were deposited. The Situlanglang Member may be proposed to be a rocks unit stratigraphically contemporaneous with those the Middle-Upper Triassic Kualu and Tuhur formations.

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Keywords**:** Northeastern Gondwana, Sibumasu, Sumatra, Middle-Late Triassic radiolarian cherts.

■ MEMO ■

GENERAL SYMPOSIUM II
SESSION 11

Evolution and Diversity

Convener: **Weihong HE**

27/Oct (Fri), 8:45–9:50

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O11-01	8:45–9:00	Zhang, Y. & Feng, Q.L.	Presence of Radiolarians from Early Terreneuvian in Liuchapo Formation, South China
O11-02	9:00–9:15	Zhang, K. & Feng, Q.L.	Cambrian radiolarians from the Niujiaohe Formation in South China
O11-03	9:15–9:30	Ma, Q.F. et al.	Discovery and significance of radiolarian from lower Qiongzhusinian Stage (Series 2, Stage 3) Shuijingtuo Formation of the Three Gorges area, South China
O11-04	9:30–9:50 (Highlight)	Danelian, T. et al.	Biodiversity patterns of Ordovician and Silurian radiolarians

■ MEMO ■

Presence of Radiolarians from Early Terreneuvian in Liuchapo Formation, South China

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Radiolarians consist an important part of plankton no matter in today or in geological history as early as Palaeozoic. And their characteristic of utilizing silica makes them a significant role in the process of cycling of silica in the oceanic system. Given their importance, the origin and early evolution of radiolarians have been of great interest for a long time. Here we present our findings of a relatively abundant number of radiolarian fossils, along with Small Shelly Fossils from the upper part of Liuchapo Formation in eastern margin of Upper Yangtze Platform. During our study, both HF acid processing and thin sections were made. With occasional thin bedded mudstone, the section is dominated by chert, from which the microfossils are recovered. Based on the comparison of the SSF with previous studies, combined with zircon geochronology, this interval should be assigned to early Terreneuvian. SEM illustration shows that the fossils are spherical shaped and have more than one layer of spheres, featured by small and intensive round pores. Some of the fossils have suspected residual of spines. The diameter of the specimens is from 100-300μm, and most of them fall into the range of 150-200μm. Although better preserved specimens are still to be found in our section for the intention of classification research, they already show the promise of obtaining radiolarians in the beginning of Phanerozoic. Further investigation of the origin of radiolarians and their contribution to early silica cycling is still needed.

Keywords: Radiolarians, Early Cambrian, South China

Cambrian radiolarians from the Niujiaohe Formation in South China

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Early history of radiolarians is still puzzling geologists due to rare fossils and debatable age. The earliest reliable radiolarians are of spicular skeletons from the Middle Cambrian (Won & Below, 1999; Dumitrica et al., 2000). However, specimens reported from the Lower Cambrian in South China (Braun et al., 2005, 2007; Cao et al., 2014; Chang et al., 2015) show different spherical morphology with latticed shells or pores. Herein, in our further inspection into the Lower Cambrian Niujiaohe Formation in Jiangxi province, South China, new radiolarian fossils showing spherical shape have been recovered.

Morphologically, some specimens exhibit spherical bodies with closely distributed valgus pores, each of which is of 5μm in diameter. Besides, one specimen possesses spherical shape and porous shell with slender cylindrical spines stretching out of the pores. The core shell shows latticed structure. Due to the unclear inner structure, they cannot temporarily be assigned to specific genus. Further experiment of Micro-CT will be undertaken.

Based on thin section (e.g. Zheng et al., 2012) and HF acid processing, more and more spherical radiolarians have been recovered from South China. These evidences show that the early history of radiolarians in South China is different from that in Australia. Moreover, radiolarians might be part of the 'Cambrian explosion', along with sponges, they have changed the silica cycle in the ocean system during the Early Cambrian.

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Keywords: Cambrian, South China, Radiolaria, Sponge.

Discovery and significance of radiolarian from lower Qiongzhusinian Stage (Series 2, Stage 3) Shuijingtuo Formation of the Three Gorges area, South China

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Due to a scarcity of records of unambiguous radiolarian occurrences in the Early Cambrian, the origin of radiolarians and their early evolution remain uncertain. Although there have been several reports of identifiable radiolarian from the Cambrian (Braun et al., 2007; Cao et al., 2014), the origin and early history of these fossils is still poorly known. It has been postulated that the Order Archaeospicularia consisting of one or more point-centered spicule(s) represents the oldest radiolarian group. It is postulated that during the Early Paleozoic it gave rise to the orders Entactinaria, Albaillellaria, and probably Spumellaria through a reduction in the number of initial spicules (Dumitrica et al., 2000). However, Braun et al. (2007) and Cao et al. (2014) reported forms with latticed shells, which are not composed of spicules from the Lower Cambrian of South China, raising doubts about the aforementioned hypothesis.

At the 14th Interrad conference in Antalya, Turkey, our group reported Early Cambrian radiolarians from Zigui, South China (Cao & Feng, 2015; Chang & Feng, 2015). However, controversy remains about the scarcity and complexity of the reported radiolarians. In order to obtain more materials and to reduce doubt in discussions regarding the early evolution of radiolarians, we expanded extraction of radiolarians to include samples from the Shuijingtuo Formation in the Jiuqunao (JQN) and Luojiacun (LJC) sections, and repeatedly processed limestone concretions and calcareous mudstone samples.

As a result, well-preserved fossils have been recovered, including radiolarians, trilobite, small shelly fossils (SSF), bradoriid, isoxys, and sponge spicules. Among them, radiolarian fossils that can be ascribed to one new genus Paraantygopora n. gen. and four new species, including Paraantygopora porosa n. sp., Paraantygopora parva n. sp., Tetrasphaera yichangensis n. sp. and Trilonche cambria n. sp. are described herein. Most of the important and characteristic radiolarian families of the Ordovician were present in the lower Qiongzhusinian Stage (Series 2, Stage 3) Shuijingtuo Fromation and played an important role in the origin and Cambrian explosion of animals, which suggests that some Ordovician radiolarians could have originated in the Early Cambrian. The material from the Shuijingtuo Formation important as it enrichs our knowledge of radiolarian taxonomy, morphology and structures and informs discussion of the early evolution of this important group.

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Keywords: Early Cambrian, Shuijingtuo Formation, radiolarians, South China

Biodiversity patterns of Ordovician and Silurian radiolarians

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Documenting long-term patterns of taxic turnover is important to understand the impact of global environmental change in relation to the tempo and mode of macroevolution. Here we present an analysis of the pattern of diversity changes in Ordovician and Silurian radiolarians in relation to known climatic and oceanographic changes during the same time interval. Using a comprehensive database of Ordovician and Silurian radiolarian occurrences, radiolarian standing diversity is explored using various quantitative methods to identify biodiversity and evolutionary trends, and to test these patterns for biases.

A global and exhaustive dataset of Ordovician and Silurian radiolarian occurrences was established from the available literature. This dataset inventoried publications with enough chronostratigraphic information to calibrate radiolarian species occurrences at the stage level. Samples mentioned in the analyzed published studies are either dated by fossils other than radiolarians (e.g. graptolites) or by absolute dating. The age of some samples has been revised or clarified from the original works when subsequent dating has become available. Samples or published studies were excluded from the analysis if the age uncertainty was too large or if most of the specimens were identified to the species level. Also, taxonomic assignments of species were reviewed in the original publications and species names were harmonized to remove nomenclatural artifacts.

The dataset analyzed in this study only contains incidence data (i.e. presence/absence), because abundance data are rarely available or not consistent among radiolarian studies. Species described under open nomenclature (e.g. “sp. A”) or with species level uncertainty (e.g. “cf.”) were counted as distinct taxa. The choice of the analyzed stratigraphic bins was a compromise guided by the resolution required to address our research questions, the available data, and the maximal precision which data can be assigned to a given stratigraphic interval of the Lower Paleozoic.

Biodiversity dynamics through time with incidence data were estimated by multiple approaches, including taxonomic richness indices, changes in richness (origination, extinction), and poly-cohort analysis. The computed analysis was performed by using the scientific environment R (R Core Team 2016) version 3.3.0 and with the package “epaleo” (C. Monnet, 2015, unpublished; for applications using this package, see Nowak et al. 2015).

Several taxonomic richness indices were calculated using incidence data for each class of taxa in and around each stratigraphic interval and normalized. The normalized diversity was calculated as the number of species ranging throughout the interval, plus half the number of taxa that originate and/or become extinct in that stage, plus half of those that are confined to the interval itself. According to Cooper (2004), normalized diversity is a good approximation of the mean standing diversity in a stratigraphic bin.

Indices of origination and extinction represent, respectively, the number of species originating and becoming extinct in a stratigraphic interval. Turnover in an interval is the sum of origination and extinction events, whereas net changes correspond to origination minus extinction. In order to remove bias imposed by the variable duration of the stages used as stratigraphic bins, rates per Myr were computed for all diversity indices.

Poly-cohorts of survivorship were calculated for all stratigraphic bins considered in our study. The slope of the cohort curves represents the rate of extinction or origination for each cohort, with a linear curve (on a logarithmic scale) implying constant rates, while changes over time or between cohorts can reveal changes in rates or biases.

Finally, the possible influence of sampling bias was also evaluated by calculating the Spearman's ρ (rho) and the Kendall's τ (tau) correlations between the computed diversity indices and the number of studies per interval.

Following the Hirnantian (end-Ordovician) mass extinction, the Rhuddanian stage recorded very low levels of diversity, which then increased gradually throughout the Llandovery series and reached a maximum by the Sheinwoodian stage, before decreasing during the Homerian, and finally, rebounded during the Gorstian stage. The early Silurian (Llandovery) appears to be an interval during which few species went extinct, although the number of last occurrences increased progressively to reach a peak in the Ludfordian. At the same time first occurrences progressively decreased and were relatively low during the Silurian. Only the Gorstian is marked by a sudden increase in origination. The early Silurian is an interval of faunal recovery from the end-Ordovician mass extinction event. Similarly, the Gorstian stage is characterized by a recovery following the Homerian low in radiolarian diversity that may be correlated with the *C. lundgreni* extinction event, which affected a number of other pelagic groups (e.g. graptolites, acritarchs, conodonts, and chitinozoans), and with the Mulde event, which coincides with a 4.6‰ positive excursion of the $\delta^{13}C$ curve.

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Keywords: Paleobiodiversity patterns, Ordovician, Silurian

■ MEMO ■

GENERAL SYMPOSIUM II
SESSION 12

Biostratigraphy

Convener: **Marco CHIARI**

27/Oct (Fri), 10:10–11:30

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O12-01	10:10–10:30 (Highlight)	Yamashita, D. et al.	Intercalibrated radiolarian–conodont biostratigraphy and magnetostratigraphy of the Upper Triassic succession, Inuyama area, Japan
O12-02	10:30–10:45	Kuwahara, K. & Sano, H.	Upper Capitanian to lower Wuchiapingian (Permian) latentifistularian interval zones and the phylogeny of their nominal species
O12-03	10:45–11:00	Adachi, M.	*Guexella nudata* coexisted with *Choffatia* (*Subgrossouvria*) sp. of upper Bathonian to lowest Oxfordian age; fossil evidence from Inuyama, Mino terrane of central Japan
O12-04	11:00–11:15	Kukoc, D. et al.	Discovery of the oldest fossils of Panama: Early Cretaceous radiolarians from Miocene conglomerate in the Canal Zone
O12-05	11:15–11:30	Motoyama, I. & Eguchi, N.	Radiolarian biostratigraphy of IODP Exp. 343 drill site C0019, Tohoku-Oki earthquake rupture area

Intercalibrated radiolarian–conodont biostratigraphy and magnetostratigraphy of the Upper Triassic succession, Inuyama area, Japan

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The Late Triassic was characterized by several catastrophic events, such as widespread eruption of flood basalts, ocean acidification, and large extraterrestrial impact. The stratigraphic record of these events has been recently recognized in the Triassic bedded chert successions from the Jurassic accretionary complex in Japan. Because the Upper Triassic cherts in Japan are considered to have been deposited in a pelagic environment within a Paleo–Pacific (Panthalassa) deep basin, their stratigraphic record is particularly important for understanding the impact of global catastrophic events in the Late Triassic. Nevertheless, this process has been hampered by the poor age control for the cherts. The ages of the Triassic bedded cherts were predominantly determined from the radiolarian biostratigraphy, based on an indirect correlation with the ages determined from European and North American radiolarian biostratigraphies. However, the accurate calibration of chronostratigraphic stages and substages has been developed using ammonite and conodont biostratigraphies and magnetostratigraphy. In order to calibrate the Upper Triassic radiolarian zonation with the standard Triassic timescale, the conodont biostratigraphic and magnetostratigraphic studies are required in the pelagic chert successions in Japan. This study undertook to establish the conodont biozones and magnetostratigraphy in exactly the same sections that Sugiyama in 1997 used as the type sections for his radiolarian biozones. The stratigraphic intervals from the Carnian to the Rhaetian (Upper Triassic) in his sections H, N, Q and R in the Inuyama area, central Japan were examined.

This study described in detail the conodont zonation and some important conodonts including 29 species referred to 11 genera from the study sections. Based on recent conodont taxonomy and the stratigraphic distribution of marker species, eight conodont zones were defined: *Paragondolella*? *tadpole* interval Zone, *Quadralella tuvalica* interval Zone, *Epigondolella quadrata* interval Zone, *Epigondolella triangularis* interval Zone, *Mockina postera* interval Zone, *Mockina bidentata* interval Zone, *Misikella hernsteini* interval Zone, and *Misikella posthernsteini* interval Zone. These were correlated with the coeval radiolarian zonation established by Sugiyama in 1997, and comparable to that in British Columbia, the Pizzo Mondello section, the Steinbergkogel section, and other sections in southwest Japan. The Carnian–Norian boundary interval in the sections studied is tentatively placed between the last occurrence of Carnian species (*Q. tuvalica*) and the first occurrence of Norian species (*E. quadrata* and *E. spatulata*) because of the absence of *Metapolygnathus parvus* and other diminutive elements reported from the GSSP candidate sections for the Carnian–Norian boundary.

Magnetostratigraphic results delineate 20 substantive normal and reverse magnetozones, defined by measurement of 357 samples from the Upper Triassic chert sections. Although the magnetostratigraphic data in the vicinity of the early-late

Carnian boundary is the first record from the marine section, the magnetostratigraphy of samples in Carnian-Rhaetian interval was well correlatable with that of Tethyan marine sections (e.g, Pizzo Mondello and Silická Brezová sections). This correlation implies that the bedded chert of Inuyama area was deposited in the Northern Hemisphere, assuming that the rocks in the Tethyan marine sections were deposited in the Northern Hemisphere.

The intercalibrated radiolarian–conodont biostratigraphy and magnetostratigraphy from the studied sections accurately calibrates the radiolarian zones in Japan with standard chronostratigraphic stages and substages. By means of magnetostratigraphic correlation to the Newark astrochronological polarity time scale (APTS, Olsen et al., 2010), a new age model of sedimentation for the Upper Triassic bedded chert successions in the Inuyama area was obtained. This correlation places the Carnian/Norian boundary in the sections studied, at the top of reverse chron E7 in the Newark APTS (~227 Ma), and the Norian/Rhaetian boundary can be placed within Chron E20r (205-206 Ma). These ages contrast with the age constraints provided by the cyclostratigraphic data of the Triassic bedded chert successions in the Inuyama area (Ikeda & Tada, 2014).

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Keywords: bedded chert, biostratigraphy, magnetostratigraphy, Upper Triassic

Upper Capitanian to lower Wuchiapingian (Permian) latentifistularian interval zones and the phylogeny of their nominal species

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We present Latentifistularia-based biostratigraphy in the upper Capitanian to lower Wuchiapingian (Permian) successions of bedded chert of the Mino Belt in the Mt. Funabuseyama and Itadori areas, central Japan, and discuss the phylogeny of selected latentifistularian species. The examined rocks are interpreted as deep-marine sediment on the lower flank of a seamount in the mid-Panthalassic region.

We established six interval zones based on the first appearance datum of the latentifistularian species in the Mt. Funabuseyama area. They are the *Foremanhelena triangula*, *Ruzhencevispongus* sp. B, *Ruzhencevispongus* sp. C, *Triplanospongos angustus*, *Cauletella paradoxa*, and *Triplanospongos musashiensis* interval zones in ascending order (Kuwahara and Sano, in press). We correlate the *F. triangula*, *R.* sp. B, *R.* sp. C, and *T. angustus* interval zones and the *C. paradoxa* and *T. musashiensis* interval zones with the *Follicucullus charveti-Albaillella yamakitai* and *Neoalbaillella ornithoformis* assemblage zones in Japan, respectively. In the Gujo-hachiman section of the Itadori area, we confirmed the similar latentifistularian succession to that in the Mt. Funabuseyama area. Our results show that the latentifistularians play a significant role for the biostratigraphic zonation of the upper Capitanian to lower Wuchiapingian stages, in which the albaillellarians are much less abundant and diverse.

One of the nominal species, *R.* sp. B, has a small, platy, and inflated test with three arms. Its central part is remarkably inflated. The three arms of *R.* sp. B are short and slightly knobby in their distal ends. Another nominal species, *R.* sp. C is characterized by a platy, robust and large, triangular-shaped test with an inflated central part. Its three arms are long and thick with rounded ends. *R.* sp. B appears earlier than *R.* sp. C, and these species successively show the marked acmes. Therefore, *R.* sp. C is thought to be a phylogenetic descendant of *R.* sp. B. *T. musashiensis* and *T. angustus* are thought to be also phylogenetically related to each other on the basis of the stratigraphic ranges and morphological similarity. We consider that *T. musashiensis* is the descendant species of *T. angustus*.

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Keywords: Permian, Latentifistularia, interval zones, chert, Japan

■ MEMO ■

Guexella nudata coexisted with *Choffatia* (*Subgrossouvria*) sp. of upper Bathonian to lowest Oxfordian age; fossil evidence from Inuyama, Mino terrane of central Japan

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Sedimentary rocks of the Inuyama area in the Mino terrane have provided key evidence for the Mesozoic geology of Japan. One such is a Jurassic ammonite identified as *Choffatia* (*Subgrossouvria*) sp. (Sato, 1974). The ammonite was found in 1951 as a float from siltstone beds then regarded as Paleozoic strata. Few geologists believed that Jurassic formations existed in that area until the discovery of middle-late Mesozoic conifer fragments of *Taxaceoxyon* sp. and *Cupressinoxylon* sp. from nearly the same horizon as the ammonite locality (Nishida et al., 1974, Kondo & Adachi, 1975). The discovery of the Mesozoic plant fossils encouraged geologists to carry out an extensive radiolarian study in the Mino terrane. The sedimentary rocks of the ammonite locality can now be assigned to belong to the *Guexella nudata* Assemblage-zone (Matsuoka et al., 1994) or the *Tricolocapsa conexa* zone (JR5: Matsuoka, 1995) of middle Jurassic age.

The first detailed geological map of the entire Inuyama area (Kondo & Adachi, 1975) provided a base map for subsequent studies in this area (e.g. Adachi, 1976; 1986; 1988; Adachi et al., 1992; Mizutani et al., 1981; Shibata & Mizutani, 1982; Yoshida & Wakita, 1999). Another important pioneer work from this area was the SEM study of radiolarian fossils in manganese carbonate nodules by Yao (1972), followed by Yao (1979, 1982), Matsuoka et al. (1994), etc.

Re-examination of the host siltstone of the *Choffatia* (*Subgrossouvria*) sp. specimen housed at the Nagoya University Museum has revealed the occurrence of middle Jurassic radiolarians exclusively of *Guexella nudata*. This is the first demonstration of the coexistence of radiolarians with a middle Jurassic ammonite. It is noteworthy that *Tricolocapsa conexa*, *Tricolocapsa tetragona*, *Protunuma turbo, Dictyomitrella (?) kamoensis*, etc., which are common in the *Guexella nudata* Assemblage (Matsuoka et al., 1994), have not been found in the *Choffatia* siltstone.

In addition to the radiolarians of the *Guexella nudata* Assemblage, Adachi (1982, 1988) noted the occurrence of radiolarians of the *Mirifusus baileyi* Assemblage (Mizutani, 1981) and those of the *Stylocapsa (?) spiralis* zone (Matsuoka, 1995) in siliceous shales about 4km southeast and 1.5km north of the ammonite locality, respectively. Using the fossil evidence, coupled with the petrological characteristics of the radiolarian-bearing rocks in the Inuyama area, the stratigraphic horizon of *Choffatia* and *Guexella nudata* will be discussed, as well as the relationship between the Kamiaso, Nabi, and Kanayama units of the Mino terrane (Wakita, 1987; Adachi et al., 1992).

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Keywords: Inuyama, Mino terrane, Middle Jurassic, *Guexella nudata*, *Choffatia* (*Subgrossouvria*) sp.

Discovery of the oldest fossils of Panama: Early Cretaceous radiolarians from Miocene conglomerate in the Canal Zone

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Here we present the first report of Panama's, so far, oldest fossils: Early Cretaceous (late Hauterivian - Barremian) radiolarians recovered by HF- treatment form chert granules-pebbles collected by D.B. and R.M. in a Miocene fluvial conglomerate recently excavated for the enlargement of the Panama Canal (Fig. 1).

Panama's oldest fossils were previously reported from radiolarites interbedded with oceanic plateau lavas in the Azuero Complex, W Panama (Kolarsky et al. 1995, references in Buchs et al. 2010). They revealed a Coniacian-Santonian radiolarian assemblage very similar to that recovered in oceanic plateau sequences from the youngest part of the Nicoya Complex, N Costa Rica (Bandini et al. 2008, Baumgartner et al. 2008). These radiolarian assemblages are also possibly similar to that reported in E Panama (Bandy & Casey 1973), where preliminary results from on-going regional work (GRIP, https://panamageology.wordpress.com/) also suggest their association with plateau lavas. Most of the Upper Cretaceous oceanic plateau sequences in the region are likely part of the Caribbean Large Igneous Province (CLIP) that extends over most of the Caribbean Plate (Fig. 1 inset). Other Cretaceous fossils in Panama include foraminifers in upper Campanian pelagic limestones that locally unconformably overlie Coniacian-Santonian oceanic plateau sequences, and are thought to represent a regional stratigraphic marker associated with the initiation of the Panama volcanic arc on top of the SW margin of the CLIP (Buchs et al. 2010, Barat et al. 2014).

The finding of Early Cretaceous radiolarians in chert clasts reworked into a Miocene conglomerate in the Canal Zone is a significant result that reveals existence of an older (pre-CLIP) oceanic basement in the Panama Isthmus. The clasts yielded poorly preserved but diverse radiolarians. Co-occurrences of *Pantanellium* sp. aff *P. cantuchapai* Pessagno & MacLeod *sensu* Baumgartner et al. (1995) and *Stylospongia* (?) *titirez* Jud give the shortest age assignment from late Hauterivian to early Barremian (UAZ95 20-21). *Squinabollum simplex* (Taketani) also has its first appearance in UAZ95 20, however, this assignment is tentative in view of corroded specimens. A somewhat broader age can be assigned by the first occurrence of *Cyclastrum planum* Jud in early Hauterivian (UAZ95 19) and disappearance of representatives of *Spinosicapsa* in early Aptian.

In Central America such assemblages are only known from Middle Jurassic to Lower Cretaceous radiolarites in the Santa Rosa Accretionary Complex, N Costa Rica (Bandini et al. 2011), and those magmatically reworked in the Nicoya Complex (Denyer & Baumgartner 2006). These occurrences, including the one reported here, suggest that Early Cretaceous and older, far-travelled plateau fragments out of Panthalassa, accreted along, or form the basement of, the CLIP. Provenance constraints from the Canal conglomerate favors occurrence of an older plateau at the base of the CLIP and the Panama Isthmus, which remains to be found in situ in central Panama.

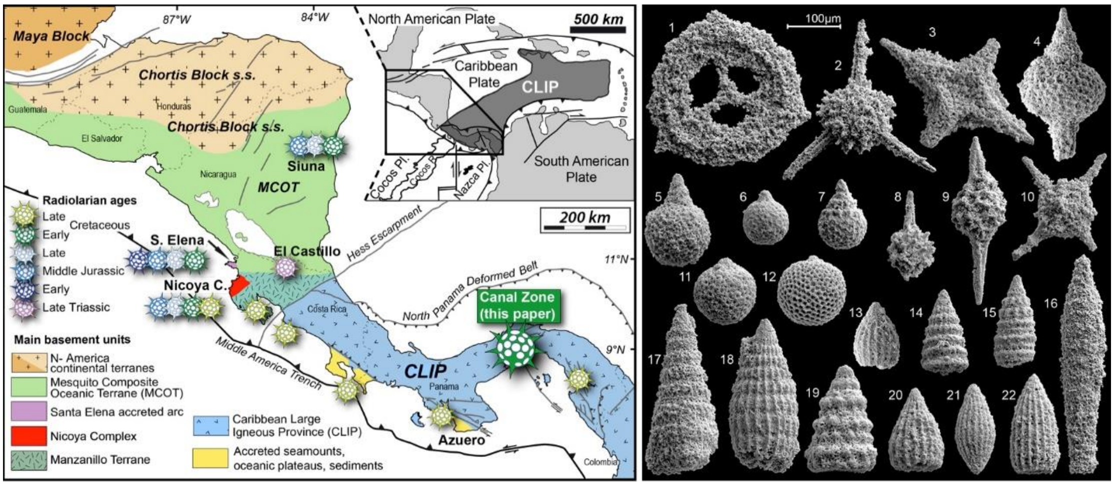

Figure 1. Late Hauterrivian – Barremian radiolarians from the Panama Canal Zone. 1) *Cyclastrum planum* (Jud), 2) *Becus helenae* (Schaaf), 3) *Crucella cachensis* Pessagno, 4) *Spinosicapsa typica* (Rüst), 5) *Squinabollum* sp. cf. *S. simplex* (Taketani), 6) *Gongylothorax* sp., 7) *Hiscocapsa uterculus* (Parona), 8) *Pantanellium* sp. aff. *P. cantuchapai* Pessagno & MacLeod *sensu* Baumgartner et al. (1995), 9) *Pantanellium squinaboli* (Tan), 10) *Stylospongia* (?) *titirez* Jud, 11) *Cryptamphorella conara* (Foreman), 12) *Cryptamphorella* sp., 13) *Thanarla brouweri* (Tan), 14) *Svinitzium puga* (Schaaf), 15) *Pseudodictyomitra lilyae* (Tan), 16) *Pseudoeucyrtis* sp., 17) *Crolanium* sp. cf. *C. cuneatum* (Smirnova & Aliev), 18) *Dictyomitra pseudoscalaris* (Tan), 19) *Xitus clava* (Parona), 20) *Thanarla conica* (Aliev), 21) *Archaeodictyomitra lacrimula* (Foreman), 22) *Archaeodictyomitra vulgaris* (Pessagno)

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Keywords: Lower Cretaceous radiolarite, Miocene, Panama Canal, Panama Isthmus

Radiolarian biostratigraphy of IODP Exp. 343 drill site C0019, Tohoku-Oki earthquake rupture area

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The March 2011 Mw 9.0 Tohoku-Oki earthquake is one of the strongest earthquakes in the world to strike the northeastern Japan, being accompanied by the huge tsunami that devastated its coastal area. The Japan Trench Fast Drilling Project (Integrated Ocean Drilling Program Expedition 343 and 343T in April to July 2012) performed an operation of in situ measurements of physical property using logging and temperature sensors and taking fault material to understand the physical mechanisms and dynamics of the large slip (~50 m) earthquake (Chester et al., 2013; Ujiie et al., 2013; Fulton et al., 2013). A coring hole, C0019E, was drilled to 844.5 meters below seafloor (mbsf) to recovered 21 cores that include highly sheared clay with scaly fabric at ~820 mbsf. This sheared zone has been interpreted as fault material at the plate boundary décollement. Cored rocks consist of clayey to silty mudstones above this level and pelagic sediments below. After the cruise cored material was distributed to onshore laboratories to investigate biostratigraphy. We have analyzed samples from core 1R to 20R for radiolarian biostratigraphy. The results are followings:

1R-CC (~180 mbsf), *Dictyophimus bullatus* Zone (4.4–4.3 Ma).
2R-CC, 3R-CC (~650 mbsf), lower part of the *Lychnocanoma magnacornuta* Zone (11.8–10.1 Ma).
4R-CC–14R-CC (~690–~810 mbsf), Quaternary; *Stylatractus universus* Zone–*Botryostrobus aquilonaris* Zone (1.03–0 Ma).
15R-CC (~820 mbsf), lower part of the *Cycladophora sakaii* Zone (4.3–2.6 Ma).
16R-CC (~820 mbsf), Quaternary.
17R-01 (~820 mbsf), lower part of the *L. magnacornuta* Zone (11.8–10.1 Ma).
17R-01 (scaly clay, ~820 mbsf), barren.
18R-CC–20R-02 (~820–~830 mbsf), *L. magnacornuta* Zone (11.8–9.4 Ma).
20R-02 (~830 mbsf), Cretaceous.

These results suggest that there are two large stratigraphic gaps at ~830 mbsf between the Cretaceous chert and the upper Miocene pelagic clay and at ~820 mbsf between the upper Miocene and the Quaternary. The former likely represents a hiatus just above the incoming Pacific Plate and the latter corresponds to the plate boundary fault. The repetition of radiolarian assemblages across the upper portion could record slumping, faulting, and folding, indicating structural complexity in the frontal prism of the subduction zone.

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Keywords: Radiolaria, Tohoku-Oki earthquake, prism, Miocene, deep-sea drilling

GENERAL SYMPOSIUM II
SESSION 13

Tibetan Tectonics

Convener: **Taniel DANELIAN**

27/Oct (Fri), 13:00–14:20

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O13-01	13:00–13:20 (Highlight)	Luo, H. & Liu, S.J.	New discovery of Paleogene Radiolarians from the Yamdrok mélange near Yongla Pass of Gyantse, Southern Tibet and its geological significance
O13-02	13:20–13:35	Liu, S.J. et al.	Lower Cretaceous radiolarian fauna from Zouxue, Zedong, southern Tibet, China and its geological significance
O13-03	13:35–13:50	Li, X. et al.	Radiolarian-based oceanic plate stratigraphy of the melanges and subduction-accretion processes in the western sector of the Yarlung–Tsangpo suture zone, southern Tibet
O13-04	13:50–14:05	Xu, B. et al.	New discovery of Early Jurassic radiolarians from Luoqu, Xigaze, southern Tibet and its geological significance
O13-05	14:05–14:20	Chen, D.S. et al.	Discovery of the oldest (late Anisian) radiolarian assemblage from the Yarlung-Tsangpo Suture Zone in the Jinlu area, Zetang, southern Tibet: indication of the origin of the Neotethys Ocean

New discovery of Paleogene Radiolarians from the Yamdrok mélange near Yongla Pass of Gyantse, Southern Tibet and its geological significance

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A moderately well-preserved radiolarian fauna was extracted from a thin bedded siliceous mudstone sample collected from the matrix of the Yamdrok mélange near Yongla pass, Gyangze, southern Tibet. Up to now, more than 9 genera 12 species are recognized, including *Petalospyris faveolata* (Ehrenberg), *Buryella pentadica* Foreman, *B. tetradica* Foreman, *Buryella helenae* O'Connor, *Dorcadospyris* aff. *confluens* (Ehrenberg), *Amphisphaera macrosphaera* (Nishimura), *Amphisphaera goruna* (Sanfilippo and Riedel), *Stylosphaera minor* Clark and Campbel, *Theocotyle fimbria* Foreman, *Bekoma divaricate* Foreman, *Lithocyclia ocellus* Eherenberg group and *Pterocyrtidium sinense* Li et Matsuoka etc. This radiolarian assemblage is characterized by the co-occurrence of *Bekoma divaricate*, *Buryella pentadica* and *B. tetradica* and is correspond to the RP7 *Bekoma campechensis*-*Bekoma bidartensis* interval zone (Hollis, 1997, 2002) which indicated latest Paleocene-Early Eocene in age. It is similar to the assemblage described by Liu and Jonathan (2002) from Rilang (several kilometers south to Yongla Pass) but differ primarily by containing some species of the genera *Buryella*. These radiolarians may be the youngest fossils known from the mélange and re-confirm the existence of the abyssal sediment of Upper-most Paleocene (or even early Eocene). They provide a new age control on the formation time of the Yamdrok mélange, which developed during collision of the India plate and Asian plate along the Yarlung-Zangbo suture zone in southern Tibet.

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Keywords: Radiolarian, Paleogene, Yamdrok mélange, southern Tibet

Lower Cretaceous radiolarian fauna from Zouxue, Zedong, southern Tibet, China and its geological significance

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Abundant well-preserved radiolarians were extracted from 21 samples collected from a sequence of dark grey cherts which are closed to the ophiolitic rocks within the eastern Yarlung-Tsangbo Suture Zone, near Zouxue Ferry, Zedong Town, southern Tibet, China. Thirty radiolarian species belonging 27 genera have been recognized. They are characterized by the dominant *Archaeospongoprunum patricki* Jud, *Holocryptocanium barbui* Dumitrica and *Tricapsula costata* Wu. Some *Becus gemmatus* Wu, *Hiscocapsa grutterinki* (Tan), *Suna hybum* (Foreman) and *Tetrapaurinella staurus* Dumitrica, which are mainly ranged in lower Cretaceous, are also occurred in this fauna. This fauna is largely similarity with that found in Congdu Formation in Xigaza area, southern Tibet (Wu, 1986; Ziabrev et al., 2003), and it can also be compared with that in west Tethys (O'Dogherty, 1994) and Oman (Dumitrica et al., 1997). Preliminary results indicate the age of these radiolarian chert of Zouxue section may be from Hauterivian to Aptian.

Ten radiolarian chert samples from this section were selected to test geochemical elements used by ICP-OES and ICP-MS. They are characterized by a high ratio (0.58±0.13) for Al/ (Al+Fe+Mn) and a low ratio (0.21±0.17) for total MnO/TiO_2.These results indicate that all cherts were not formed in hydrothermal but biogenic environment purely (Adachi et al., 1986; Yamamoto, 1987). REE data show that the value of Ce/Ce^* (0.96±0.09) and La_N/Ce_N (0.90±0.13) fit perfectly the criteria (Murray et al., 1990; Murray, 1994), which infers that these cherts may be deposited near continental margin. The characteristics of radiolarian fauna and geochemical analyses reveal that the depositional environment of chert sequences of Zouxue section are probably similarity with Congdu Formation in Xigaze area, which seems to be the sedimentary environment of a trench closed to continental margin.

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Keywords: Radiolarian; Lower Cretaceous; Yarlung-Tsangbo Suture Zone; Southern Tibet; Geochemistry

Radiolarian-based oceanic plate stratigraphy of the melanges and subduction-accretion processes in the western sector of the Yarlung–Tsangpo suture zone, southern Tibet

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The Yarlung–Tsangbo Suture Zone (YTSZ), as the southernmost and the youngest amongst the sutures which subdivide the Tibetan Plateau into several east–west trending blocks, marks where the Neo-Tethys was consumed as the Indian continent approached northward and collided with the Eurasian continent. Melanges represent the oceanic remnants from the oceanic plate through subduction and collision (Allègre et al., 1984; Hébert et al., 2012). Analyses of melanges from the YTSZ can clarify the reconstructed oceanic plate stratigraphy and the subduction-accretion processes (Li et al., 2013; Li et al., 2016).

The melanges in our research area are divided into two units, the Northern unit and the Southern unit. The Northern unit (the Erba melange) is characterized by highly sheared volcanoclastic or siliceous mudstone matrix including blocks of chert, claystone, and basalt. Broken formations of tens-meters are observable in this melange. The Southern unit (the Maquanhe melange) is characterized by the broken formation. The Southern unit is located north to the Indian passive margin deep marine sediments.

In the Erba melange, radiolarian assemblages from the highly sheared siliceous mudstone matrix of this melange are comparable with the *Aurisaturnalis carinatus* (KR3) zone, the *Turbocapsula costata* Zone and the *Spoletoensis* Zone, Aptian to Albian in age. Radiolarian assemblages from the chert blocks are comparable with the *Trillus elkhornensis* (JR2) Zone, the *Loopus primitivus* (JR8) zone, the *Pseudodictyomitra carpatica* (KR1) zone, and the *Cecrops septemporatus* (KR2) zone, Pliensbachian–Toarcian and Tithonian–Barremian in age.

The Maquanhe melange is located south of the Erba melange. They are connected by faults. It consists of siliceous mudstone, chert, basalt, and limestone. This melange does not display the typical blocks-in-matrix fabric. Strata are grossly continuous. Radiolarian assemblages from the chert of the Maquanhe melange are comparable with the *Spoletoensis* Zone, late Albian in age.

Ocean Plate Stratigraphy (OPS) is reconstructed based on the melanges mentioned above. The Northern unit is composed of the Early Jurassic to the Early Cretaceous chert followed by the mid-Cretaceous siliceous mudstone. The Southern unit is composed of the mid-Cretaceous chert, limestone and siliceous mudstone. The siliceous mudstone becomes dominant in the Southern unit which stands for sediments accumulated in close proximity to the northernmost edge of Indian continent. The presence of limestone interbedded with chert in the Southern unit indicates sedimentation above or near the calcium carbonate compensation depth (CCD). The age of siliceous mudstone of the OPS becomes younger toward the south. This polarity distribution indicates that the oceanic plate subducted northward under the Lhasa terrane during the Cretaceous.

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Keywords: Yarlung–Tsangbo Suture Zone, Melange, Ocean Plate Stratigraphy, subduction-accretion process

New discovery of Early Jurassic radiolarians from Luoqu, Xigaze, southern Tibet and its geological significance

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There is a well exposed sequence of purple red radiolarian chert in Luoqu Section, about 30 km south of Xigaze, which is the westward extension of the Xialu Chert (Wu, 1993; Matsuoka et al., 2001, 2002). These cherts are faulted against the overlying ultramafic rocks to the north and were assigned to Bainang terrane within Yarlung Tsangpo suture zone by Aitchison et al. (2000) and Ziabrev et al., (2004).

Moderately preserved Tethyan affinity radiolarian fossils were extracted from one of 72 chert samples from the Luoqu Section. Ninety-three species belonging to 35 genera, predominantly composed of nassellarians, including *Ares mexicoensis*, *Canoptum dixoni*, *Canutus* sp. O, *Eucyrtidiellum nagaiae*, *Helvetocapsa minoensis*, *Helvetocapsa plicata semiplicata*, *Lantus praeobesus*, *Pantanellium inornatum*, *Praeconocaryomma whiteavesi*, *Xiphostylus simplus* and so on were recognized. Most of them are documented for the first time in Tibet. This radiolarian assemblage can well be compared with that found in Oman, Japan, Oregon and Queen Charlotte Islands and can be assigned to the late Pliensbachian *Eucyrtidiellum nagaiae-Praeparvicingula tlellensis* zone of Carter et al. (2010), which infers that the pelagic deposits of Neotethys in Xigaze area at least had begun from late Pliensbachian, much earlier than previously considered (Matsuoka et al., 2001, 2002).

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Keywords: Radiolarian; Early Jurassic; late Pliensbachian; Luoqu section; Yarlung Tsangpo suture zone; southern Tibet

Discovery of the oldest (late Anisian) radiolarian assemblage from the Yarlung-Tsangpo Suture Zone in the Jinlu area, Zetang, southern Tibet: indication of the origin of the Neotethys Ocean

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Abundant, moderately well-preserved Middle-Upper Triassic radiolarian fossils have been obtained from versicolor bedded-cherts outcropped on the Buruocang section near Jinlu village, Zetang, Southern Tibet. These radiolarian-bearing rocks should be some fragmented remnants of the Neotethys Ocean sediment belonging to the mélange complex of the east part of the Yarlung-Tsangpo Suture Zone.

Preliminary result reveals that one grey chert sample (No.14xzbrc-11) from Buruocang section contains *Triassistephanidium laticornis, Triassistephanidium anisicum, Tiborella magnidentata, Baumgartneria retrospina, Baumgartneria bifurcate, Falcispongus* sp. and *Oertlispongus* sp. ect. This radiolarian assemblage indicates a late Anisian in age compared with the radiolarian faunas of Europe (Kozur & Mostler 1994, 1996; Kozur, 2003), Japan (Sugiyama, 1997) and Turkey (Tekin et al., 2016). Up to now, it is the oldest radiolarian assemblage obtained from bedded chert all along the Yarlung-Tsangpo Suture Zone and possibly infers the opening time of the Neotethys Ocean in southern Tibet.

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Tekin U.K., Yavuz Bedi, Cengiz Okuyucu, M. Cemal G€oncüoglu, Kaan Sayit. 2016. Radiolarian biochronology of upper Anisian to upper Ladinian (Middle Triassic) blocks and tectonic slices of volcano-sedimentary successions in the Mersin Melange, southern Turkey: New insights for the evolution of Neotethys. Journal of African Earth Sciences 124 (2016) 409-426.

Keywords: radiolarians, late Anisian, Yarlung-Tsangpo Suture Zone, Neotethys Ocean

■ MEMO ■

GENERAL SYMPOSIUM II
SESSION 14

European Tectonics

Convener: Hui LUO

27/Oct (Fri), 14:40–16:00

Lecture Room of TOKIMATE, Eki-nan Campus, Niigata Univ.

O14-01	14:40–15:00 (Highlight)	Chiari, M. et al.	Radiolarian biostratigraphy and geochemistry of the ophiolites from the Coloured Mélange Complex (North Makran, SE Iran)
O14-02	15:00–15:15	Tekin, U.K. et al.	New evidence of Middle Triassic (late Anisian to late Ladinian) radiolarians from blocks of pelagic volcano-sedimentary successions in the Mersin Mélange, southern Turkey: Implications for the evolution of Neotethyan Izmir-Ankara-Ocean
O14-03	15:15–15:30	Cifer, T. et al.	Pliensbachian (Early Jurassic) radiolarians from Mt. Rettenstein, Northern Calcareous Alps, Austria
O14-04	15:30–15:45	Bertinelli, A. et al.	Middle Triassic radiolarian assemblages from the Monte Facito Formation (Lagonegro succession, Southern Apennines, Italy)
O14-05	15:45–16:00	Goričan, Š. et al.	Jurassic and Cretaceous radiolarian biostratigraphy of the Al Aridh Group (Hawasina Nappes, Oman Mountains)

■ MEMO ■

Radiolarian biostratigraphy and geochemistry of the ophiolites from the Coloured Mélange Complex (North Makran, SE Iran)

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The Coloured Mélange Complex is part of the North Makran domain (SE Iran) and consists of volcanic rocks, locally stratigraphically associated with radiolarian cherts. In this paper, we present new biochronological data on cherts and geochemical data on the associated volcanic rocks. These data indicate the occurrence of a wide range of volcanic rocks-types, which are: 1) normal type mid-ocean ridge basalts (N-MORB); 2) oceanic plateau basalts (OPB); 3) alkaline basalts; 4) calc-alkaline basalts, basaltic andesites, andesites, and dacites; 5) volcanic arc tholeiitic basalts and dacites, and metabasalts.

The age of the volcanic arc tholeiites range from late Hauterivian-early Aptian for the presence of *Pantanellium masirahense* Dumitrica with *Orbiculiformella titirez* (Jud) (Gorevi 2 section, sample MK145) to latest Cenomanian-lower late Campanian for the presence of *Acanthocircus hueyi* (Pessagno) (Gorevi 1 section, sample MK152).

The age of calc-alkaline rocks is early Coniacian-Santonian for the presence of *Theocampe* (?) *urna* (Foreman) with *Crucella cachensis* Pessagno (Gorevi 3 section, sample MK146) while the age of OPBs is early Turonian-early Campanian for the presence of *Afens liriodes* Riedel and Sanfilippo with *Archaeospongoprunum bipartitum* Pessagno (Kahmij-e-Balo section, sample MK63).

Alkaline basalts, OPBs, and NMORBs represent remnants of the Mesozoic Neo-Tethys oceanic branch located between the Arabian plate and the Lut block. In this work we document that this oceanic sector was characterized by the development of an oceanic plateau in the Late Cretaceous. In contrast, calc-alkaline and volcanic arc tholeiitic rocks represent remnants of a continental volcanic arc and forearc, respectively, developed onto the southernmost realm of the Lut block.

Keywords: Ophiolite, radiolarian biostratigraphy, geochemistry, mélange, Cretaceous, Makran, Iran.

New evidence of Middle Triassic (late Anisian to late Ladinian) radiolarians from blocks of pelagic volcano-sedimentary successions in the Mersin Mélange, southern Turkey: Implications for the evolution of Neotethyan Izmir-Ankara-Ocean

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The Mersin Mélange (MM) as a part of the Mersin Ophiolitic Complex is a sedimentary complex including blocks and tectonic slices of oceanic litosphere and continental crust of various sizes. MM is mainly located to the north and northwest of city of Mersin in southern Turkey. Based on studies on four stratigraphic sections (the Cakalkayrak, the Aliclipinar-Southwest, the Sorgun-South and the Kocatepe-South) from either blocks or tectonic slices in MM reveals the presence of successions composing of thick basaltic pillow-and massive lava alternating with pelagic-clastic sediments and radiolarian cherts.

Oldest radiolarian fauna corresponds to *Spongosilicarmiger transitus* zone of late Anisian age have been obtained from the Cakalkayrak section very close to contact with underlying basic volcanic. Higher in sequences of late Anisian age, radiolarian assemblages corresponding to *Spongosilicarmiger italicus* zone of late Anisian age have also been determined from alternation of chert and mudstone in the Cakalkayrak, the Aliclipinar-Southwest and the Sorgun-South sections. Considering the presence of sandstone layers over alternation of chert and mudstone in the Aliclipinar-Southwest section, it is suggested that latest Anisian was the beginning period of sandstone accumulation. Wide-spread sandstone sedimentation lasted at middle Early Ladinian taking into the consideration of sandstone layers at the base of the Kocatepe-South section. Lower and middle part of the Kocatepe-South section is represented by green chert-mudstone alternation corresponding to *Muelleritortis firma* Subzone of *Muelleritortis cochleata* Zone of late Early Ladinian and *Pterospongus priscus* and *Spongoserrula rarauana* subzones of *Muelleritortis cochleata* Zone of early-middle Late Ladinian age. The uppermost part of the section is represented by green-colored mudstones revealing that clastic sedimentation previaled up to the latest Ladinian time.

Taking into the consideration of litho- and biostratigraphical data from Middle Triassic successions of several blocks in the MM, it is concluded that they correspond mainly to the blocks/slices of the Beysehir-Hoyran Nappes, which were originated from the southern margin of the Neo-Tethyan Izmir-Ankara Ocean. The late Anisian age found in the radiolarian cherts is the maximum age of a back-arc type basaltic volcanism in the Mersin Mélange. This is the first finding of representatives of the Middle Triassic oceanic basin formed above an intra-oceanic subduction zone in the

Izmir-Ankara Ocean.

Keywords: The Mersin Mélange, late Anisian-late Ladinian, pelagic sediment-lava associations, radiolarian dating, Neo-Tethyan evolution.

Pliensbachian (Early Jurassic) radiolarians from Mt. Rettenstein, Northern Calcareous Alps, Austria

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Pliensbachian radiolarians are rare in the western Tethyan realm. Only two well-preserved assemblages have been described so far, one from Turkey (sample 1662D of De Wever, 1982) and one from the Northern Calcareous Alps, Austria (sample BMW-21 of O'Dogherty & Gawlick, 2008). Continuous stratigraphic sections with well-preserved Early Jurassic faunas are known only from Haida Gwaii (Queen Charlotte Islands) in British Columbia (Carter et al., 1998, 2010). We are currently working on taxonomy and biostratigraphy of diverse and well-preserved Pliensbachian assemblages from a succession of marly and slightly silicified bedded limestone from Mt. Rettenstein in the Northern Calcareous Alps. This study is aimed to provide new data on stratigraphic distribution of taxa and to improve the comparison between low latitude (Tethyan) faunas and mid latitude faunas of Haida Gwaii.

Mt. Rettenstein is located on the southern rim of the Northern Calcareous Alps near Salzburg. The Jurassic succession is tectonically isolated but well preserved. It starts with an approximately 60 m thick sequence of marly and slightly silicified bedded limestones (Hettangian to Early Pliensbachian) which become slightly more calcareous towards the top and pass abruptly into red marls and red marly limestones with rich ammonite fauna. The ammonites indicate late Carixian (Early Pliensbachian) and to Early Toarcian ages (Meister & Böhm, 1993). The Middle Jurassic is represented by condensed Bajocian *Bositra*/*Protoglobigerina* limestones followed by Bathonian to Oxfordian radiolarites and Kimmeridgian-Tithonian shallow-water limestones (Auer et al., 2009).

Two samples (Rö416, Rö417) of grey marly limestone have been studied for radiolarians. Age determination is based on the zonation of Carter et al. (2010). In sample Rö416, 51 species belonging to 36 genera have been identified so far. Based on short-ranged taxa *Cyclastrum veracruzense* Whalen & Carter (UA 3–10), *Cyclastrum scammonense* Whalen & Carter (UA 2–9), *Ares sutherlandi* Whalen & Carter (UA 1–3) and *Charlottea triquetra* Whalen & Carter (UA 1–2), the sample was assigned to the lowermost Pliensbachian *Katroma clara – Canutus tipperi* Zone (UA 2–5). Sample Rö417 contains 49 species belonging to 30 genera. *Bipedis japonicus* Hori (UA 4–13), *Palaeosaturnalnis tetraradiatus* (Kozur & Mostler) (UA 1–4) and *Katroma clara* Yeh (UA 3–26) assign the sample to the *Katroma clara – Canutus tipperi* Zone as well. The aforementioned assemblages from Austria (BMW-21) and Turkey (1662D) were assigned to the upper Lower Pliensbachian *Gigi fustis – Lantus sixi* Zone (UA 12–18) by Carter et al. (2010).

Some identified species have not been found in samples of this age until now. Well preserved specimens of *Palaeosaturnalis prinevillensis* (Blome) are common in both samples. Up until now, the latest occurrence of this species was reported from the Sinemurian *Canutus rockfishensis – Wrangellium thurstonense* Zone (Carter et al., 1998). The situation is similar for the Hettangian–Sinemurian *Palaeosaturnalis* *liassicus* Kozur and Mostler, but we found way fewer specimens than for *Palaeosaturnalis prinevillensis*. Abundant well-preserved specimens of *Thurstonia minutaglobus* Whalen & Carter, so far known from the Hettangian and Sinemurian, were also found. On the other hand, *Gorgansium morganense* Pessagno and Blome was supposed to first appear in the middle part of the Lower Pliensbachian, in UA 10 (Carter et al., 2010) but well-preserved specimens are common in both samples studied.

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Keywords: Lower Pliensbachian, Tethyan realm, biostratigraphy

Middle Triassic radiolarian assemblages from the Monte Facito Formation (Lagonegro succession, Southern Apennines, Italy)

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The Lagonegro Basin represents, since Middle Triassic, the northernmost witness of the Ionian Ocean (Finetti, 2004), the south-western branch of the Tethys, and its sedimentary record is now exposed in the Southern Apennines (southern Italy).

The Lagonegro succession is constituted by different lithofacies, mostly pelagic, which in stratigraphic order, from bottom to top, are (Scandone, 1967; Passeri & Ciarapica, 2010):

- terrigenous deposits with argillites, siltstones, sandstone, marl, with breccias and conglomerates; calcareous shallow water sediments and limestones, with calcirudites and calcarenites; radiolarian cherts and radiolarites (*Monte Facito Formation*, Permian-Ladinian);
- thin-bedded cherty limestones (*Calcari con Selce Fm*, Ladinian-Upper Norian/Rhaetian);
- radiolarian cherts and radiolarites, with calcarenites and rare calcirudites (*Scisti Silicei Fm*, Upper Norian/Rhaetian-Tithonian);
- shales and fine-grained calcarenites, with scattered radiolaritic intercalations (*Flysch Galestrino*, Tithonian-Lower Cretaceous).

The Monte Facito Formation radiolarian cherts represent the oldest portion of the Lagonegro succession and the oldest deep water sediments of the Lagonegro Basin, indicating pelagic condition since the Late Anisian.

Six outcrops have been examined in detail: three of them are in the Cerchiara area, three others are, respectively, at Capelluzzo, Mt. Facito and Tempa di Rocca Rossa.

Rich and well preserved radiolarian assemblages coming from the radiolarian cherts of the six sampled outcrops of the Monte Facito Formation.

These radiolarian assemblages contain Late Anisian/Ladinian taxa. The following genera and species are referred only to Late Anisian: *Anisicyrtis, Baratuna, Celluronta, Parasepsagon tetracanthus, Parasepsagon variabilis, Spongosilicarmiger posterus, Tetrapaurinella tetraedrica, Tiborella florida florida, Triassistephanidium laticorne, Triassobipedis balatonica.*

Some new species were previously described by Marcucci & Bertinelli (2017) and some other will be described with open nomenclature herein.

The radiolarian biostratigraphy of the Monte Facito Formation has been revised after the ratification and the approval of the GSSP of the Ladinian stage at Bagolino (Italy) by the International Commission on Stratigraphy (Brack et al., 2005).

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Keywords: radiolarian assemblages, radiolarian chert, Late Anisian/Ladinian, Lagonegro Basin, Southern Apennines, Italy

Jurassic and Cretaceous radiolarian biostratigraphy of the Al Aridh Group (Hawasina Nappes, Oman Mountains)

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The Hawasina Nappes preserve remnants of a deep-water basin (the Hawasina Basin), its slopes and intrabasinal pelagic platforms (known as the Oman Exotics). These nappes are defined as a series of imbricates situated between the autochthonous sequences of the Arabian Platform below and the Samail Ophiolite Nappe above. From bottom to top (palaeogeographically from proximal to distal), the Hawasina Nappes are subdivided into four tectonostratigraphic units: the Hamrat Duru Group, the Al Aridh Group, the Kawr Group (Oman Exotics) and the Umar Group.

The Jurassic to Cretaceous Musallah Formation of the Al Aridh Group has been studied and dated with radiolarians. This formation overlies calcareous turbidites of the Buwaydah Formation and consists of bedded radiolarian cherts punctuated by coarse-grained breccias and conglomerates. Radiolarian analyses allowed us to establish the time span of chert-dominated intervals, to constrain the ages of the intervening mass-flow deposits and to provide evidence of considerable stratigraphic gaps.

The Musallah Formation starts with varicoloured thin-bedded radiolarian chert with shale interlayers and ranges in age from the early Pliensbachian to the middle-late Toarcian. This chert unit is overlain by up to several meters thick, generally channelized, debris-flow deposits, which contain clasts of underlying lithologies and include sub-rounded blocks of Permian and Triassic shallow-water limestones. A late Aalenian age has been documented in a chert bed between two conglomerate levels. Two superimposed units of bedded radiolarian chert then follow. The first unit of reddish and yellowish thin-bedded chert spans from the lower-middle Bajocian to the lower Bathonian, and is directly overlain by the second unit of thicker-bedded dark red chert that is assigned to the upper Tithonian-Berriasian to the lower Hauterivian. At least three stages are missing between these two chert units without any clear evidence of erosion. The long stratigraphic gap is considered as a "hidden discontinuity", which resulted from down-slope sliding of semi-consolidated siliceous ooze. Upper Aptian to Albian and Coniacian radiolarian cherts were also documented but occur in pervasively folded upper part of the Musallah Formation that has not been completely reconstructed yet.

The correlation with the Hamrat Duru Group reveals that the Pliensbachian to Toarcian chert unit was uniformly deposited over the entire Hawasina Basin. The onset of siliceous sedimentation is roughly correlative with a Pliensbachian marine transgression over siliciclastics on the Arabian Platform and approximately corresponds to formation of ferromanganese hardground on the drowned Oman Exotics. These facies changes were related to the regional rifting phase that is well documented from the Arabian Peninsula to the western Mediterranean. The debris-flow deposits around the Aalenian–Bajocian boundary record a rapid subsidence pulse and correlate to the Mid-Cimmerian unconformity that is also a Tethyan-wide phenomenon. The Al Aridh Group is higher in the succession composed almost exclusively of radiolarian cherts and lacks Bathonian oolitic carbonate gravity-flow deposits that are characteristic of the Hamrat Duru Group and were widely distributed in proximal settings of all platform-bounded Tethyan basins. The conspicuous pre-Tithonian stratigraphic gap was concomitant with major subsidence on the edge of the Arabian Platform and can be explained by sediment removal due to block tilting related to the final breakup between the Arabian and Indian plates. The effects of this tilting are well marked only in the eastern part of the Hawasina Basin. Further west, in the Sumeini Group (NW Oman Mountains) and in the Pichakun Nappes (Zagros, Iran), there is no evidence of a pre-Tithonian gap in basinal successions; Oxfordian and Kimmeridgian bedded cherts and shales occur in proximal as well as in distal settings.

Keywords: Oman, Mesozoic continental margin

■ MEMO ■

ABSTRACTS (POSTER)

■ MEMO ■

SPECIAL SYMPOSIUM I
SESSION 15

Paleoceanography of Tethys and Panthalassa

Poster Core time (inc. lunch):

23/Oct (Mon), 12:40–14:40; 24/Oct (Tue), 11:15–13:15

Library Gallery of Ikarashi Campus, Niigata Univ.

P15-01	Baumgartner, P.O. et al.	Evolution of Late Cretaceous Radiolaria - in relation with the Caribbean Large Igneous Province and carbon isotope shifts
P15-02	Bole, M. et al.	Secular variations of oxygen and silicon isotopes in Mesozoic radiolarites from Panthalassa and Tethys - proxies for paleotemperature and paleoproductivity
P15-03	Ibaraki, Y. et al.	Late Silurian radiolarians from a conglomerate of a float block in Kotaki, Itoigawa, central Japan: Oldest fossil record in Niigata Prefecture
P15-04	Ito, T. et al.	Radiolarian research in geological maps of the Quadrangle Series (1:50,000) published by the Geological Survey of Japan, AIST
P15-05	Kamata, Y.	Paleozoic and Mesozoic Back-Arc basin chert of the Paleo-Tethys in Thailand (preliminary report)
P15-06	Muto, S. et al.	Conodont biostratigraphy of Lower Triassic pelagic deep-sea sedimentary rocks in Japan
P15-07	Nakagawa, T.	Permian Pseudoalbaillella from manganese carbonate rocks of Akiyoshi accretionary complex, Southwest Japan
P15-08	Paleozoic Genera Working Group (Presenter: Suzuki, N.)	Paleozoic genera and the history of their study
P15-09	Tomimatsu, Y. & Onoue, T.	Radiolarian age constraints of Triassic-Jurassic stratiform manganese deposits in the Chichibu Belt, Southwest Japan
P15-10	Uchino, T. & Suzuki, N.	Deposition ages of clastic rocks in the Northern Chichibu Belt, eastern Kii Peninsula, Southwest Japan

Evolution of Late Cretaceous Radiolaria - in relation with the Caribbean Large Igneous Province and carbon isotope shifts

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Published regional Late Cretaceous radiolarian biozonations provide rather conflicting ranges of individual radiolarian species, making precise age calls difficult. Principal reasons may be: 1. radiolarian preservation becomes very spotty in post-Cenomanian sediments and is restricted to Oceanic Anoxic Events (AOE) and deeper, or upwelling settings espcaping the dominant pelagic marl/carbonate sedimentation. Hence, radiolarians rarely co-occur with calcareous microfossils that allow for biochronologic calibration. 2. The "semantics" of Late Cretaceous radiolarian species has gradually widened, resulting in long ranges of loosely defined groups. 3. Paleogeographic and paleoenvironmental factors cause truncated ranges of many species, especially of low latitude forms in high latitude assemblages.

In cotrast, a major radiolarian faunal turnover was proposed across the Cenomanian/Turonian Boundary Event (CTBE, OAE2, Bonarelli-level), marked by a major positive carbon-isorope shift (+2-3‰ ∂^{13}C, Jarvis et al. 2006; Fig.1). About 40% of radiolarian species disappear, and about 35% new species appear (Musavu-Moussavou et al. 2007). At present, the only compilation on post-CTBE radiolarian faunal turnover is that of O'Dogherty et al. (2009). It shows an important generic radiolarian turnover also at other Late Cretaceous boundaries. Their informal time subdivisions (53-65) can be matched well with carbon-isotopic events (Fig. 1).

The CTBE has been usually correlated with the formation of the Caribbean Large Igneous Province (CLIP). According to Kerr (1998) the CTBE, then dated around 90 Ma, was caused by the formation of oceanic plateaus, including the CLIP. A more recent compilation of Ar/Ar ages of the CLIP (Fig.1) shows indeed, that most ages of the CLIP cluster around 90 Ma, while the recent ICS chart pins the C/T-boundary at 93.9 Ma. While the CLIP only starts around 94 Ma, the Agulhas Plateau, NE-Georgia Rise, Maud Rise, Hess Rise and the Central Kerguelen Plateau formed between 100-94 Ma, just before the CTBE. Together, these plateaus produced about 9 times more magma volume than the CLIP and are, hence, better candidates for causing the CTBE.

Radiolarian assemblages interbedded with, and overlying basalt flows of the main CLIP phase, can be dated as Coniacian to/or Santonian, based on the current, status of Late Cretaceous radiolarian biochronology (Baumgartner et al. 2008) This age corresponds well with the youngest Ar/Ar ages of the main CLIP phase. We work on a systematic revision of radiolarian genera and species, using many DSDP, ODP and land samples from the Tethyan and Pacific realms, with the objective to elaborate a new global, low-latitude radiolarian Late Cretaceous biochronology.

According to our data, Coniacian-Santonian samples have only a minority of species in common with the assemblages from the lower Turonian Scaglia Bianca Limestone of Umbria-Marche. Radiolarian faunal turnover may be very important during the Late Turonian/Santonian, marked by a minor positive carbon isotope shift

(+1 ‰ ∂ ^{13}C, Fig.1), but continuous radiolarian-bearing sections are difficult to find for this interval. Radiolarian faunal turnover may be even more important during the Campanian-Maastrichtian time interval, as shown in Fig. 1.

Oceanic anoxic events, if related to super greenhouse climate, should favour radiolarian productivity through intensified continental weathering and nutrient input to the ocean. Anoxia of bottom waters clearly enhances radiolarian preservation. Good examples are radiolarian-rich cherts marking OAEs in otherwise calcareous pelagic series. Hence, peri-tropical radiolariates of the Coniacian-Santonian may be related to the isotopically poorly defined "OAE3", whereas the Campanian to middle Eocene radiolarite occurrences of S-Central- and N-South-America could be related with upwelling along the peri-tropical W-coasts of the Americas.

Besides the chert-rich OAEs, well-preserved and abundant radiolarians are restricted to settings, such as: 1. areas of coastal or equatorial upwelling (e.g. fore-arc areas around the Pacific), 2. hemipelagic to "flysch" basins in the Tethyan realm, 3. in the open ocean, below a deepening, global CCD. Radiolarian preservation seems to be enhanced in glass-rich, tuffaceous, volcanogenic sediments.

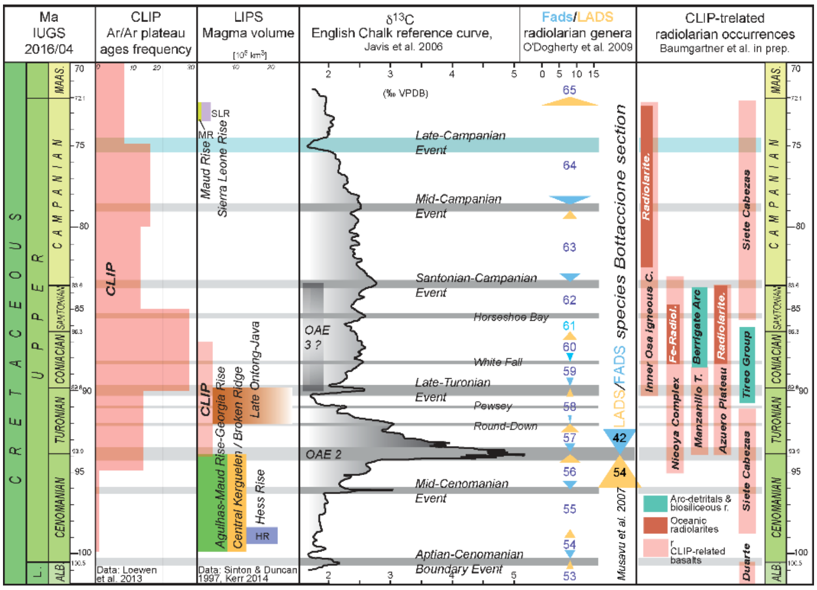

Figure 1. Chronostratigarphc chart of the Upper Cretaceous showing: Frequency of ages of CLIP-basalts; magma volume of world LIPS; ∂^{13}C reference curve of the English chalk, positive events in grey, negative events in blue (Jarvis et al. 2006); radiolarian generic FADS and LADS (0-15) for subdivisions 53-65, after O'Dogherty et al. (2009); age and lithology of CLIP-related basalts and radiolarites (this paper).

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Keywords: CLIP, Late Cretaceous Radiolaria, carbon isotope events

Secular variations of oxygen and silicon isotopes in Mesozoic radiolarites from Panthalassa and Tethys - proxies for paleotemperature and paleoproductivity

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The stable isotope ratios δ^{18}O- and δ^{13}C are most commonly used as proxies for paleotemperature and the state of the carbon cycle, routinely measured in low magnesium carbonate (LMC) shells. By contrast, the isotopes of radiolarians have not been investigated in detail, despite the fact that these siliceous organisms have controlled the oceanic silica cycle from the Paleozoic to the early Cenozoic, when diatoms started to dominate. We have performed in situ measurements of δ^{18}O and δ^{30}Si with SIMS in the chalcedony infills in radiolarians of Mesozoic radiolarites from Panthalassa and Tethys (Fig.1). We assume that this chalcedony is directly derived from opal-A of radiolarian tests by early diagenetic dissolution-precipitation, without remobilization of detrital/aeolian quartz. This method reduces isotopic contamination by clays and other detrital/authigenic minerals. We conclude that δ^{18}O- and δ^{30}Si- ratios in radiolarians may record paleotemperature and paleoproductivity respectively.

δ^{18}O measured in Mesozoic radiolarians covaries with δ^{18}O of LMC shells. A δ^{18}O-maximum can be observed during the Middle Jurassic, whereas minimum values are found during the Early Triassic, Early Jurassic and during Barremian-Aptian. That is good evidence for the recording of paleoclimates and/or paleotemperatures by δ^{18}O in radiolarites. In addition, the good correlation between δ^{18}O from LMC shells and from radiolarites suggests that the long Phanerozoic δ^{18}O trend is definitively not a diagenetic signal, because the early diagenetic chalcedony, once formed, is relatively resistant to diagenetic resetting.

Regarding other siliceous organisms, silicon isotopes have been studied more in diatoms and sponges than in radiolarians. These investigations have demonstrated that these organisms incorporate preferentially ^{28}Si over heavier isotopes. That is relatively similar to the extraction of ^{12}C by organisms. δ^{30}Si in diatoms has been proposed as a record for the paleoproductivity of diatoms (De La Rocha et al., 1997). The δ^{30}Si fractionation of radiolarians is still poorly known, due to the lack of data. To solve this problem, we ran a principal component analysis of our data. We deciphered from this analysis that silicon isotopes firstly depend on the silicon supply, secondly on the paleoproductivy of radiolarians and then on diagenetic processes. This conclusion is coherent with the inference of Frings et al. (2016) that climate controls the continental silicon supply to the ocean and that this component has to be removed before estimating productivity. The fractionation of silicon by radiolarians and diatoms is thus relatively similar. It is therefore, not surprising that the δ^{30}Si-range of our radiolarites is in pair with the δ^{30}Si range observed in diatoms. This is also coherent with the first estimation by Abelmann et al (2015) of the δ^{30}Si fractionation by radiolarians at about -0.8‰ whereas diatoms fractionate silicon only slightly more (-1.1‰ in average).

Our data show a global δ^{30}Si increase from the Triassic to the Middle Jurassic in the Inuyama section (Gifu Prefecture, Japan). The maximal value reached during the

Middle Jurassic is comparable with the maximal value obtained on in the Tethyan Middle Jurassic Sogno section in the Lombardian basin. From the Middle Jurassic to the Cretaceous, we then observe a worldwide δ^{30}Si decrease in several sections. Our data then suggest an increase until the Barremian-Aptian followed by a decrease, which possibly continues until the Cenomanian. The Triassic-Jurassic δ^{30}Si increase probably reflects shortage in silicon supply due to arid climate on Pangea. However, the low values during Early Triassic are also the consequence of the Permo-Triassic crisis affecting radiolarian productivity. This can be asserted because the radiolarian turn over after the Norian impact is associated with low δ^{30}Si-values between 214 Ma and 210 Ma. The δ^{30}Si-decrease since the Middle Jurassic might be explained by the break-up of the Pangea. This period is also marked by a return to more humid conditions and to a cooler climate. Data for the Cretaceous needs further investigation to be correctly interpreted but there is a potential maximum during the Barremian-Aptian interval followed by a δ^{30}Si-decrease up to the Cenomanian-Turonian. The problem is that the Barremian-Aptian interval corresponds to a maximum of the greenhouse effect with high productivity and potential dryer climate whereas there is evidence of Atlantic glaciation in the Turonian.

Isotopes in radiolarians can be used as a proxy for paleoclimates and the paleoproductivity of radiolarians. Radiolarites can thus complete and extend our knowledge based on LMC shells. Additional data are required at higher resolution and more particularly during the Paleozoic, the Cretaceous or the Tertiary.

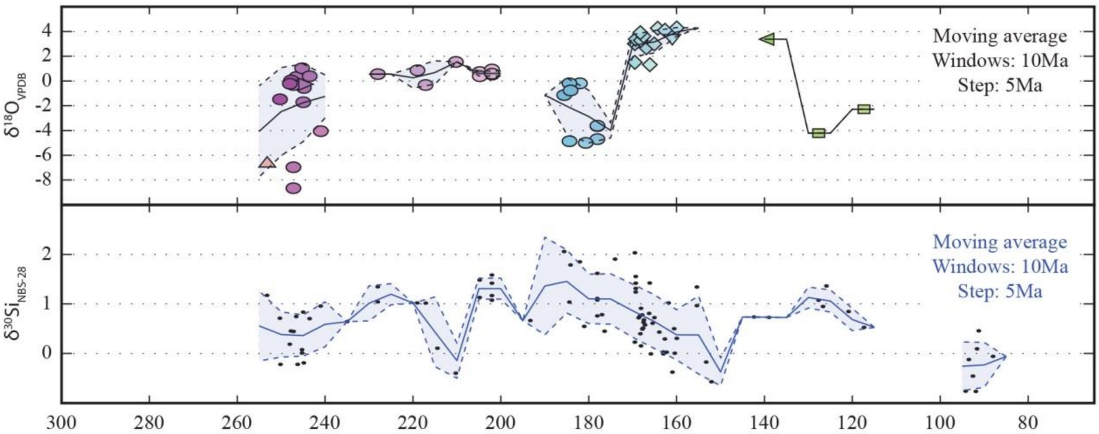

Figure 1. δ^{18}O- and δ^{30}Si- ratios in Mesozoic radiolarites. The colors in the first graph correspond to geological time scale chart and the symbols correspond to different sections/samples.

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Keywords: Isotopes, Paleoproductivity, Paleotemperature, Radiolarites

Late Silurian radiolarians from a conglomerate of a float block in Kotaki, Itoigawa, central Japan: Oldest fossil record in Niigata Prefecture

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Radiolarian-bearing rock clasts have been reported from Cretaceous strata in the Hokuriku District of central Japan, such as the Tetori Group (e. g., Saida, 1987; Ito et al., 2012, 2014, 2015). In contrast to these works on the Cretaceous strata, fewer studies have reported radiolarian-bearing clasts from Jurassic strata in the district.

The Lower Jurassic Kuruma Group (Kobayashi et al., 1957) is distributed over prefectural boundaries among Niigata, Nagano, and Toyama prefectures, central Japan. There has been only one brief report of radiolarian-bearing clasts from the Kuruma Group by Kumazaki and Kojima (1996); however, they showed no radiolarian image.

Recently, the collaborative research group comprising Itoigawa City, Niigata University, and Geological Survey of Japan, AIST discovered late Silurian radiolarians from a radiolarite pebble within a conglomerate float block that was collected in the riverbed of the Kotakigawa River in the Kotaki area, Itoigawa, Niigata Prefecture, central Japan (Ito et al., 2017). *Futobari morishitai* Furutani, Inaniguttidae gen. et sp. indet., and Palaeoscenidiidae gen. et sp. indet. were recognized on etched surfaces of the pebble (Fig. 1). *Pseudospongoprunum* sp., *Zadrappolus* sp., and *Rotasphaera* sp. were discovered in residues obtained by chemically treating the conglomerate. This assemblage may be compared to the assemblage around the boundary between the *Pseudospongoprunum tauversi* to *Futobari solidus–Zadrappolus tenuis* Assemblage Zones of Kurihara (2004, 2007) and corresponds to the late Silurian. The discovery marks the first identification of Silurian radiolarians in Niigata Prefecture, which also is the oldest recorded fossil from the prefecture. The clast is also the oldest recorded radiolarian-bearing clasts within conglomerates of the Japanese Islands and the Korean Peninsula.

The source exposure for the conglomerate is undiscovered yet. We here consider that the origin of the conglomerate is the Lower Jurassic Kuruma Group or unknown geological unit in neighbor areas.

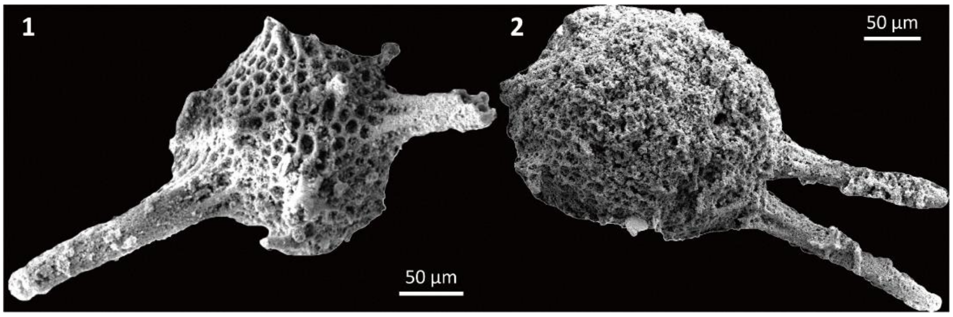

Figure 1. Scanning electron microscope images of radiolarians on etched surfaces of the radiolarite pebble. 1: *Futobari morishitai* Furutani. 2: Inaniguttidae gen. et sp. indet. (modified from Ito et al., 2017)

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Keywords: conglomerate, etched surface, Jurassic, Kuruma Group, Silurian radiolaria

Radiolarian research in geological maps of the Quadrangle Series (1:50,000) published by the Geological Survey of Japan, AIST

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The Geological Survey of Japan (GSJ), established in 1882, marks the 135th anniversary this year. In long history, the GSJ published numerous geologic maps in several scales. The GSJ started to publish geological maps of the Quadrangle Series (1:50,000) in 1950's (Kato et al., 2011).

We here compile the previously-published geological maps of the Quadrangle Series (1:50,000) and review radiolarian description within these works. Along the publication history in 1950–2015, the term of "radiolaria" appears in 240 geological maps of the series in total.

Before the 1980's, i.e. before the "radiolarian revolution", radiolarian remains within rocks have been recognized in some studies although most of the descriptions is gracile. Meanwhile, in the 1950's, S. Igi had shown species list of radiolarians (identified by K. Ichikawa) from cherts of the Hidaka Group in the Erimo-Misaki District (Igi & Kakimi, 1956) and from cherts of the Sorachi Group in the Horokanai District (Igi et al., 1958). They had regarded the Hidaka and Sorachi groups as the pre-Cretaceous and Upper Jurassic, respectively. Yamada (1966) showed a thin section photograph of radiolarian remains within phyllites of the Sangun metamorphic rocks in the Chizu District, which was the first-time illustration of radiolarians in the geological maps of the series.

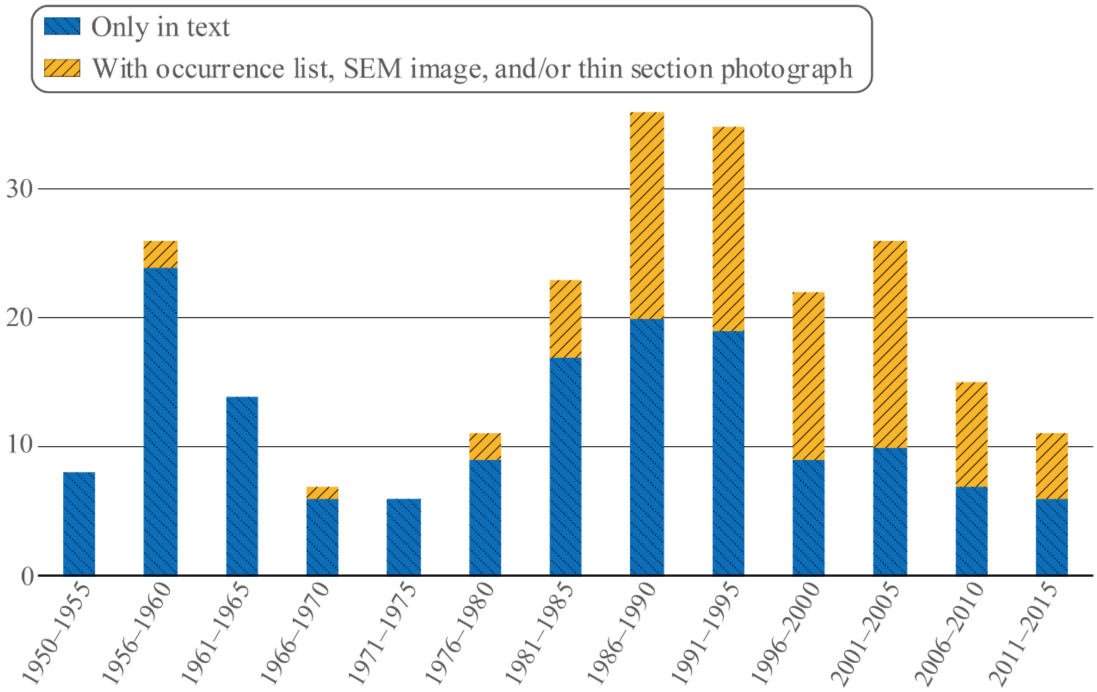

Figure 1. Quinquennial number of previously-published geological maps of the Quadrangle Series (1:50,000) of the GSJ that include "radiolaria" in the text.

Sakamoto et al. (1984) showed Jurassic radiolarians from siliceous rocks in the Nagoya-Hokubu District, which was the first-time radiolarian description with scanning electron microscopy (SEM) images in the geological maps of the Quadrangle Series (1:50,000). Subsequently, the description of "radiolaria" in the geological map of the series increased (Fig. 1). Among the geological maps in 1981–2015 that include the description of "radiolaria", about half of them show the occurrence list, SEM images, and/or thin section photograph of radiolarians (Fig. 1) but not only in the text. The increment of radiolarian works is consistent with "radiolarian revolution".

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Keywords: Geological map, term of "radiolaria", bibliographic study

Paleozoic and Mesozoic Back-Arc basin chert of the Paleo-Tethys in Thailand (preliminary report)

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Geologically, SE Asia consists of the several continental blocks derived from Gondwana Supercontinent during the Paleozoic to Mesozoic era. Geological history of the formation of SE Asia contains various tectonic settings such as the dispersion of supercontinent, the subduction of oceanic crust, the formation of the Arc, and the collision of continents after the closure of huge main oceans (e.g., Metcalfe, 1999, 2013). Well-established radiolarian biostratigraphy is useful to estimate the temporal and spatial extents of the oceans stretched between the continents by age dating of the oceanic sediments. Radiolarian chert, one of main oceanic sediments, has been understood as an indicator of pelagic and "deep-sea" environments of the huge ocean (e.g., Isozaki et al.,1990: Matsuda and Isozaki, 1991). However, deposition of the radiolarian bedded chert on the continental shelf and continental margins (e.g., Kamata et al., 2009, 2014). These occurrence of the radiolarian bedded chert shows that the sedimentation of the radiolarian chert may not necessarily occur integrally in pelagic and "deep-sea" site on basaltic abyssal planes. For implication of geotectonic history the SE Aisa, we should clarify the sedimentary environments of these sediments precisely not only the main ocean basin but also associated smaller basins such as fore-arc and back-arc basins.

In eastern Thailand, Sa Kaeo Suture Zone, which contains ultramafic, mafic rocks with Permian to Triassic radiolarian chert, have long been considered to represent the closure zone of the main Paleo-Tethyan ocean between the Sibumasu and Indochina continental Blocks (e.g., Bunopas, 1981; Metcalfe, 1999). In the last decade, however, accumulation of geological information such age determination by radiolarian biostratigraphy and origin of the ultramafic rocks have led to the new interpretation of the geotectonic divisions of the mainland Thailand (e.g., Ueno and Charoentitirat, 2011), and the new geological significance of the Sa Kaeo Suture Zone as a closure zone of back-arc basin situated between the Sukhothai Zone (arc system) and the Indochina Continental Blocks (e.g., Ueno and Hisada, 1999; Ueno, 2002).

In this presentation, the author will report the stratigraphy, lithology, depositional age by radiolarian biostratigraphy, mineral contents and geochemical natures of the radiolarian chert distributed in the Sa Kaeo Suture Zone and examine of the geological significance of the suture zone with considering the back-arc tectonic setting.

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Keywords: radiolarian bedded chert, Paleo-Tethys, back-arc basin, Sa Kaeo Suture Zone.

Conodont biostratigraphy of Lower Triassic pelagic deep-sea sedimentary rocks in Japan

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Conodonts are one of the most useful guide fossils of the Triassic allowing global correlation of sedimentary rock bodies. Koike (1981) proposed the framework of Triassic conodont biostratigraphy for pelagic sediments deposited in the Panthalassa Superocean based on investigations of palaeo-seamount limestones and deep-sea chert. Of these, pelagic deep-sea sediments may provide a more chronologically continuous biostratigraphic record of conodonts, because sedimentation on the deep-sea floor is less likely to be interrupted by events such as sea-level change compared to sedimentation of carbonates on seamounts. However, the conodont biostratigraphy of the pelagic deep-sea sedimentary sequence was not fully understood due to the scarcity of conodont fossils and the lack of continuous sections. The Lower Triassic interval of the pelagic deep-sea sequence, which is characterised by the occurrence of siliceous claystone instead of bedded chert (the deep-sea chert gap), was especially poorly understood, because both conodont preservation and sedimentary records of the deep-sea chert gap are even worse compared to the bedded chert.

We studied conodont biostratigraphy of the Lower Triassic pelagic deep-sea sediments in five areas in Japan: Ogama (Tochigi Prefecture), Momotaro-jinjya (Aichi Prefecture), Ryugadake (Kyoto Prefecture), Ashidani (Kyoto Prefecture), and Tsukumi (Oita Prefecture). We conducted detailed geologic investigations to reconstruct the sedimentary sequence in the studied areas, which have experienced deformation during and after accretion. Conodont fossils were found from siliceous claystone samples by observing the surface of cleaved rocks (the 'chip method' in Takemura et al., 2007), which allows observation of cracked or moulded specimens that are impossible to extract safely from the host rock.

By correlation of the studied areas and comparison with a previous study in Momotaro-jinjya (Takahashi et al., 2009b), we recognised four laterally traceable conodont biozones for the upper Olenekian (Spathian); the *Novispathodus brevissimus-Icriospathodus collinsoni* Zone, the *Triassospathodus homeri* Zone, the "*Neohindeodella dropla*" Zone and the *Chiosella gondolelloides* Zone in ascending order. As for the Induan and lower Olenekian (Smithian), conodont occurrence is sparse. Therefore, chronologically continuous and laterally traceable conodont biozones were not successfully established for this interval. However, age diagnostic conodonts such as *Hindeodus parvus*, *Conservatella conservativa* and *Novispathodus waageni* have been reported from several distant sections (Sano et al., 2012; Takahashi et al., 2009a; Yamakita, 1987; Yamakita et al., 1999). The occurrence of these conodonts allows a rough correlation between these distant deep-sea sedimentary sections. Further biostratigraphic studies of the Induan and Smithian interval of the pelagic deep-sea sediments may lead to an establishment of a continuous zonal scheme of conodont biostratigraphy for the Lower Triassic pelagic deep-sea sediments.

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Keywords: Conodonts, Lower Triassic, chert gap, Panthalassa

Permian *Pseudoalbaillella* from manganese carbonate rocks of Akiyoshi accretionary complex, Southwest Japan

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This presentation introduces Early to Middle Permian radiolarians extracted from manganese carbonate rocks. The rocks are recovered from the Permian accretionary complex, “Nishiki Group” of the Akiyoshi Belt, Southwest Japan. The Nishiki Group is a Permian accretionary complex consisting mainly of sandstone, mudstone, siliceous mudstone, felsic tuff and chert. The manganese carbonate rocks are intercalated within siliceous mudstone deposited in hemi-pelagic condition. There are two manganese carbonate rocks, which occur at the two different localities with about 3 km distance.

These two manganese carbonate rocks contain very well preserved radiolarians of different ages. One of the manganese carbonate rocks yields Lower Permian radiolarian assemblages including *Pseudoalbaillella* aff *aidensis* Nishimura and Ishiga*,* *P.* cf. *lanceolata* Ishiga and Imoto*,* *P.* cf. *yanaharaensis* Nishimura and Ishiga and so on. Another contains Middle Permian assemblages such as *Pseudoalbaillella* cf. *fusiformis* Holdsworth and Jones, *P.* cf. *globosa* Ishiga & Imoto, *P.* cf. *longtanensis* Sheng and Wang, *Follicucullus* cf. *monacanthus* Ishiga & Imoto and *F.* cf. *scholasticus* Ormiston & Babcock.

This paper focuses mainly on the detailed structures of *Pseudoalbaillella* aff, *aidensis*, and *P.* cf. *fusiformis*. *Pseudoalbaillella* aff. *aidensis* is characterized by a longer form than *P*. *aidensis* without clear annulations, although *P. aidnesis* has a long pseudoabdomen with 5-7 annulations. The longest overall length of *P*. aff. *aidnesis* is about 800 µm. At the bottom, several specimens of *P*. aff. *aidensis* yield foot and flap with fine structure. Pseudoabdomen of *P.* aff *aidensis* is cimposed of two segment. The first segment is directly connected with pseudothrax, and is followed by the second segment of about 400 µm in length.

Pseudoalbaillella cf. *fusiformis* is characterized by being barrel-shape and wings in symmetry similar to *P. fusiformis* Holdsworth and Jones. The length from apical corn to flap of *Pseudoalbaillella* cf. *fusiformis* is about 300 µm in length. It yields wings on both sides obviously leads to flap in each side. Pseudoabdomen of *P.* cf. *fusiformis* is composed of two segments. The second segment is bulging more round than pseudothrax.

Keywords: *Pseudoalbaillella*, Permian, manganese carbonate, Akiyoshi Belt

■ MEMO ■

Paleozoic genera and the history of their study

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Considerable progress has been made in Paleozoic radiolarian studies since the 1970s, and we now know that their fossil record goes back to the Cambrian. Despite these recent advances, many questions still remain about the origin, evolution, and radiation of radiolarians, and has shown the need for a concerted effort to evaluate the taxonomic status and relationships of the existing body of described taxa. The InterRad Paleozoic Genera Working Group (leader: T. Danelian) (PGWG) was organized in order to summarize current state of knowledge on Paleozoic radiolarian genera. We briefly introduce our result which will be published in *Geodiversitas*.

Danelian et al. (in press) summarizes the history of descriptive genus-level taxonomy on Paleozoic radiolarians grouped in five major phases: (I) initial discoveries in the 1890's; (II) Inactive period, first half of the 1900's; (III) 1950's-1970's renewed interest; (IV) Late 1970's-1990's fast years; and (V) 21st century quest for the oldest. This paper reviews contributions of researchers from Europe and North America as well as Korea, China, Japan and Russia.

Caridroit et al. (in press) is the cornerstone of the PGWG's contribution as it is an illustrated catalogue of type species for all Paleozoic "radiolarian" genera, and resulted from group evaluation of the taxonomic status and family level placement of each. Valid taxa as well as homonyms, synonyms, *nomina dubia*, *nomina nuda*, and other organisms erroneously published as Radiolaria (such as siliceous sponges) are designated. All Paleozoic "radiolarian" genera were reviewed one by one by examining original papers in two major meetings with all 12 members in Lille and Cadiz, and several smaller meetings with part of the members; the PGWG has come to a consensus on 345 genera of Paleozoic "radiolarians". The group analyzed all taxa carefully; In rare cases, disagreements have led to a democratic decision. This summary shows the valid genera of 24 Albaillellaria, 24 Archaeospicularia, 58 Entactinaria, 28 Latentifistularia, 12 Nassellaria (?), and 34 Spumellaria. A total of 27 genera have not been classified into appropriate orders.

Noble et al. (in press) is a text companion to Caridroit et al. (in press) which provides the original diagnosis and/or description of all 345 Paleozoic "radiolarian" genera, both in the original language in which it was published, as well as in its English translation, and provides either explanation or attribution for any decisions to synonymize or treat as other than valid. This chapter largely does not include emended definitions by later publications, does in some instances refer to emendations where the original usage has changed considerably from the original text.

Aitchison et al. (in press, a) compiles the biozones and a brief summary of the evolutionary history of radiolarians since the Cambrian till the end Permian for the end-users of radiolarian taxonomy. Although it is apparently needed to refine the applicability of the established biozones and the resolution of ages, four Cambrian, 12 Ordovician, nine Silurian, 18 Devonian, 17 Carboniferous and 23 Permian assemblages, faunas or maker taxa were summarized in a stratigraphic chart with the international time scale.

Aitchison et al. (in press, b) presents, for the first time, a complete list of Paleozoic radiolarian species described between 1880 and early 2016. It records 2,337 names of taxa described originally as new species or subspecies that have been assigned to radiolarians. This list attempts to only provide an objective record without evaluation or revision of taxonomic status, and thus includes invalid taxa and those which may rightfully belong in other genera (junior objective or subjective synonyms, *nomina dubia* and *nomina nuda*).

It is hoped that this catalog will serve as a launching point to continue the evaluation of Paleozoic genera and species, and to provide a more stable taxonomic framework from which the important topics of paleogeography, phylogeny can be addressed. For the lower Paleozoic, it has made several additional problems clear, including the need to acquire more data for most of the type species in order to reliably establish stratigraphic ranges. We hope that we can establish this as a future objective, similar to what has been done for the Mesozoic genera. However, it is our hope that this publication will be a useful tool for future Paleozoic radiolarian researches.

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Keywords: Paleozoic, genera, taxonomy, review

Radiolarian age constraints of Triassic-Jurassic stratiform manganese deposits in the Chichibu Belt, Southwest Japan

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Many stratiform manganese deposits have been known to occur in the Triassic to Jurassic cherts or chert-greenstone complex in the Chichibu Belt, Southwest Japan, which are considered to have accumulated in a mid–oceanic basin of the Panthalassa Ocean(Sato & Kase, 1996; Nakamura, 1990). To constrain the age and depositional environments of these manganese deposits, we describe the field occurrence, stratigraphy, and age of chert-hosted manganese deposits of the Takahira, Takahama, and Kubodomari deposits from the Chichibu Belt in the Saiki area, Oita Prefecture.

The stratiform manganese deposits range in thickness from 80 to 150 cm, and occur intercalated within the bedded cherts. Our biostratigraphic analysis of radiolarians reveals that the stratiform manganese deposits were deposited in the early Late Triassic and late Early Jurassic. The red-bedded cherts above Upper Triassic manganese ores contain Late Triassic radiolarian fossils, including *Trialatus longicornutus* and *Trialatus megacornutus*. These radiolarians indicate that age of manganese deposits can be correlated with the late Carnian age. Lower Jurassic manganese deposit occurs intercalated within the gray to dark gray bedded cherts. Detailed biostratigraphic analysis of radiolarians indicates that the manganese deposit is embedded in the upper Pliensbachian to Toarcian (*Mesosaturnalis hexagous* Zone - *Parashuum*(?) *grande* Zone).

Chemical compositions of the Upper Triassic manganese deposits are characterized by the enrichment in Mn content and the depletions of Co, Ni and Zn. These geochemical features are similar to those of modern submarine hydrothermal manganese deposits. In contrast, the enrichments in Cr, Ni and Zn were recognized just below the Lower Jurassic manganese deposits, suggesting an anoxic depositional environment. It is likely that the Lower Jurassic manganese deposits were formed by an oceanic anoxic event in the Early Jurassic (e.g., Early Toarcian anoxic event: Jenkyns, 1988).

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Keywords: stratiform manganese deposit, accretionary complex, Chichibu belt

■ MEMO ■

Deposition ages of clastic rocks in the Northern Chichibu Belt, eastern Kii Peninsula, Southwest Japan

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The eastern Kii Peninsula (Shima Peninsula) is a geologically important area because it provides a suit of strata of a Paleozoic–Mesozoic arc-trench system in the eastern Asian margin, where is marked by an array of, from the north to the south, Cretaceous high-*P/T* metamorphic rocks (Sambagawa Belt); Jurassic accretionary complex (Northern Chichibu Belt); Jurassic accretionary complex and Early Cretaceous shallow-marine deposits with subordinate Paleozoic igneous and sedimentary rocks and Paleozoic-Mesozoic metamorphic rocks (Kurosegawa Belt); Jurassic accretionary complex with subordinate shallow-marine deposits (Southern Chichibu Belt); and Cretaceous accretionary complex (Shimanto Belt) (Fig. 1).

The Northern Chichibu Belt is our topic in this presentation. It is subdivided into the Kochi, Osakatoge and Shiraki complexes from the north to the south. Radiolarian age control, but a few, presumably indicated that the clastic rock of the Kochi and Osakatoge complexes is the Middle Jurassic and Early Jurassic in age, respectively (Tsuzuki & Yao, 2006). This presumption was verified by detrital U–Pb zircon ages for sandstones (Uchino, 2017). We newly obtained mudstone samples with many radiolarian faunas which is enable age determinations to previously undated clastic rocks of the Shiraki Complex.

These examined Shiraki Complex samples contain Middle Jurassic radiolarian faunas such as *Archaeodictyomitra prisca*, *Eoxitus elongatus*, *Eucyrtidiellum unumaense*, *Hsuum crassum*, *Hsuum maxwelli*, *Minutusolla michelei*, *Minutusolla nishimurae*, *Praewilliriedellum yaoi* and *Striatojaponocapsa synconexa*. The Shiraki Complex is about the same age as the Kochi Complex. However, more basalt and chert content, more intense deformation and partly higher-grade metamorphism in the Kochi Complex than the Shiraki Complex could be explained by a different unit displaced tectonically over the Shiraki Complex, rather than by a disrupted same unit.

The tectonostratigraphic scheme "Shiraki Complex" in the eastern Kii Peninsular is a regional one, so that a tectonostratigraphic correlation to the standard scheme for the entire Northern Chichibu Belt is geologically meaningful. Based on the lithology and clastic rock age, the Shiraki Complex can be correlative to the Kamiyoshida Unit. Southern part of the Shiraki Complex used to be part of the Kurosegawa Belt (part of the Sirataki Group) (e.g. Saka, 2009). Based on its lithofacies, geological structure, stratigraphic continuity to the remaining part of the Shiraki Complex, and radiolarian ages from clastic rocks, there is no doubt that the entire part of the Shiraki Complex belongs to the Northern Chichibu Belt.

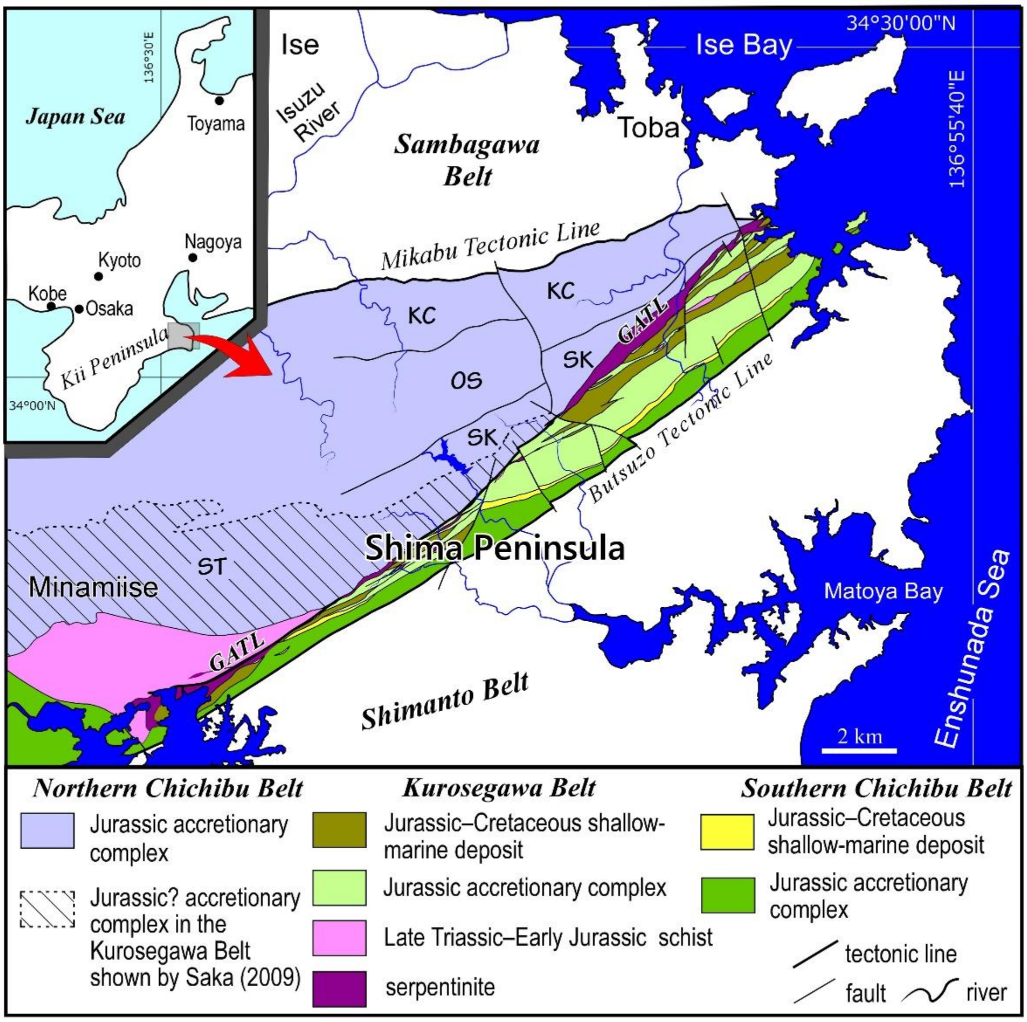

Figure 1. Geological index map in the eastern Kii Peninsula (Shima Peninsula). KC: Kochi Complex, OS: Osakatoge Complex, SK: Shiraki Complex, ST: Shirataki Group, GATL: Gokasho-Arashima Tectonic Line.

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Keywords: radiolarian fossil, Northern Chichibu Belt, Middle Jurassic, Shiraki Complex, Shima Peninsula, Kii Peninsula, Southwest Japan

■ MEMO ■

SPECIAL SYMPOSIUM I
SESSION 16

Cenozoic Paleoceanography of Marginal Seas

Poster Core time (inc. lunch):

23/Oct (Mon), 12:40–14:40; 24/Oct (Tue), 11:15–13:15

Library Gallery of Ikarashi Campus, Niigata Univ.

P16-01	Matsuzaki, K.M. et al.	Paleoceanography of Japan Sea over the past 9.5 Myr based on radiolarians (IODP Exp. 346, Site U1425)
P16-02	Zhang, K.X. et al.	Late Paleocene radiolarian fauna from the Yarlung Zangbo Suture Zone of Tibet, and its geological implications

Paleoceanography of Japan Sea over the past 9.5 Myr based on radiolarians (IODP Exp. 346, Site U1425)

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Since the Middle Miocene (ca. 15 Ma), the climate of Earth record a progressive cooling leading the establishment of the Northern Hemipshere Ice Sheet (ca. 2.7-3.2 Ma). During this interval, climate changes are mainly paced by the obliquity cycle (41 kyr) and long eccentricity cycle (400 kyr). Based on the work of Holbourn et al. (2013) , the variation in the $\delta^{18}O$ of benthic foraminifera was at that time at its maximum around 0.5‰, which correspond to a Δ sea level of ca. 40 m (Fairbanks and Matthews, 1978).

Our studied area, the Japan Sea, a back-arc basin opened by a continental rifting during the Early to Middle Miocene (ca. 25–13 Ma). In modern condition, the Japan Sea is connected to adjacent marginal seas and the Pacific Ocean by four straits shallower than 130 m. However, due to the tectonic activity of this area, the paleogeography of the Japan Sea such as the sill depth of its key straits were different in the past. Previous studies showed that for the Mio- Pliocene, the southern Strait (close to Tsushima Strait), was closed, the northern Strait (close to present Tsugaru Strait) was opened and its sill depth was likely deep (upper-mid bathyal), while the eastern Strait (close to present Fossa Magna) and the strait west off Hokkaido Island were likely opened but with shallow water depths (Iijima and Tada, 1990). Therefore, even for the Mio-Pliocene, the Japan Sea was likely connected to its adjacent seas by straits, having a deep sill depth (northern Strait), but also straits with shallow sill depths enabling only exchanges in surface water. A sea level changes of ca. 40 m can be expected for this period due to the glacial-interglacial cycle. Such sea level variation could be critical for straits with shallow sill depths. Therefore, in this study we propose to quantify how the Milankovitch cycle can influence the local oceanography analyzing changes by using relevant radiolarian species relative abundances (%).

Radiolarians are Protista, one of the planktic micro-organism group bearing siliceous skeletons. Their species comprise shallow to deep water dwellers, sensitive to changes in sea water physical/ecological properties forced by climate changes. Their fossils are known for well preserved in the deep-sea sediments of the North Pacific. Therefore, in this study we propose to reconstruct major changes in the Japan Sea hydrography since the late Miocene, using radiolarian fossils as an environmental proxy.

In 2013 the IODP Expedition 346 retrieved sediment cores at different sites in the Japan Sea (Tada et al., 2015). In this study, we have analyzed 160 core sediments samples collected at Site U1425. This site is situated in the middle of the Yamato Bank. We selected this site because the past 10 Myr could be traced continuously without hiatuses, enabling continuous data acquisition.

As a primary result, radiolarians suggesting relatively warm condition seem to be paced by the 400 kyr eccentricity cycle between ca. 7 and 9.5 Ma. By comparing with other radiolarian data (e.g. Kamikuri et al., 2004), relative abundances of warm water radiolarian are lower at Site 1151 (Pacific side of Northern Japan) than in the Japan Sea suggesting that the subtropical front should be at lower latitude than Site 1151 (Figure 1). This suggest that warm water should have penetrated the Japan Sea from the eastern strait, and the fact that at 7 Ma, which correspond to the definitive closure of the Eastern Strait, we have no more warm taxa in the Japan Sea strengthen this hypothesis.

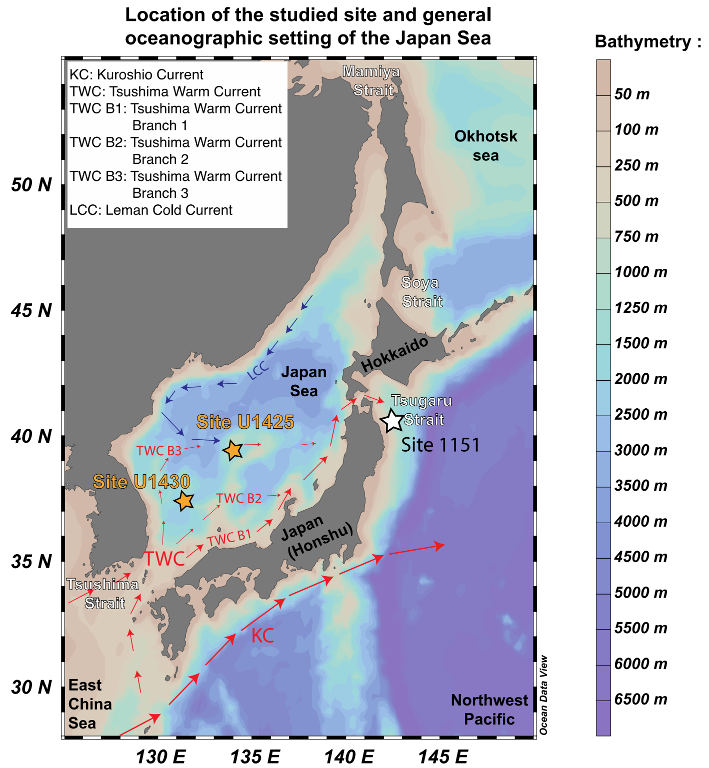

Figure 1. Location of the studied site (IODP Exp. 346 Site U1425)

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Keywords: Japan Sea, Paleoceanography, Sea level changes, radiolarians

Late Paleocene radiolarian fauna from the Yarlung Zangbo Suture Zone of Tibet, and its geological implications

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A diverse, abundant, and well-preserved radiolarian fauna in the Denggang Formation of Jiazhu, Zhongba County of Tibet, in the western sector of Yarlung Zangbo Suture Zone defines a late Paleocene radiolarian zone, the *Buryella pentadica* Biozone, spanning 59-56.5Ma. The radiolarian fauna is dominated by Nassellarians, characterized by conical shell or bell-shaped shells of deep-water (>1000m) origin. The sedimentary facies point to a bathyal-abyssal environment for the radiolarian fauna. Regionally, a late Paleocene basalt block in the bathyal-abyssal siliceous mudstone and greywacke yieded an age of 59.1 Ma (Zircon SHRIMP U-Pb) . The late Paleocene radiolarian fauna and the basalt block indicate that oceanic crust persisted in the Zhongba area until the late Paleocene and initial collision between the India and Eurasia plates post-dates the late Paleocene. It is inferred that the Neo-Tethys transformed into a remnant oceanic basin in the late Paleocene at the terminal stage of the oceanic crust subduction, and the closure of the remnant oceanic basin in the studied region took place after the late Paleocene.

Keywords: Radiolarians; late Paleocene; remnant oceanic basin; Yarlung Zangbo Suture

SPECIAL SYMPOSIUM II
SESSION 17

Biology and Paleobiology of Shelled Protista

Poster Core time (inc. lunch):

23/Oct (Mon), 12:40–14:40; 24/Oct (Tue), 11:15–13:15

Library Gallery of Ikarashi Campus, Niigata Univ.

P17-01	Fujii, M. et al.	A study on chemical composition of living acantharian (Radiolaria) shell
P17-02	Ichinohe, R. et al.	Planktonic capability of discoid spumellarian radiolarians
P17-03	Nakamura, Y. et al.	Cell division of phaeodarians—the first step to clarify the life cycle—
P17-04	Toyofuku, T.	Various imaging approaches revealing the secrets of foraminiferal calcification process
P17-05	Yuasa, T. & Takahashi, O.	Observations of the reproductive swarmer cells of polycystine and acantharian radiolarians in the east China Sea

A study on chemical composition of living acantharian (Radiolaria) shell

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Radiolarians can be divided into two major groups based on the chemical composition of shell: the first group, Polycystine, has opal ($SiO_2 + nH_2O$) shell, preserved from Cambrian to Recent sediments, and the second one possessing celestite ($SrSO_4$) shell called Acantharia. The acantarian shells do not remain as fossil because they melt in seawater after died. In this study, we examined the chemical composition of shells of both radiolarian groups, and their biomineralization process was estimated though culturing procedure.

A total of 11 radiolarian individuals were picked up from the plankton samples obtained from the surface seawater off Kashiwa-jima Island, Kochi prefecture, Japan, and culture experimental studies were conducted in the laboratory of Ehime University. The individual radiolarians were incubated under an artificial day-night cycle (day: night = 12 h : 12 h) at 27ºC with white and blue LED lights. One day after the settlements of radiolarians, the solution including fluorescent compound, HCK-123, was added into each well of the cell culture plate, and the radiolarian cells were left for 24–30 hours. The cultured cells were then mounted on slides, and observed by using a confocal laser scanning microscope (Carl Zeiss, LSM510). Certain fluorescent compounds such as PDMPO and HCK-123 have been used one of the tracers for biological silicification (ex. Shimizu et al., 2001; Desclés et al., 2007; Ogane et al. 2010), which can stain newly formed siliceous skeletons of microplanktons because these agents are incorporated in siliceous depositions during biogenic mineralization. Through this method, we found that Acantharian shells contain SiO_2 in the growth parts of their skeletons. Four specimens of Acantharia, *Acanthometra muelleri*, *Amphilonche complanata*, *Acanthostaurus conacanthus* and *Acanthometron pellucidum*, among culturing radiolarian specimens were clearly emitted fluorescence using by a fluorescent compound HCK-123 labeling. Each specimen shows fluorescence emission at the following parts: surface of spines and central soft parts for *A. muelleri*, proximal parts of spines and centrals for *A. complanata*, proximal surface parts of spines for *A. conacanthus*, and broken spines including its tip parts for *A. pellucidum*.

In order to further clarify the biomineralization process and Si-distribution in these acantharian shells, we also conducted FE-SEM and WDS analyses. The WDS analysis of *A. complanata* detected Si signals in a tip of spines. The FE-SEM analysis on the thin membrane films of the spine tip of *A. muelleri*, we observed Si signal from whole of the tip. Considering the results from these culturing experiments and WDS analyses in this study, it is suggested that living acantharian cells contain Silica, in particular on the active growth part of the skeleton. Further culturing study and WDS analysis of acantharian shells are required to confirm these suggestions.

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Keywords: Radiolaria, Acantharia, skeletal composition

Planktonic capability of discoid spumellarian radiolarians

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Adaptation to life at a stable water depth is crucial to the survival of zooplankton, including radiolarians, because the seawater column shows numerous environmental gradients such as temperature, nutrient, salinity and light intensity. Because their cells and shells are denser than seawater and therefore sink (Takahashi & Honjo, 1983), radiolarians may possess a unique capability for a planktonic mode of life except for the specialisation of buoyant organs such as the bubble-like structures of the collodarian radiolarian *Thalassicolla nucleata* (Anderson, 1983). It is likely that the pseudopodia function to generate an uplifting force in the seawater column, but this conjecture remains controversial. Using culture experiments, the spatial behaviours were examined to determine whether or not the discoid spumellarian radiolarians could surface under the condition of static seawater. Based on the experimental results, we discuss how they utilise the seawater column to maintain the planktonic lifestyle.

For the culture experiments, we used *Dictyocoryne* spp., *Spongodiscus biconcavus*, *Spongaster tetras*, and *Euchitonia elegans*, all of which were collected from near Sesoko Island, Okinawa, Japan. When discoid spumellarians were placed on the bottom of a water tank, many pseudopodia extended from both flat surfaces of the discs. Subsequently, the individuals rose but remained attached to the bottom, with the pseudopodia at the lower side of each disc (Fig. 1A). These results suggest that the discoid spumellarians examined herein lack the ability to surface by obtaining a lower density relative to the seawater. Although discoid spumellarians moved towards the downstream direction of convection flow, this occurred only in cases in which the pseudopodia were completely extended, under flow conditions of approximately 10 μm/s (Fig. 1B). When the convection flow moved upwardly, the individual also moved along the flow, thus surfacing. In addition, the convection flow altered the direction of a long, thick pseudopodium, the so-called axoflagellum (Matsuoka, 1992; Sugiyama & Anderson, 1997), keeping it parallel with the flow. Consequently, the axoflagellum was always oriented towards the downstream side, whereby one side of the disc faced upward. Given that the discoid spumellarians have symbiotic algae inside their cells (Takahashi et al., 2003), the unique planktonic capability leads to stable efficiency of algal photosynthesis, though the depth of the habitat would be constrained within the photic zone of the seawater column.

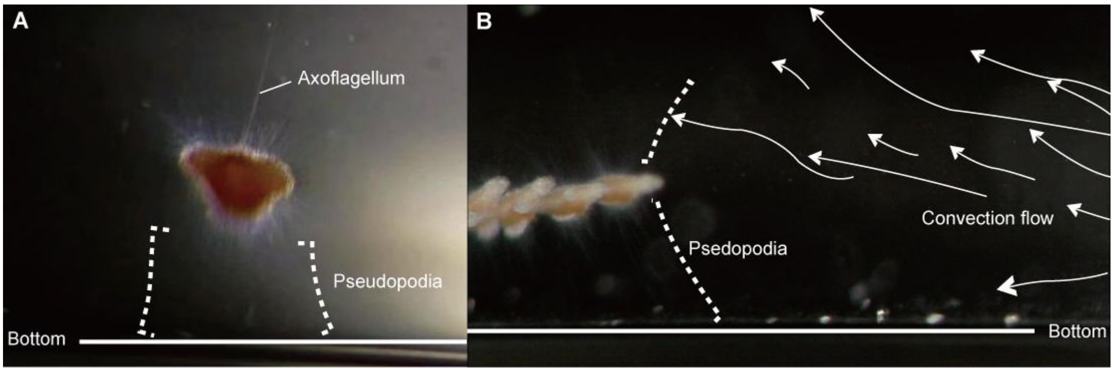

Figure 1. Spatial behaviours of discoid spumellarians. (A) Individual uplifted just above the bottom of the water tank, while the pseudopodiuma remained attached to. (B) Movement of an individual by means of via convection flow.

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Keywords: Spumellaria, floating mechanism, behavioural ecology, functional morphology

Cell division of phaeodarians—the first step to clarify the life cycle—

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Phaeodarians are a group of marine protests belonging to the phylum Cercozoa, composing Rhizaria (SAR) (Adl et al. 2012). The species belonging to Phaeodaria commonly have “central capsule” (including the nuclei) and “phaeodium” (mass of brown particles), and the most of them bear siliceous skeleton. These unicellular zooplankton occasionally show high biomass in the ocean (Nakamura et al. 2013), and they were found in the gut contents of fish, salps and crustaceans (e.g. Raymont 1983). Although phaeodarians have a great importance from the viewpoints of marine biology and fisheries science, their basic biological information is still wrapped in mystery. However, the clarification of the life cycle is indispensable for understanding their ecology, and therefore, culture experiments were conducted in this study to clarify their reproduction style.

Plankton were sampled from four stations in the Kuroshio region off Japan in 2015–2017. After the sampling, phaeodarians were individually isolated into filtered seawater and cultured at 27°C under a light : dark regime (12 h : 12 h). Each phaeodarian was photographed almost every three hours under the microscope. A part of the samples was cultured in the filtered seawater with HCK-123, which can label nascent silica, in order to visualize the skeleton formation. The labeled phaeodarians were then observed by a confocal laser scanning microscope. The underwater optics-based surveys by a Visual Plankton Recorder (VPR) were also conducted in different sea areas, to photograph the colonies of meshwork-type phaeodarians.

Two meshwork-type species, Aulosphaeridae sp. 1, Sagosphaeridae sp. 1 and one test-type species, *Gazelleta* sp. 1, were cultured in this study, because these species were the most frequently sampled. During the culture experiments of meshwork-type phaeodarians, the central capsule and phaeodium were first divided into four masses. These four masses then got out of the skeleton and formed four new daughter cells outside of the original skeleton (mother cell), 18 hours (in Aulosphaeridae sp. 1) and 12 hours (in Sagosphaeridae sp. 1) after the beginning of the cultivation. The mother cell and daughter cells remained connected several hours, forming a colony. The colonies of meshwork-type phaeodarians were also pictured by the VPR surveys. Cell division was observed also in *Gazelleta* sp. 1. In the ventral side of one individual, a new skeleton (daughter cell) was formed ca. 24 hours after the sampling. The observation of the phaeodarians treated with HCK-123 clarified that the silica is accumulated in the central capsule at first and then supplied to all over the skeleton, through the extended protoplasmic soft part and the tube-like structure inside the skeleton.

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Keywords: biogenic silica, cell division, Cercozoa, Phaeodaria, zooplankton, Radiolaria, Rhizaria

Various imaging approaches revealing the secrets of foraminiferal calcification process

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Calcareous foraminifera are considered as one of the major carbonate producer in ocean. Their tests are key tools as paleoceanographic indicators in various studies because their tests have been archived as numerous fossils in sediment for geologic time and various environmental information are brought by population, morphology and geochemical signatures as well as radiolaria fossils. Meantime, the production process of calcareous test itself is interested by many paleontologists because the process is exactly the timing of environmental information are recording. The knowledge about the environmental controls on chamber formation process has been documented over the century using by multi approaches. Scientists wish to understand that minute foraminiferal control of material uptake into shells from ambient seawater are of great interest.

Our previous studies showed the potential to understanding the biomineralization of foraminifera by the application of fluorescent indicators. Recently, we apply the method to show the spatial distributions of cytological calcium and pH of living cell and micro-environment around foraminifera (Toyofuku *et al.*, 2008; de Nooijer *et al.*, 2009; Toyofuku *et al.*, 2017). Observed results show that foraminifera controls pH and concentration of calcium at the site of calcification. Meantime, the surrounding water environments are also altered by its foraminifera activity. We show that calcification is driven by rapid transformation of bicarbonate to carbonate inside the cytoplasm, achieved by active outward proton pumping. We furthermore show that a V-type H^+ ATPase is responsible for the proton flux and thereby, calcification using with inhibitor of the enzyme. External transformation of bicarbonate into CO_2 due to the proton pumping implies that biomineralization does not rely on availability of carbonate ions, but total dissolved CO_2 in perforate foraminifera may not reduce calcification, thereby potentially maintaining the current global marine carbonate production.

Furthermore, conventional SEM observations are also major powerful weapon to figure the detailed morphology out even for the scene of calcification process of foraminifera. Recently, we concentrate to visualize both the soft tissue and the hard tissue simultaneously at the calcification site with the individuals with SEM. Though scientists have been minded that the importance of the detailed observation on the site of calcification, it was not really rose because there are some difficulties are remained. Since only the surface structure can be seen from outside on SEM, it can not be understood that there is such internal structures where is exactly the interesting events are progressing. Meanwhile TEM observation can show the cell structure, usually calcium carbonate is dissolved or calcium carbonate drops out during sample preparation procedure though the correlation between calcium carbonate and cellular activities are really interesting. Therefore, it was impossible to observe the correlation between the solution at the shell formation site and the precipitated crystals. To break this slow situation, we try to apply focused ion beam (FIB) technique to show the cross section of the site of calcification during the chamber formation (Nagai *et al.*, in prep). The calcification site will be described with size measurement to estimate the volume at the calcification site. This estimation will be key knowledge in considering the flux of materials in shell formation. These series of observation of SOC will give suggestions to consider about elemental incorporations and calcification pathway of the related species of foraminifera.

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Keywords: Foraminifera, Biomineralization, Calcification, Visualization, Laboratory Culture

Observations of the reproductive swarmer cells of polycystine and acantharian radiolarians in the east China Sea

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We have examined reproductive swarmer cells of polycystine and acantharian radiolarians in the east China Sea, using light, scanning and transmission electron microscopy. Those are one nassellarian *Pterocanium praetextum*; four spumellarians of *Didymocyrtis ceratospyris*, *Hexacontium pachydermum*, *Tetrapyle* sp., and *Triastrum aurivillii*; one collodarian *Sphaerozoum punctatum*; and two acantharian species.

The swarmer cells had varied in shape and size (see also Table 1), however, they all had a single crystalline inclusion of celestite ($SrSO_4$) in their cell bodies. Centering on the crystal inclusion, they swam in a rapid rotational movement both clockwise and anticlockwise.

Table 1. Comparison of the measurements and cell morphology of the swarmers of radiolarians.

		Cell shape	Cell size	Crystalline inclusion ($SrSO_4$)	Flagella	Lipid droplets
nassellarian	*Pterocanium praetextum*			○		○
spumellarian	*Didymocyrtis ceratospyris*	subspherical–ovoid	3.0–3.5 μm long, 2.0 μm wide	○ 1.0–1.5 μm	two unequal and tapered to whip-like ends	
	Hexacontium pachydermum		ca. 5 μm long	○	two unequal	
	Tetrapyle sp.			○		○
	Triastrum aurivillii	spindle-shape	3.7–5.5 μm long, 1.8–2.2 μm wide	○	two unequal and tapered to whip-like ends	
collodarian	*Sphaerozoum punctatum*	pear-like shape with a conical	8–10 μm long	○ ca. 5 μm	two unequal	○
acantharian	arthracanthid acantharia	pear-like shape	ca. 8 μm long	○	two unequal	
	caunacanthid acantharia	pear-like shape	ca. 8 μm long	○	two unequal	

The morphological features and molecular phylogeny of the reproductive swarmers show evidence of ancestral traits of radiolarians. The radiolarians might have arisen from a common progenitor with the ability to fix $SrSO_4$. After the acquisition of $SrSO_4$ fixation ability in Radiolaria, only the polycystines acquired the ability to fix SiO_2 through geologic time, and then the $SrSO_4$ constituted the main skeletal material in the acantharians.

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Keywords: acantharians, collodarians, nassellarians, reproductive swarmer cells, spumellarians, $SrSO_4$

SPECIAL SYMPOSIUM II
SESSION 18

Forms: An Interface between Function and Evolution

Poster Core time (inc. lunch):

23/Oct (Mon), 12:40–14:40; 24/Oct (Tue), 11:15–13:15

Library Gallery of Ikarashi Campus, Niigata Univ.

P18-01	Aita, Y. et al.	Diversity and newly revealed internal morphology of Middle Triassic Radiolaria *Glomeropyle* species
P18-02	Niimura, K. et al.	Detailed internal structures of Middle Triassic *Glomeropyle galagala*? and unnamed *Glomeropyle* sp. with the use of X-ray micro-CT
P18-03	Teshima, Y. et al.	Development of Enlarged Skeleton Models of Radiolaria (with Hands-on Exhibition)
P18-04	Teshima, Y. et al.	Development of Enlarged Skeleton Models of Foraminifera (with Hands-on Exhibition)
P18-05	Yoshino, T. et al.	Origami Representation of the Cortical Shell Structures of radiolarian *Pantanellium* (with Hands-on Exhibition)
P18-06	Ishida, N. & Kishimoto, N.	Submicron order three-dimensional imaging for polycystine radiolarians using X-ray micro-computed tomography
P18-07	Shiino, Y. et al.	Head or tail? Morphological analysis of the discoid spumellarian radiolarian *Dictyocoryne*
P18-08	Uetake, Y. et al.	Analysis of internal structure of Eocene *Lithochytris vespertilio* by Cross section Polisher method using a broad Ar^+ ion beam

Diversity and newly revealed internal morphology of Middle Triassic Radiolaria *Glomeropyle* species

Yoshiaki AITA[1], Rei KUKI[1], Sakurako SUZUKI[1], Kento NIIMURA[2], Kako MASHIKO[3], Yoshino ISHIZAKI[4] & Naoko KISHIMOTO[5]

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Radiolarian *Glomeropyle* is an endemic taxon that is restricted to oceans in the higher latitudes both of the southern and northern hemisphere during the Early to Late Triassic. In addition to the eight species from New Zealand and seven species from Russia belonging to the Triassic radiolarian genus *Glomeropyle* have been described (Aita & Bragin, 1999; Hori et al., 2003, Bragin, 2011, 2014; Bragin et al., 2012), at least other five new morphotypes are present yet to be described from North and South Island, New Zealand.

Since we have analyzed the 3-D images of morphology and internal structure of the genus *Glomeropyle* in order to understand the initial spicule system of the each species, we reported a new information of the internal structure on three species of *Glomeropyle, G. aurora, G. mahinepuaensis* and *G. grantmackiei* by using X-ray micro-CT (Aita et al., 2015). *Glomeropyle waipapaensis* occurred within the Middle Triassic (Late Anisian) from Mahinepua Peninsula, Arrow Rocks, Bull Creek and Kaka Point. A new data on the initial spicule of *G. waipapaensis* obtained by X-ray micro-CT is presented.

Outer shell of *G. waipapaensis* consists of a dome like upper half and funnel like lower half with four curved facets. The 3-D model shows that the initial spicule is composed of three Apical Rays, four Basal Rays and a Median Bar (MB). Seven spines are present and 4 short spines out of seven spines arise from the apex of neighboring three facets. The other three spines extend downward. Other species of the genus *Glomeropyle, Glomeropyle galagala*? and *Glomeopyle* sp. are also examined in terms of the initial spicule arrangement.

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Keywords: diversity, internal structutre, *Glomeropyle*, endemic, Middle Triassic, New Zealand, X-ray micro-CT

Detailed internal structures of Middle Triassic *Glomeropyle galagala*? and unnamed *Glomeropyle* sp. with the use of X-ray micro-CT

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The radiolarian genus *Glomeropyle* is a bipolar taxon that is restricted to oceans in the higher latitudes both of the southern and northern hemisphere during the Early to Middle Triassic. The genus has a large, globular to pyriform thick-walled cortical shell with a rounded aperture and pylome. Since the first seven species had been described from the New Zealand and NE Siberia by Aita and Bragin (1999), successive new studies revealed that eight species from New Zealand and seven species from Russia belonging to the genus have been reported (Hori et al., 2003, Bragin, 2011, 2014; Bragin et al., 2012). In addition, other five undescribed morphotypes are present from North and South Island, New Zealand.

On three species of *Glomeropyle aurora, G. mahinepuaensis* and *G. grantmackiei,* we have reported the 3-D images of morphology and detailed internal structure of these three species by using X-ray micro-CT (Aita et al., 2015). Although we partly presented the structure of *Glomeropyle* sp. (Niimura et al.,2017), we would newly present the internal structures of unnamed *Glomeropyle* sp. and *Glomeropyle galagala*? with the use of X-ray micro-CT (Skyscan Micro-CT in SEM) in order to make clear inter-species evolution of the genus *Glomeropyle.* The obtained micro-CT data was reconstructed as a 3-D model by OsiriX MD software.

The examined specimen of *Glomeropyle* sp. indicates its cortical shell consisting of several facets with radiating four spines; one is upward and the other three are laterally extended (Fig.1). The reconstructed 3-D image is made by 667 transmitted X-ray images. The specimen was collected from the manganese carbonate concretion of Unit 6, Oruatemanu Formation, Arrow Rocks. The initial spicule of *Glomeropyle* sp. is composed of three Apical Rays (3 ARs), four Basal Rays (4 BRs) and a median bar (MB), with several inter-connecting arches (Ach). The most characterizing feature shows that numerous arches between initial rays well developed and the presence of spine that does not directly connect with the initial ray.

Glomeropyle galagala? has a rounded, flattened outer shell with distinct two radiating spines and a tube-like pylome (Fig. 2). The reconstructed 3-D image is made by 470 transmitted X-ray images by using OsiriX MD software. The specimen examined with the use of X-ray micro-CT comes from the manganese carbonate concretion within the purple siliceous shale of Middle Triassic (Anisian) from Motutapu Island. A detailed internal structure of this species is presented.

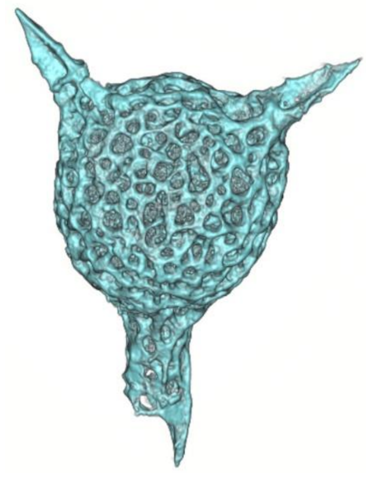

Figure 1. *Glomeropyle* sp.

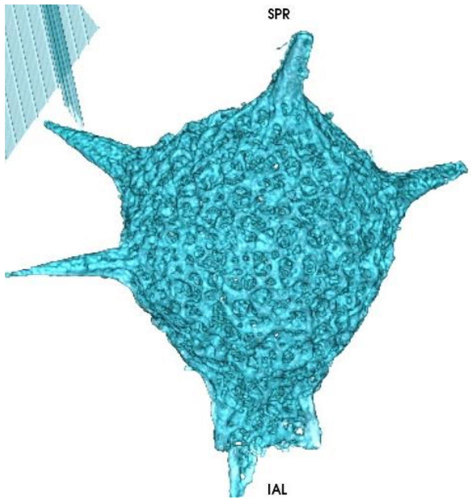

Figure 2. *Glomeropyle galagala*?

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Hori, R.S., Campbell, J.D. and Grant-Mackie, J.A., 2003. Triassic Radiolaria from Kaka Point Structural Belt, Otago, New Zealand. Jour. Royal Society of New Zealand, 33(1): 39-55.

Niimura, K., Mashiko, K., Ishizaki, Y., Kishimoto, N., and Aita, Y., 2017. The morphology and internal structure of the radiolarian genus *Glomeropyle* by using X-ray micro-CT: Part 1 *Glomeropyle* sp., Abstract with Programs 166th Regular Meeting, The Paleontological Society of Japan. January 27-29 2017, Shinjuku, Tokyo Metropolis. 40.

Keywords: internal structutre, *Glomeropyle*, Middle Triassic, New Zealand, X-ray micro-CT

Development of Enlarged Skeleton Models of Radiolaria (with Hands-on Exhibition)

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This paper presents the exact three-dimensional (3D) models of radiolaria. Their 3D shape data are measured using micro X-ray CT (computed tomography), and their exact 3D models are constructed using the additive manufacturing (AM).

Such exact 3D models are useful for tactile learning by the blind (Teshima et al., 2010). Moreover, the exact 3D models are also significant for researchers (Matsuoka et al., 2012; Ishida et al., 2015; Yoshino et al., 2015). The accurate models can be powerful tools that guide researchers' thinking and hypothesis in the right direction.

Figure 1. X-ray CT apparatus: ScanXmate-DF160TSS105 (belonging to JAMSTEC)

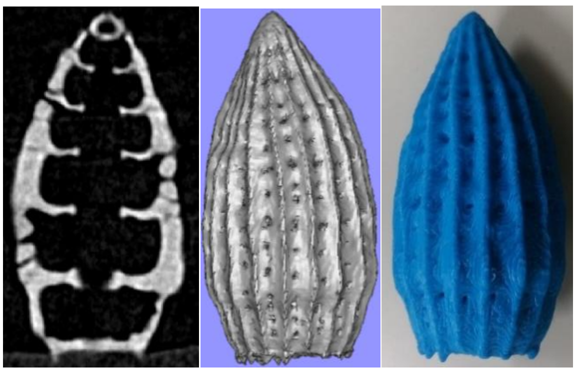

Figure 2. Left: Picture of computed tomography (*Archaeodictyomitra* sp.). Center: Modeling data after removal of noises. Right: Enlarged 3D model.

Twenty six microfossils of radiolaria were scanned by using X-ray CT. Twenty six types of modeling data (STL format) were generated, and noises were removed using STL editing software. Twenty one types of enlarged models of radiolaria were created by the AM technologies.

Figure 3. Twenty one types of enlarged skeleton models (to be exhibited)

References

Teshima, Y., Matsuoka, A., Fujiyoshi, M., Ikegami, Y., Kaneko, T., Oouchi, S., Watanabe, Y., Yamazawa, K., 2010. Enlarged Skeleton Models of Plankton for Tactile Teaching, Lect. Notes. Comput. Sci., 6180, 523-526.

Matsuoka, A., Yoshino, T., Kishimoto, N. Ishida, N., Kurihara, T., Kimoto, K., and Matsuura, S., 2012. Exact number of pore frames and their configuration in the Mesozoic radiolarian *Pantanellium*, An application of X-ray micro-CT and layered manufacturing technology to micropaleontology, Marine Micropaleontology, 88-89, 36-40.

Ishida, N., Kishimoto, N., Matsuoka, A., Kimoto, K., Kurihara, T., Yoshino, T., 2015. Three-dimensional imaging of the Jurassic radiolarian *Protunuma* ? *ochiensis* Matsuoka: an experimental study using high-resolution X-ray micro-computed tomography, Volumina Jurassica, XIII (1), 77–82.

Yoshino, T., Matsuoka, A., Kisimoto, N., Ishida, N., Kurihra, T., Kimoto, K., 2015. Polyhedron Geometry of Skeletons of Mesozoic Radiolarian *Pantanellium*, Revue de micropaléontologie, 58, 51-56.

Keywords: radiolaria, microfossil, X-ray CT, 3D printer, enlarged skeleton model

Development of Enlarged Skeleton Models of Foraminifera (with Hands-on Exhibition)

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The exact three-dimensional (3D) models of foraminifera are shown in this paper. Their 3D shape data are measured using micro X-ray CT (computed tomography), and their exact 3D models are constructed using the additive manufacturing (AM).

Such exact 3D models are useful for tactile learning by the blind (Teshima et al., 2010). Moreover, the exact 3D models are also significant for researchers (Matsuoka et al., 2012; Ishida et al., 2015; Yoshino et al., 2015). The accurate models can be powerful tools that guide researchers' thinking and hypothesis in the right direction.

Twenty six microfossils of foraminifera were scanned by using X-ray CT. Twenty six types of modeling data (STL format) were generated, and trivial noises were removed using STL editing software. These modeling data were made as real models once and further elimination of noise was performed on modeling data after indication of nonobvious noises by the experts of the foraminifera. Twenty types of enlarged models of foraminifera were created by the AM technologies which were the fused deposition modeling (FDM) and the selective laser sintering (SLS) .

Figure 1. X-ray CT apparatus: ScanXmate-DF160TSS105 (belonging to JAMSTEC)

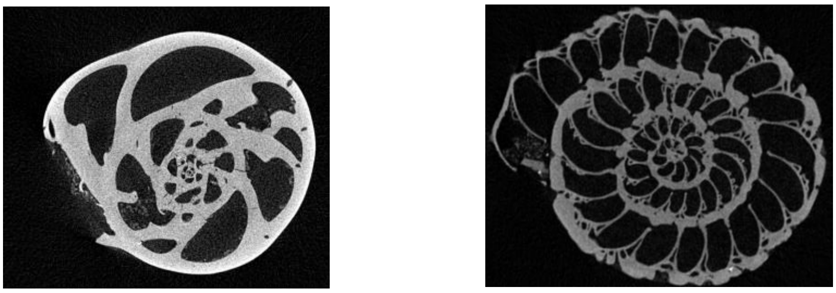

Figure 2. Picture of computed tomography. Left: *Cassidulina* sp., Right: *Elphydium* sp.

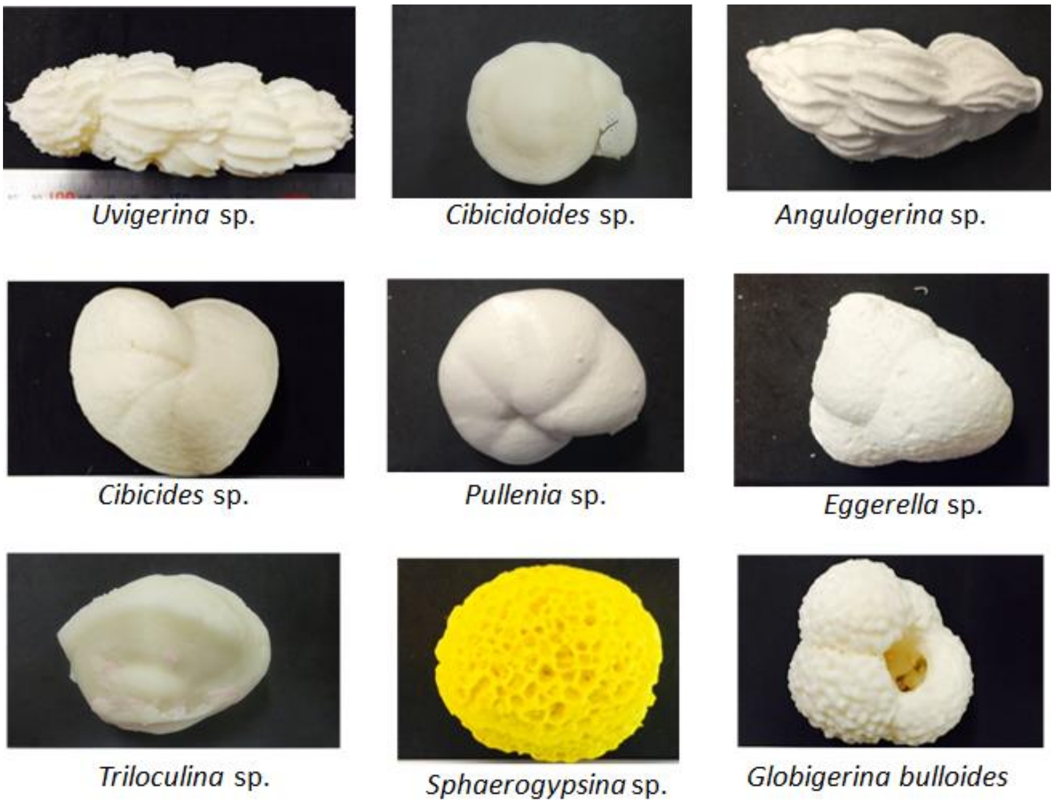

Figure 3. Enlarged skeleton models

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Keywords: foraminifera, microfossil, X-ray CT, 3D printer, enlarged skeleton model

Origami Representation of the Cortical Shell Structures of radiolarian *Pantanellium* (with Hands-on Exhibition)

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We made the origami models of the cortical shells of radiolarian *Pantanellium* using the method of unit origami (Fuse, 2006). The unit origami method is a composition of the equally folded paper parts called “unit”. This method was introduced for representation of the regular or semi-regular polyhedrons and can be classified into several types depending on the nature of the polyhedron to be made. We introduced “double-sided concave hexagonal ring unit” (“Kamenoko unit” in Japanese) which is used for the polyhedrons consisted of regular pentagons and hexagons mainly like a dodecahedron and a truncated icosahedron.

The origami models constructed in this study were based on the real skeletal structures of *Pantanellium*. The 3D data of skeletal structures were obtained by X-ray micro CT (Matsuoka et al., 2012 and Yoshino et al., 2015). The method for obtaining 3D data of the structures was same as Ishida et al. (2015). We transferred the 3D data to planar graphs (Yoshino et al., 2014) and constructed the skeletal models according to the graphs. We have eleven planar graphs obtained from eleven specimens at present. Figure 1 shows the examples of the planar graphs. All of the eleven graphs show different structures.

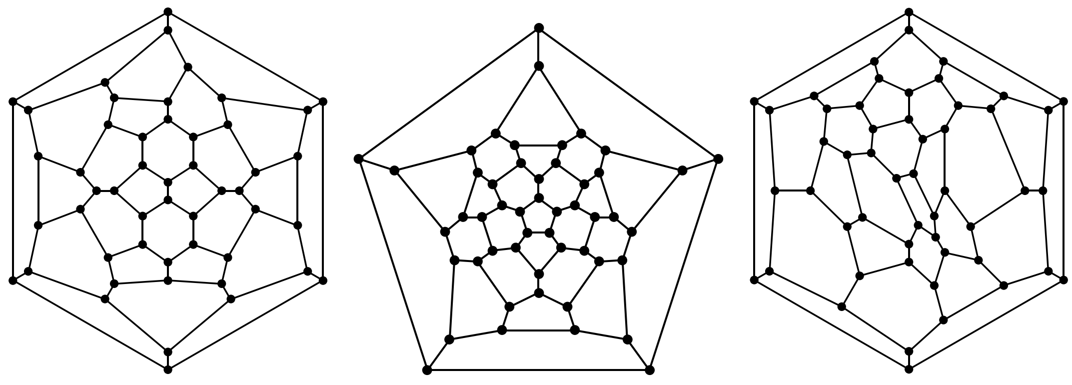

Figure 1. Examples of the planar graphs describing the cortical shell structure of *Pantanellium*.

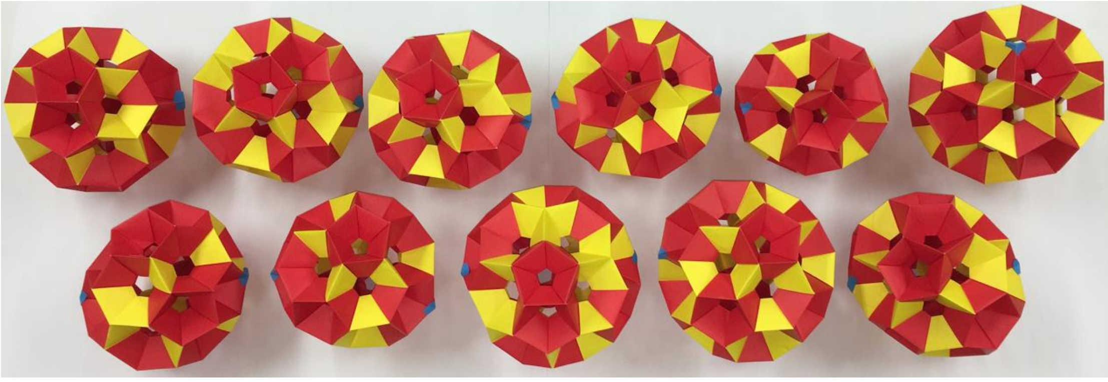

Figure 2. Origami representation of the cortical shells.

We succeeded in constructing all cortical shell models using the unit origami method. Figure 2 shows the picture of the real models. The fact that the pores of the most specimens of *Pantanellium* consist of almost equilateral pentagons and hexagons enables us to make the models. We used two colors as units in order to represent the location of the pentagons. This is because the arrangement of the pentagons is important to analyze the structure of the cortical shell (Matsuoka et al., 2012). The models show that the allocation of the pentagons was different among the specimens and there was no characteristic feature of the arrangements of pentagons and hexagons. The models are slightly different in their sizes because the number of pores is different, although the sizes of the units are same. We plan hands-on exhibition of some of the Origami representations with our poster.

The mechanism to produce this variation is still unclear. One of the possibilities is the sensitivities of reaction-diffusion equations to initial value distribution and radius of spherical surface (Yoshino, 2017).

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Keywords: origami, cortical shell, *Pantanellium*, skeletal structures

Submicron order three-dimensional imaging for polycystine radiolarians using X-ray micro-computed tomography

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X-ray computed tomography (CT), which is a nondestructive method of visualizing internal geometries of opaque objects, is commonly used for medical and industrial purposes. Several years of tests on the utility of our three-dimensional imaging system using micro-CT devices in radiolarian investigations have been conduced some innovative results: pore distribution analysis of the genus *Pantanellium* based on 3D scanning data (Matsuoka et al., 2012), automatic determination method for the pore numbers of spherical polycystine skeletons (Yoshino et al., 2014), and so on. Furthermore, Ishida et al. (2015) have been demonstrated effectiveness of the technique for paleontological description of radiolarians based on the case study of Jurassic radiolarian fossil *Protunuma* ? *ochiensis*.

Subsequent renewal of X-ray detector, target metal and some scanning parts improved the spatial resolution of this system to ca. 300 nm/pixel. A computer graphics (CG) of a specimen of the genus *Callimitra* is shown in Figure 1a. Apical, dorsal, and two lateral spines are interconnected by six delicate meshwork panels composed of lattice bars with diameters of 0.6 to 0.8 µm. As the meshwork structure is completely represented in the CG, this system certainly has a submicron resolution.

From the aspect of resolution, the 3D imaging system has performances comparable to SEM and biological microscope, which have been conventionally used for the description of radiolarians. As an example, fine structure of initial spicules of *Pterocorys zancleus* is shown in Figure 1b. An overwhelming advantage of this new method is the omnidirectional observation of the internal and external structures of a single specimen. This system has high practicality for analysis of polycystine skeletons. Several enlarged radiolarian models are displayed as a hands-on exhibition.

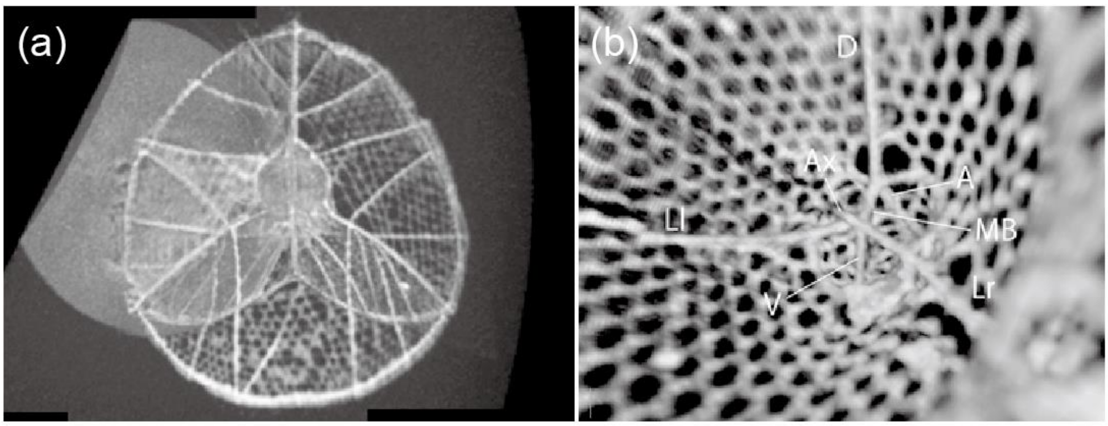

Figure 1. Computer graphics of polycystine radiolarian skeletons. (a) A specimen of the genus *Callimitra*. The height is 177 µm. (b) Initial spicules of *Pterocorys zancleus*.

References

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Matsuoka, A., Yoshino, T., Kishimoto, N., Ishida, N., Kurihara, T., Kimoto, K. & Matsuura, S., 2012. Exact number of pore frames and their configuration in the Mesozoic radiolarian *Pantanellium:* An application of X-ray micro-CT and layered manufacturing technology to micropaleontology. Marine Micropaleontology 88/89, 36–40.

Yoshino, T., Kishimoto, N., Matsuoka, A., Ishida, N., Kurihara, T. & Kimoto, K., 2014. Pores in spherical radiolarian skeletons directly determined from three-dimensional data. FORMA 29, 21–27.

Keywords: three-dimensional imaging, X-ray micro-computed tomography, polycystine radiolaria

Head or tail? Morphological analysis of the discoid spumellarian radiolarian *Dictyocoryne*

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The discoid form of radiolarians is one of key morphological innovations that may lead to a new level of ecological performance within the planktonic mode of life. Among the living discoid spumellarians, Genus *Dictyocoryne* is characterised in having a triangular discoid shell with spongiose structure of three arms and patagium (Matsuoka, 1992; Sugiyama & Anderson, 1997). In addition, the shell has a circular depression close to the triple junction of arms, which is an attachment trace of long, thick axopodium, the so called axoflagellum (Matsuoka, 1992). Such a morphological characteristic suggests a presence of head or tail of discoid shell in life time, while there is no precise examination of three dimensional morphology and adaptive strategy regarding the postural stability and spatial behaviour. As a preliminary step to understand the life posture in the seawater column, we examined morphological features of *Dictyocoryne* spp., with special reference to the centers of gravity and buoyancy in the siliceous shell and supposed living cell body.

Three-dimensional morphological data of *Dictyocoryne* spp. were constructed from X-ray CT images. The sequential cross-sectional images of the *Dictyocoryne* spp. were taken using a microfocus X-ray CT scanner. Subsequently, the volume data were translated into surface morphological data of shell model by the image-processing function of structural analysis software VOXELCON 2014 (Quint Corporation, Japan). The surface morphological data was implemented into the mesh-processing function of SC/Tetra (Cradle co. ltd., Japan), and its smoothly wrapping volume data were generated. The centers of gravity and buoyancy were calculated from the shell and wrapped models, respectively (Fig. 1).

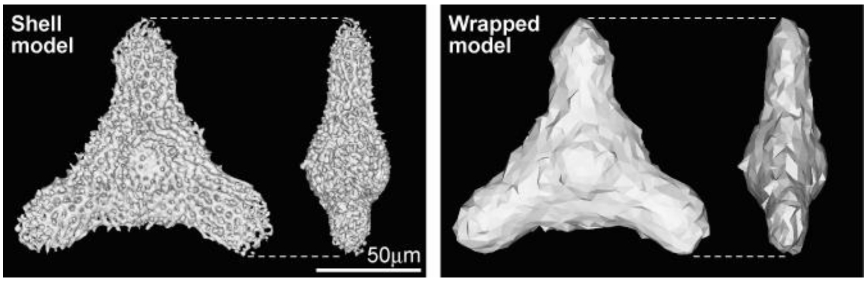

Figure 1. Shell and wrapping models of *Dictyocoryne*. The cell body was approximated to volume data that was generated to wrap the shell model smoothly.

Regardless of the shell size, the centers of gravity and buoyancy were close to the approximated-triangle center of gravity. In a larger individual, the center of gravity differs from the triple junction of three arms, because of smaller angle between the arms beside the patagium bearing a depression of axoflagellum. We here defined anterior and posterior directions of shell on the basis of the position of axoflagellum (Fig. 2). In lateral view, arms show gentle sigmoid appearance with its convex shape around the posterior part (Fig. 2A: lower). An anterior spine is tendency to be parallel to its arm, while two posterior spines obliquely extend to the opposite directions of axoflagellum (Fig. 2: Compare the direction of spine 2 with that of AX). Although the depression of axoflagellum still remains unclear in the present 3D models, the difference of spine angle is also recognised in the other individuals of *Dictyocoryne*. The presence of morphological direction in shell form may provide a postural orientation whereby one side of disc could be head or tail.

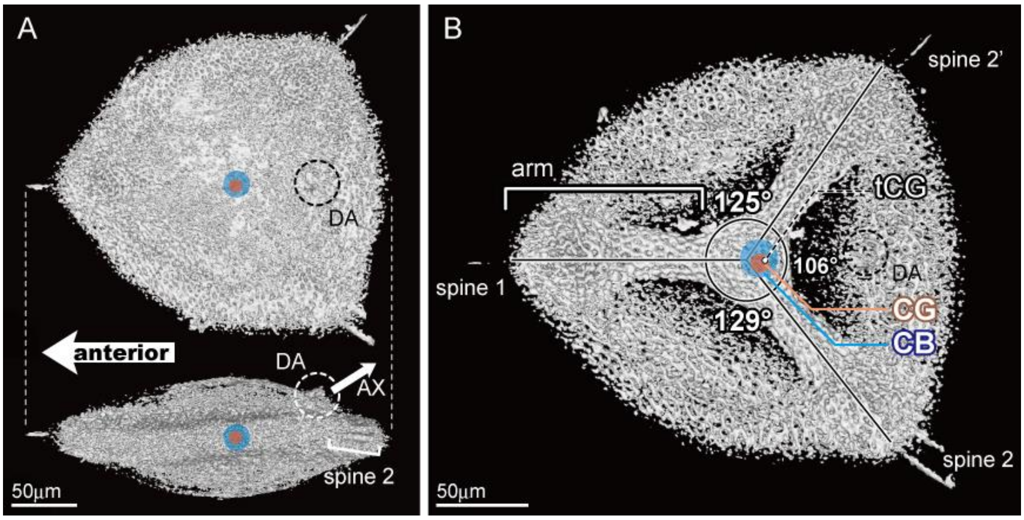

Figure 2. Centers of gravity and buoyancy in a larger individual. Shell model of *Dictyocoryne* (A), and its reduced version (B) are shown. The centers of gravity and buoyancy are close to the approximated triangle center of gravity (tCG), while the triple junction of arms is slightly anterior to the both centers. CG: center of gravity. CB: center of buoyancy. DA: depression of axoflagellum. AX: approximated direction of axoflagellum.

The discoid form has evolved from the spumellarians more than once through Phanaerozoic time, suggesting a typical example of morphological convergence. Previous studies revealed that *Dictyocoryne* possesses symbiotic algae (Matsuoka, 1992; Sugiyama & Anderson, 1997), and thus possibly resulting in the functional requirement of life posture for photosynthetic activity. Further morphological and functional analyses could provide a better explanation of how discoid radiolarians take an advantage in adaptation under the condition of the fluidic seawater.

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Keywords: ecomorphology, function, adaptation, morphotype

Analysis of internal structure of Eocene *Lithochytris vespertilio* by Cross section Polisher method using a broad Ar^+ ion beam

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Lithochytris vespertilio is a common Eocene Radiolaria which has a tetrahedral three-segmented shell with three short feet. Analyzing for understanding the internal cephalic structure of the species with a complex fine topology is important to enhance reliability for classification of Radiolaria [2]. To give a concise description of the nassellarian internal skeletal structure in nano-level, it is requiring with high spatial resolution and large depth of field. Since the scanning electron microscopy (SEM) has both features, it is suitable for radiolarian observation with high spatial resolution at sample surface. Because SEM utilizes the surface signals such as secondary electrons (SE), backscattered electrons (BSE) and characteristic X-rays, therefore we had to pick up a broken specimen and observe the internal structure from the open box when analysis of the internal structure is required. In addition, it is difficult to aim the region of interesting at siliceous skeleton of Radiolaria. For those reasons, SEM has not been used as a method for analysis the internal structure of Radiolaria. Recently, we have successfully developed a new product, the Cross section Polisher (CP) which is a method to prepare pristine cross section at intended area by a broad Ar^+ ion beam [1]. Since the CP method uses a broad Ar^+ ion beam, it is possible to process cross section in a short time with width of 1 mm, without applying mechanical stress to the specimen. Here, we have applied to use CP method for opening outer shell of *Lithochytris vespertilio* that is to be analyzing for the internal structure by SEM.

Schematic diagram of the CP method is shown in Fig. 1. A broad Ar^+ ion beam processes a pristine cross section to the region protruding from edge of shielding plate. The position of accuracy for CP method is less than ±5 μm. The processing condition was acceleration voltage of 4.0 kV for 30 minutes by using CP: IB-19530CP (JEOL Ltd.) (Fig. 2). The JSM-7200F (JEOL Ltd.) was used for high spatial resolution SEM imaging.

SEM image of the specimen before CP processing is shown in Fig. 3a, and after CP preparation is shown in Fig. 3b. It was confirmed that the initial spicular system was appeared within the segment between cephalis and thorax after CP processed a vertical section of the shell. Fig. 3c shows a magnified view of the initial spicule. It clearly shows that there are *MB* (median bar), *A* (apical ray), *V* (ventral ray), *LL* (primary lateral ray) and *II* (secondary lateral ray). In addition, *D* (dorsal ray) was appeared in the edge of *MB* by stage tilted image in Fig. 3d. Our observation clearly shows that initial spicule morphology seems shape like a sheet instead of a bar.

Now, combined system of both SEM and CP (SEM-CP) method has successfully applied to aim and observe internal nano-structure of skeleton of *Lithochytris vespertilio*. In this report, we would like to discuss about the principle of SEM-CP method and it's applications.

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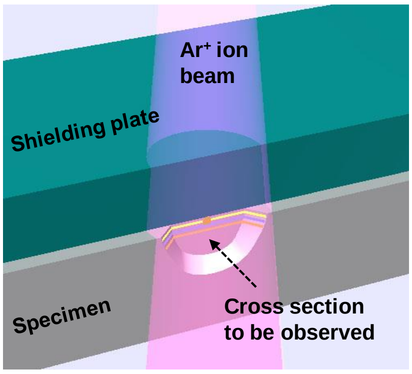
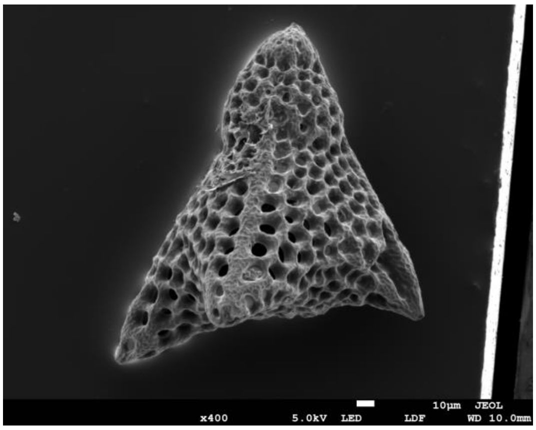
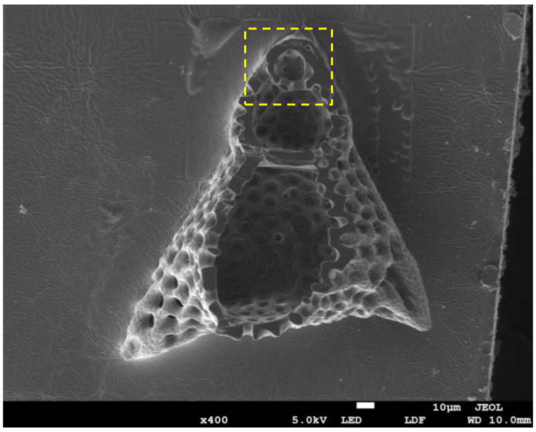


Figure 1. Schematic diagram during CP processing

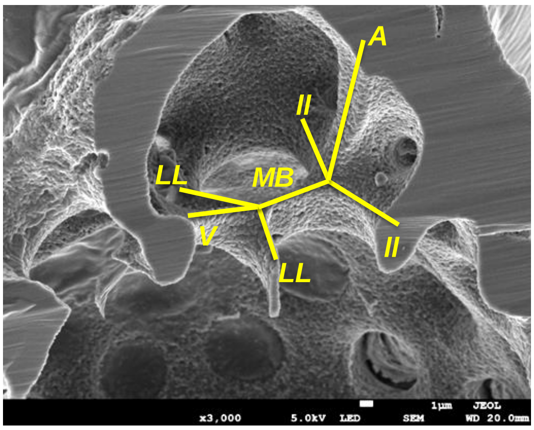
Figure 2. Overview of IB-19530CP (JEOL Ltd.)



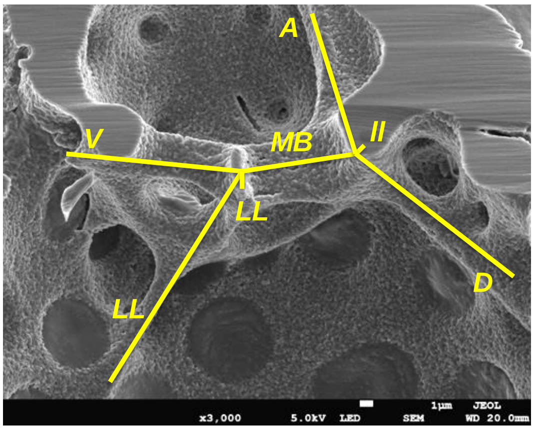
(a) Original specimen of *Lithochytris vespertilio*



(b) Cross section after CP preparation



(c) Magnified view of the initial spicules



(d) Tilted SEM image of the initial spicules

Figure. 3. SEM observation images of *Lithochytris vespertilio*

Keywords: scanning electron microscopy, Eocene, Nassellaria, classification, morphological analysis, internal skeleton

■ MEMO ■

General Symposium Session 19

Jurassic and Cretaceous Stratigraphy

Poster Core time (inc. lunch):

23/Oct (Mon), 12:40–14:40; 24/Oct (Tue), 11:15–13:15

Library Gallery of Ikarashi Campus, Niigata Univ.

P19-01	Bortolotti, V. et al.	The Jurassic-Early Cretaceous basalt-chert association in the ophiolites of the Ankara Mélange east of Ankara, Turkey: age and geochemistry
P19-02	Kamimura, M. & Hoyanagi, K.	Possibility for Jurassic/Cretaceous boundary identified from carbon-isotope stratigraphy of the Tetori Group in Shokawa, Gifu Prefecture, central Japan
P19-03	Li, X. et al.	Phylogeny and spatial distribution of the early Cretaceous radiolarian *Turbocapsula*
P19-04	Matsumoto, K. & Matsuoka, A.	Newly discovered marine beds in the Lower Jurassic Kuruma Group in the Otari Village, Nagano Prefecture, Central Japan
P19-05	Nishizono, Y. & Yonemitsu, I.	Jurassic radiolarians from Toyora Group, Southwest Japan
P19-06	O'Dogherty, L. et al.	Radiolarian stratigraphy from the proposed GSSP for the base of the Aptian Stage (Gorgo Cerbara, Umbria-Marche Apennines, Italy)
P19-07	Sakai, Y. et al.	The Early Cretaceous fossil plants from the Itsuki and Nochino formations of the Tetori Group in the Kuzuryu area, central Japan and their paleoclimatic implications
P19-08	Sakata, R. & Matsuoka, A.	Lithostratigraphy and bivalve associations of the Lower Jurassic Niranohama Formation in the Hashiura area, South Kitakami Belt, Miyagi Prefecture, Northeast Japan
P19-09	Taketani, Y.	Lowermost Cretaceous radiolarian assemblage from the South Kitakami Terrane, Northeast Japan
P19-10	Tamura, T. et al.	Lithostratigraphy and biostratigraphy of the Tomizawa and Koyamada Formations in the Somanakamura Group, Northeast Japan — Jurassic–Cretaceous transition beds in the eastern margin of Asia
P19-11	Yoshino, K. et al.	Integrated mega- and micro- biostratigraphy of the Campanian–Maastrichtian Izumi Group, Southwest Japan –Application to the Songliao Basin–

The Jurassic-Early Cretaceous basalt-chert association in the ophiolites of the Ankara Mélange east of Ankara, Turkey: age and geochemistry

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In this work is reported a study on slide blocks including oceanic lavas associated with pelagic sediments within the eastern part of the Ankara Mélange. A detailed biochronological investigation of the radiolarian cherts and a detailed petrological characterization of the associated volcanic rocks in eight sections, east of Ankara, was carried out. The volcanic rocks are largely represented by basalts and minor ferrobasalts and trachytes. They show four different geochemical affinities and overlapping ages.

Late Jurassic - Early Cretaceous garnet-influenced MORB:

Section 5, south of Küre village (sample TU10.38); middle late Oxfordian to late Kimmeridgian-early Tithonian (UAZ. 9-11) based on the presence of *Podocapsa amphitreptera* Foreman and *Zhamoidellum ovum* Dumitrica.

Section 5, south of Küre village (sample TU10.36); early-early late Tithonian (UAZ. 12) based on the occurrence of *Cinguloturris cylindra* Kemkin & Rudenko, *Eucyrtidiellum pyramis* (Aita), *Ristola cretacea* (Baumgartner) and *Loopus primitivus* (Matsuoka & Yao).

Section 8 - northeast of Yukariöz village (sample TU10.47); late Valanginian-early Barremian (UAZ. 17-21) for the presence of *Cana septemporatus* (Parona).

Early Cretaceous enriched-MORB:

Section 4, southeast of Bogazkale (sample TU10.31); middle late Barremian-early early Aptian for the occurrence of *Aurisaturnalis carinatus perforatus* Dumitrica & Dumitrica-Jud.

Section 7, road Iskilip - Tosya (sample TU10.45); Valanginian to middle Aptian-early Albian (Valanginian to *Costata* Subzone of *Turbocapsula* Zone) for the presence of *Cryptamphorella clivosa* (Aliev) and *Praeconosphaera* (?) *sphaeroconus* (Rüst).

Middle Jurassic plume-type MORB:

Section 2, road Sorgun - Çekerek (sample TU10.11); early-middle Bajocian to late Bathonian-early Callovian (UAZ. 3-7) based on the presence of *Stichomitra* (?) *takanoensis* Aita.

Late Jurassic - Early Cretaceous alkaline basalts:

Section 3, Gökdere village (sample TU10.28); middle-late Oxfordian to late Kimmeridgian-early Tithonian (UAZ. 9-11) for the presence of *Podocapsa amphitreptera* Foreman with *Fultacapsa sphaerica* (Ozvoldova).

Section 1, road Elmadag - Kırıkkale (sample TU10.4); late Valanginian to late Hauterivian (UAZ. 17-20) for the presence of *Aurisaturnalis variabilis variabilis* (Squinabol).

The coexistence of chemically different rock types from Middle Jurassic to Early Cretaceous times suggests that they were formed in a mid-ocean ridge setting from partial melting of a highly heterogeneous mantle characterized by the extensive occurrence of OIB-metasomatized portions, which were likely inherited from Triassic mantle plume activity associated with the continental rift and opening of the Neotethyan branch.

Keywords: Ophiolites, geochemistry, radiolarian biostratigraphy, Jurassic, Early Cretaceous, Ankara Mélange, Turkey.

Possibility for Jurassic/Cretaceous boundary identified from carbon-isotope stratigraphy of the Tetori Group in Shokawa, Gifu Prefecture, central Japan

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The Tetori Group is famous Middle Jurassic to Early Cretaceous marine and non-marine siliciclastic succession in Japan. The Shokawa area is one of the most important localities for discusstion of the stratigraphy of the Tetori Group. Biostratigraphy by annmonoid in the Shokawa area was reported by Sato et al. (2008), and that by bivalves was reported by Sha and Hirano (2012). Numerical ages in the Shokawa area were obtained by Gifu-ken Dinosaur Research Committee (1993) and Kusuhashi et al. (2006), respectively FT zircon age and U-Pb zircon age. However, these data indicated different ages on same formations. Hence this study attempted to estimate depositional age of the strata in Shokawa area by stable carbon isotope stratigraphy.

The Ushimaru, Akahoke, Mitarai, Otaniyama, Okurodani, and Amagodani formations are distributed in the study area. Total organic carbon (TOC) and organic carbon isotope ($\delta^{13}C_{org}$) were analyzed in these formations. Organic carbon isotopes ($\delta^{13}C_{org}$) in bulk sedimentary rocks of these formations show characteristic distribution of the carbon isotopic values. Their stratigraphic fluctuations have four negative peaks (Ns1-4) and three positive peaks (Ps1-3). These peaks may correlate with those from many Tethyan marine carbonate. The corresponding $\delta^{13}C$ peaks may suggest that the Ushimaru Formation was deposited from earlier late Kimmeridgian in age, the Akahoke Formation was deposited from earlier late Kimmeridgian to early Berriasian, the Mitarai Formation was deposited middle Berriasian, the Otaniyama Formation was deposited from late Berriasian to middle Hauterivian, the Okurodani Formaion was deposited from late Hauterivian to middle Barremian, the Amagodani Formation was deposited from late Barremian to early Aptian. The $\delta^{13}C_{carb}$ values in these ages in Tethyan marine carbonate sections indicate negative excursion before the weissert carbon isotope excursion on J/K boundary. On the basis of this correlation, this negative excursion could correlate with the age of upper Akahoke to Mitarai formations. It may indicate J/K boundary exist in these horizons. Further studies are needed in order to determine J/K boundary of the Tetori Group in the Shokawa area.

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Keywords: J/K boundary, Tetori Group, Shokawa, carbon isotope

Phylogeny and spatial distribution of the early Cretaceous radiolarian *Turbocapsula*

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The genus *Turbocapsula* was originally described based on mid-Cretaceous sediments collected from the Northern Apennines (Italy) and the Betic Cordillera (Spain) (O'Dogherty., 1994). This genus includes *Turbocapsula tetras* LI & MATSUOKA, *T. fugitiva* O'DOGHERTY, *T. giennensis* O'DOGHERTY, and *T. costata* (WU). *Turbocapsula* was a significant genus during the mid-Cretaceous period. Based on the phyletic evolution of Aurisaturnalis and Turbocapsula, two radiolarian zones have been defined: the Aurisaturnalis carinatus Zone and the Turbocapsula costata Zone (Li et al., 2017).

The species of the genus Turbocapsula have been reported in pelagic sediments in the Indian Ocean (Riedel & Sanfilippo, 1974; Renz, 1974), the Atlantic Ocean (Foreman, 1978), Spain (Aguado et al., 1991, 1993, 2014), Tunisia (Elkhazri et al., 2015), Italy (O'Dogherty, 1994), Austria (Ozvoldova, 1990), Poland (Gorka & Geroch, 1989), Montenegro (Goričan, 1994), Australia (Ellis, 1993), southern Tibet (Wu, 1986; Matsuoka et al., 2002; Ziabrev et al., 2003; 2004), and Ladakh (Zyabrev et al., 2008). Available paleomagnetic data suggest that the genus Turbocapsula bearing rocks in these localities accumulated in low- to middle latitudes of the Early Cretaceous paleoequator. The wide distribution of Turbocapsula indicates that this genus has a high tolerance of temperature. Therefore, the phyletic evolution of Turbocapsula is a useful indicator of radiolarian zonation for low- to middle-latitude assemblages.

However, no specimen of Turbocapsula has been reported from the contemporary strata in the Pacific Ocean. This means that Turbocapsula cannot be utilized for the Early Cretaceous radiolarian zonal correlations between Pacific and other regions.

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Keywords: Early Cretaceous, *Turbocapsula*, phyletic *evolution*, distribution

Newly discovered marine beds in the Lower Jurassic Kuruma Group in the Otari Village, Nagano Prefecture, Central Japan

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The Lower Jurassic Kuruma Group is distributed in the Japan Sea side of central Japan. The distribution of the group is divided into two areas, the main area and the eastern area (Kumazaki & Kojima, 1998). The age of the Kuruma Group in the main area is Late Pliensbachian–Late Toarcian based on ammonites (Sato, 1955 ; Kobayashi et al., 1957). On the other hand, that in the eastern area has not been determined yet by marine biota. There are a wide variety of bivalve fossils (Hayami, 1958, 1959, 1960a, b, 1961, 1962), but these bivalves are not able to give the sedimentary ages cleatly. The sedimentary environment in the eastern area was considered to be non-marine to brackish.

In this study, a geological survey was conducted on the Kuruma Group in the eastern area, especially on a large outcrop along the Himekawa River. Some crinoids and bivalves were newly found. The discovery of these fossils clearly shows the existence of marine environment in the eastern area.

These marine fossils from the eastern area can give a clearer basis for the geological age.

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Keywords: Japan, Kuruma Group, Bivalves, Crinoids, Low Jurassic, Pliensbachian, Toarcian

Jurassic radiolarians from Toyora Group, Southwest Japan

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The Toyora Group is typical Japanese Lower to Middle Jurassic system distributed at Yamaguchi Prefecture, Southwest Japan. Various fossils are occurred from Toyora Group, such as ammonoids, bivalves, corals and plants. Particularly, as the result that many studies on ammonoids in detail have been done from the beginning of the 20th century, Japanese typical ammonoids biostratigraphy has established in the Early to Middle Jurassic Toyora Group. However, microfossils such as radiolaria has not been reported despite researcher's much endeavors from the latter half of 1970s. Several years ago, radiolarian fossils are discovered, and its preliminary study was reported (Nishizono et al., 2009). After that, because detailed radiolarian ages are further examined, this outline is discussed in here.

Localities: Utano, Kikugawa-chou, Shimonoseki, Yamaguchi Pref. (39°09'N, 131°01'E)

Stratigraphy and Lithology of radiolarian localities: Toyora Group (Hirano, 1971) is consisted of three Formations: Higashinagano, Nishinakayama and Utano in ascending order. The Utano Formation is subdivided to four Members, such as Up, Ub, Uh and Ut from the bottom. Radiolarians are occurred in Uh and Ut Members. Radiolarian localities locate at the axial part and both wings of gentle antiform in Utano Formation. Uh Member is composed of massive hard black shales. Those of Ut Member is black sandy shales and alternated beds of sand and shale. Radiolarians are occurred in one locality of Uh Member, and six localities of Ut Member. All of those lithologies are black shales.

Faunal composition of radiolarians: *Paronaella pygmaea*, *Archycapsa pachyderma*, *Canutus* sp., *Dictyomitrella*(?) *kamoensis*, *Hsuum matsuokai*, *Parvicingula dhimenaensis*, *Stychocapsa convexa*, *Transhsuum* sp., *Th*. aff. *brevicostatum*, *Th*. aff. *hisuikyoense*, *Th*. aff. *robustum*, *Tricolocapsa plicarum*, *Unuma latusicostatus* and *U*. aff. *typicus*

Radiolarian ages: On the basis of radiolarian zonation established by Nishizono et al.(1997), coexisting of those in upper part of Ut Member is correlated to the *T. plicarum* zone, such as *A. pachyderma*, *S. convexa*, *U. latusicostatus* and *T. plicarum*. It is correlated to *Transhsuum hisuikyoense* zone that *A. pachyderma* and *S. convexa* are coexisted without *T. plicarum* at below this coexisting horizon. This correlation is not contradiction on the evidences that the resembling species of *Th. hisuikyoense* is found from sample UT2 , and *Hsuum matsuokai* is found from sample UT5 located at lower part of Ut Member. *Th. hisuikyoense* zone is correlated to Aalenian. *T. plicarum* zone is assigned as Bajocian to early Bathonian. It is estimated that the boundary of both radiolarian zones locates at middle part of Ut Member, which is located higher than the border of Uh and Ut Members; between samples UT5 and UT7.

Correlation with ammonoids age: Ammonoids are occurred from near the radiolarian localities of Uh Member is assigned as late Toarcian to early Bajocian, and that of upper Uh Member is Bathonian considering with inoceramids age(Hirano, 1973).

Because the boundary between *Th. hisuikyoense* zone and *T. plicarum* zone is located at middle of Ut Member, that of both radiolarian zones is assigned to after Bajocian; slightly younger than border between Aalenian and Bajocian.

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Keywords: Jurassic, radiolaria, ammonoids biostratigraphy, Toyora, Japan.

Radiolarian stratigraphy from the proposed GSSP for the base of the Aptian Stage (Gorgo Cerbara, Umbria-Marche Apennines, Italy)

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A revision of the radiolarian stratigraphy recorded at the proposed GSSP stratotype for the Barremian/Aptian boundary is presented. This revision encompasses the overlap interval of the biostratigraphic works carried out by Jud (1994) and O'Dogherty (1994) in the Gorgo Cerbara section.

We have re-examined a total of 52 productive samples yielding moderately to well-preserved radiolarians throughout the upper part of the Maiolica Formation and the Lower part of the Marne a Fucoidi Formation (up to the Lower Reddish Member). This interval corresponds to the stratigraphic levels 882m to 915m of Lowrie and Alvarez (1984), which are equivalent to -14m to 19m of Patruno et al. (2011). The Marne a Fucoidi consist of thick red pelitic levels with short intervals of whitish siliceous limestone beds and radiolarian sands, whereas the Maiolica is made up of whitish cherty limestones bearing discrete levels of black shales in its upper part. This sharp change in the lithology led to an uneven sample spacing, closer in the Marne a Fucoidi and looser at the upper part of the Maiolica Formation (46 samples from the Marne a Fucoidi Formation and only 6 form the upper part of the Maiolica Formation).

A detailed stratigraphic and taxonomic revision of the radiolarian assemblages from the uppermost Barremian–lower Aptian succession is presented, and a new subdivision of former radiolarian zones is proposed. In addition, we also present a brief analysis on the radiolarian turnover that occurred at the Barremian/Aptian boundary. The uppermost Barremian is characterized in Gorgo Cerbara by an important faunal crisis, encompassing the extinction of more than half of radiolarian species, whereas the earliest Aptian is characterized by a moderate and slow recovery (only a third of the fauna is renewed). An unusual biotic aspect is the absence of a true radiolarian extinction within the OAE-1a (Selli level), with the extinction of only seven radiolarian species immediately before or during the anoxic event and a high survivor number of species.

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Keywords: Cretaceous, GSSP, Aptian, Apennines

The Early Cretaceous fossil plants from the Itsuki and Nochino formations of the Tetori Group in the Kuzuryu area, central Japan and their paleoclimatic implications

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The Cretaceous was one of the most remarkable periods in geological history, with a "greenhouse" climate and several important geological events (Wang et al., 2014). The Early Cretaceous deposits in East Asia are dominated by non-marine successions, thus the palaeoclimatic reconstruction for this time interval largely depends on the terrestrial proxies. Plant fossils are important as the proxy. The Tetori Group is a Middle Jurassic to Early Cretaceous marine and non-marine sequence distributed in the Inner Zone of southwest Japan, on the eastern margin of Asia (Maeda, 1961) and yielded many plant fossils (e.g., Oishi, 1940; Kimura, 1987; Yabe et al., 2003).

Kimura (1987) classified the Late Jurassic and Early Cretaceous floras of East Asia into three types, the Tetori-, Ryoseki- and Mixed-type. The Tetori-type Flora flourished under warm-temperate and humid climate conditions. The Ryoseki-type Flora flourished under tropical to subtropical climatic conditions with an arid season. The former was distributed in the Inner Zone of southwest Japan, whereas the latter was distributed in the Outer Zone of southwest Japan. The mixed-type floristic provinces were distributed in between the Tetori- and the Ryoseki-type floristic provinces. The composition of the Tetori- and Ryoseki-type floras was completely different with no species in common. They were relatively uniform throughout the Late Jurassic to the Early Cretaceous (Kimura, 1987).

Fossil plants from the Tetori Group are known as the Tetori Flora. The Tetori Flora includes osmundaceous and dicksoniaceous ferns, and several taxa of *Podozamites* and Ginkgoaleans which are classified as Tetori-type (or Siberian) elements, which flourished under a humid warm-temperate climate (Kimura, 1987). In recent decade, some climate-indicator plants (such as thermophilic plants) have been reported from the Inner Zone of southwest Japan (Yabe et al., 2003). Some thermophilic plants were previously documented from the Lower Cretaceous Tetori Group (Yabe et al., 2003). However, the stratigraphic occurrences and diversity characters of plant taxa are still not clear.

We collected a variety of plant fossil specimens from the Kuzuryu area which has a standard stratigraphic section in the Lower Cretaceous Tetori Group. The Itsuki Formation is composed mainly of alternating beds of mudstone and sandstone, radiolarian chert-bearing conglomerate. The formation is tentatively regarded as Barremian in age based on fossil evidence, stratigraphic relationships between the underlying and overlaying sediments, and U–Pb dating of detritus zircon grain with a concordant age of 127.2 ± 2.5 Ma (Kawagoe et al., 2012). The overlying Nochino Formation is composed mainly of coarse-grained sandstone, orthoquartzite-bearing conglomerate and alternating beds of mudstone and sandstone. Plant fossils occur commonly in the alternating beds of the Itsuki and Nochino formations.

This study revealed that the late Early Cretaceous plant assemblages from the Nochino Formation have some thermophilic plants. The occurrence of thermophilic plants is considered to be the best indicator of floral and climatic change. The middle Early Cretaceous plant assemblage from the Itsuki Formation is characterized by osmundaceous and dicksoniaceous ferns, *Neozamites*, *Dictyozamites*, several species of *Nilssonia*, ginkgoaleans, several species of *Podozamites* as well as conifers with needle-like leaves. The assemblage indicates the Tetori-type floral elements but it is obvious that the composition of the late Early Cretaceous assemblage from the overlying Nochino Formation is different from the typical Tetori Flora. The late Early Cretaceous assemblage is characterized by gleicheniaceous ferns, ginkgoaleans, several species of *Podozamite*s and *Elatocladus* as well as microphyllous coniferous foliages such as *Pagiophyllum* and *Brachyphyllum*, and is considered to be the Mixed-type Flora including thermophilic plants. Our floral analysis suggests a distinct phenomenon of a major change in conifers around the boundary between the Itsuki and Nochino formations. We added these plant assemblages to fossil records known so far and reviewed the stratigraphic occurrence of fossil plants.

It had been presumed that the occurrence of the microphyllous coniferous foliages which favored climate with drying season is consistent with floral change and a warming and drying climate trend during the deposition time of the uppermost part of the Tetori Group (Yabe et al., 2003). However, this study suggests the possibility that such a trend started from the deposition time of the Nochino Formation earlier than previously thought. The floral change recorded in the eastern margin of East Asia represented by the Tetori Group may be reflected by the global climate change during the late Early Cretaceous time.

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Keywords: Early Cretaceous, Flora, Paleoclimate, Stratigraphy, Tetori Group

Lithostratigraphy and bivalve associations of the Lower Jurassic Niranohama Formation in the Hashiura area, South Kitakami Belt, Miyagi Prefecture, Northeast Japan

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The Lower Jurassic Niranohama Formation is brackish and shallow-marine sedimentary deposits in the South Kitakami Massif of Northeast Japan. The Niranohama Formation is a rare terrigenous sedimentary facies which was deposited in Hettangian age in Japan. The formation contains rich shell concentrations dominated by bivalves with minor gastropods, ammonites and belemnites.

Many bivalve fossils have been reported from the Niranohama Formation (e.g. Hayami, 1961). Hettangian bivalve assemblages in the Niranohama Formation are the most diverse benthic faunas in the brackish and shallow-marine environments in the world (Hallam, 1977). Sugawara and Kondo (2004) analyzed bivalve associations and sedimentary environments of the Niranohama Formation at the type locality. According to their results, the Niranohama Formation is composed of tidal flat, tidal channel fill, tidal channel margin, lower shoreface, and inner shelf deposits. Non-siphonate suspension-feeding bivalves such as *Vaugonia* are a dominant life habit group in shallow marine benthic environments and short-siphonate bivalves such as *Eomiodon* occur only in tidal flat deposit (Sugawara & Kondo, 2004).

To investigate the detailed lithostratigraphy of the Niranohama Formation is necessary to find out sedimentary process of these bivalve beds. We discussed lithostratigraphy of the Niranohama Formation of the Hashiura area (38°37'40"N and 141°27'45"E). As a result of lithostratigraphic analysis, the Shizugawa Group of the Hashiura area was divided into the Uchinohara Formation, the Niranohama Formation and the Hosoura Formation. The Uchinohara Formation is barren of fossils. Therefore there are two opinions. Kase (1979) suggested that the Uchinohara Formation is included in the Upper Triassic while Takizawa et al. (1990) suggested that it belongs to the lowest part of the Shizugawa Group of Jurassic age. However, in this study, we found the outcrop which suggests that the relationship between the Uchinohara Formation and the Niranohama Formation is conformable. Considering the results, the Uchinohara Formation is redefined as the lowest part of the Shizugawa Group.

We collected bivalve fossils from eight localities in the Niranohama Formation and recognized two bivalve associations; the *Eomiodon-Modiolus-Bakevellia* association in the lower part and the *Vaugonia* association in the upper part. The *Vaugonia* association includes belemnite fossils. Thus our results of the stratigraphic distributions of bivalve associations are similar to that presented in Sugawara and Kondo (2004).

It is possible that the Triassic-Jurassic (T/J) boundary of Northeast Japan is within the Uchinohara Formation or within the lower part of the Niranohama Formation. Further researches are needed to yield any findings where the T/J boundary is in Northeast Japan. These studies must focus on age and sedimentary process of the Uchinohara Formation.

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Keywords: bivalve association, sedimentary environment, Lower Jurassic, Triassic-Jurassic boundary, Shizugawa Group, Niranohama Formation, Hashiura area

Lowermost Cretaceous radiolarian assemblage from the South Kitakami Terrane, Northeast Japan

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Middle Jurassic to lowermost Crertaceous strata of the South Kitakami Terrane, Northeast Japan are composed mainly of terrigenous shallow marine formations intercalated with terrestrial ones, formed in the continental margin. Lowermost Cretaceous radiolarian assemblages are obtained from two areas of the South Kitakami Terrane. One of them is from the upper part of the Koyamada Formation of the Somanakamura Group distributed in the eastern margin of the Abukuma mountainous region (Matsuoka, 1989; Taketani, 2013). Another is from the Isokusa Formation of the Karakuwa group exposed along the Nagasaki coast in Oshima Island, the southeastern part of the Kitakami mountains (Taketani, 1987). Two formations, composed mainly of shale intercalated with tuff and fine sandstone layers, were formed probably on the outer shelf or continental slope based on the rock facies and fossil occurrence.

The radiolarian assemblages of the two formations are very similar, mainly composed of cryptocephalic and cryptothoracic Nassellaria, for example *Cryptamphorella, Hemicryptocapsa* and *Holocryptocanium*. Genera of *Archaeodictyomitra, Sethocapsa* and *Pantanellium* are also commonly yielded. The assemblage contains radioalraian species of Acaeniotyle umbilicata, Alievium regulare, Pantanellium squinaboli, Hemicryptocapsa capita, Holocryptocanium barbui, Pseudodictyomitra carpatica, Sethocapsa aff. kaminogoensis, Sethocapsa? zweilii, Stichocapsa pulchella, Svinitzium depressum, Svinitzium pseudopuga and Tethysetta boesii. The age of the assemblage is assigned to Berriasian to early Valanginian based on UAZones established in the Tethyan province by Baumgartner et al. (1995) and the radiolarian zones established in Japan and the western Pacific by Matsuoka (1995). The radiolarian age is not contradictive to the age (Berriasian to Valanginian) based on ammonites yielded from the Koyamada Formation (Sato & Taketani, 2008; Sato et al., 2011) and the lower part of the Isokusa Formation (Nara et al., 1994).

The radiolarian and ammonite assemblages of both formations are constituted of elements exclusively of the Tethyan to Pacific biogeographic province in the low to middle latitude. The sedimentary basin of the South Kitakami Terrane was surely situated in the province in the lowermost Cretaceous age.

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Keywords**:** radiolarian assemblage, lowermost Cretaceous, Koyamada Formation, Isokusa Formation, South Kitakami Terrane

Lithostratigraphy and biostratigraphy of the Tomizawa and Koyamada Formations in the Somanakamura Group, Northeast Japan — Jurassic–Cretaceous transition beds in the eastern margin of Asia

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The Somanakamura Group (Mori, 1963) is distributed along the eastern margin of Abukuma Mountains, Northeast Japan. It is exposed in a north-south directed narrow belt, about 27 km in length and 3–4 km in width. This group is composed of terrigenous sediments, with subordinate bituminous limestone lenses at its upper part. It represents a series of continental shelf sediments and river or lake deposits, accumulated on the Pacific coast in the Middle Jurassic to Early Cretaceous. The Somanakamura Group is divided into six formations; Awazu, Yamagami, Tochikubo, Nakanosawa, Tomizawa and Koyamada Formations in ascending order.

The study area is a construction site of the Joban Motorway in Minamisoma City, Fukushima Prefecture (Figure 1). Beds were well exposed when the highway was under construction during 2010–2013. The exposed geologic units are the upper part of the Tomizawa Formation and the Koyamada Formation of the Somanakamura Group. The Tomizawa Formation is composed mainly of coarse sandstone intercalated with mudstone and coarse tuff beds. Terrestrial fossils such as plants (Takimoto et al., 2008), spores and pollen (Li et al., 2015) are reported from the formation. This formation is regarded to be latest Jurassic (most likely late Tithonian) on the basis of stratigraphic relationship with ammonite-bearing beds of the underlying Nakanosowa Formation (Sato & Takatani, 2008) and the overlying Koyamada Formation (Sato & Takatani, 2008; Sato et al., 2011).

In the uppermost part of the Tomizawa Formation, tuff and tuffaceous sandstone beds become dominant and gradually change to the Koyamada Formation. The Koyamada Formation is subdivided into the lower member (45 m) and the upper member (150 m). The lower member is composed of tuff and tuffaceous sandstone, intercalated with mudstone beds. It is conformably overlain by the upper member. The upper member is composed mainly of siltstone, intercalated with fine sandstone, tuff and siliceous siltstone. Abundant marine fossils such as pelecypods, ammonites and radiolarians (Matsuoka, 1989; Sato & Takatani, 2008; Sato et al., 2011; Taketani, 2013) are reported from the Koyamada Formation. The age of this formation is Berriasian to probably Valanginian on the basis of these fossils. Spores and polen assemblages are also described in the Koyamada Formation (Li et al., 2015). The Jurassic/Cretaceous boundary is expected around the lithological boundary between the Tomizawa Formation and the Koyamada Formation.

Figure 1. New outcrops of the Tomizawa and Koyamada Formations along a construction of the Joban Motorway.

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Keywords: Somanakamura Group, Jurassic/Cretaceous boundary, ammonite, radiolarian, palynomorph

Integrated mega- and micro- biostratigraphy of the Campanian–Maastrichtian Izumi Group, Southwest Japan –Application to the Songliao Basin–

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The Cretaceous was a time of long-term climate stability with warm equable climates resulting from higher atmospheric greenhouse gas content by volcanic activity. However, it is insisted the global cooling had occurred during the Campanian–Maastrichtian by recent works (e.g., Linnert et al., 2014). It needs to establish a precise chronostratigraphic framework during the Campanian–Maastrichtian for discussion about the relationship between biota and the global cooling.

The Izumi Group is the upper Cretaceous marine deposit distributed in southwest Japan. This group yields mollusk, radiolarian, and terrestrial-derived palynomorphs such as spores and pollen (Morozumi, 1985; Hashimoto et al., 2015; Seike and Hirano, 2013). Therefore, the Izumi Group is favorable to establish an integrated mega- and micro- biostratigraphy that is applicable to the Campanian–Maastrichtian pelagic and terrestrial deposits. This study considers lateral tension of molluscan zone, palynomorph biostratigraphic framework, and compositional changes of radiolarian assemblage for establishment of the integrated biostratigraphy.

The Izumi Group is divided into three lithofacies: the Northern Marginal Facies (NMF), the Main Facies (MF), and the Southern Facies (SF). The NMF accumulated contemporaneously with the MF in different place within the basin. Most of the molluscan specimens and biozones have been recognized in the NMF (Morozumi, 1985; Shigeta et al., 2010). Meanwhile, radiolarian zones are established by specimens occurring mainly in the MF (e.g., Hashimoto et al., 2015). Thus, molluscan biostratigraphy is applicable only to the NMF, whereas radiolarian one is available only to the MF. To integrate both biostratigraphies, chronozones based on the time spans of molluscan zones are proved to be effective on both facies.

The *Pravitoceras sigmoidale* Zone within the NMF extends to the MF and thickens toward southwestern direction. The *P. sigmoidale* Chronozone also continues from the NMF to the MF (Yoshino and Matsuoka, 2016). It is interpretable that chronozones based on other molluscan zones continue into both lithofacies. In other words, these chronozones are applicable to the MF and/or radiolarian zones. Thus, molluscan biostratigraphy enables to integrate with radiolarian one.

Based on the first occurrences of marker genera and species of the genus *Aquilapollenites*, four palynomorph interval zones are defined in the Izumi Group (in ascending order): *Tricolporopollenites*, *Betulaepollenites*, *Toroisporis*, and *Hymenophyllumsporites* interval zones. Palynomorph-bearing horizons are insufficient to define zonal boundary precisely. However, the *Betulaepollenites*/*Toroisporis* zonal boundary is regarded as the same stratigraphic position of the *Pachydiscus awajiensis*/*Nostoceras hetonaiense* boundary. In other words, the

Betulaepollenites/*Toroisporis* zonal boundary approximates the Campanian/Maastrichtian (C/M) boundary within the Izumi Group.

The SK1 (N) is a core in the centre of the Songliao Basin. The stratigraphic position of the C/M boundary within the Songliao Basin has been controversial yet. Thus, the integrated biostratigraphy of the Izumi Group is expected to provide new insights into the stratigraphic position of the C/M boundary in the Songliao Basin. Four palynomorph interval zones are established (in ascending order): the *Jianghanpollis*, *Chenopodipollis*, *Toroisporis*, and *Betulaceoipollenites* interval zones (Yoshino et al., 2017). On the basis of co-occurring genera and species composition of *Aquilapollenites*, the *Chenopodipollis*/*Toroisporis* zonal boundary within the SK1 (N) could coincide with the *Betulaepollenites*/*Toroisporis* zonal boundary within the Izumi Group. In this case, it is implied that the former boundary corresponds with the *P. awajiensis*/*N. hetonaiense* and/or C/M boundaries of the Izumi Group. The C/M boundary within the SK1 (N) could be at 748.5 m depth according to palynomorph biostratigraphic correlation with the Izumi Group.

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Keywords: Latest Cretaceous, Campanian, Maastrichtian, Izumi Group, Songliao Basin, integrated biostratigraphy

■ MEMO ■

GENERAL SYMPOSIUM SESSION 20

Application and Outreach

Poster Core time (inc. lunch):

26/Oct (Thu), 12:00–14:00; 27/Oct (Fri), 11:30–13:00

Multi-purpose Space of TOKIMATE, Eki-nan Campus, Niigata Univ.

P20-01	Nagai, H. & Shiraki, K.	Japanese radiolarian study and education in the 19th century
P20-02	Matsuoka, A.	How to present diversity of geologic entities? – Proposal of Radiolarian age Diversity IndeX (RADIX)
P20-03	Trubovitz, S. et al.	How good are we at inventorying the biodiversity of radiolarian species?

Japanese radiolarian study and education in the 19th century

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Studies of radiolarian fossils and living radiolarians in Japan started in the early 1880s (Nagai & Shiraki, 2010; 2017). In 1883, Kikuchi Yasusi submitted his graduation thesis entitled “Report on the Geology of the Province Awa in Shikoku” and “On some Mesozoic Fossils of the Province Awa in Shikoku” to Carl Christian Gottsche, Professor of Geology and Paleontology of the University of Tokyo. Kikuchi noted in this thesis the occurrence of radiolarian fossils such as *Cenosphaera* and *Dictyomitra* from quartzite (present day chert) in the southeastern part of the Province Awa (present day Tokushima Prefecture) and considered them to be of Cretaceous age on the basis of the description of Zittel (1876). Kikuchi’s report was the first as to the occurrence of radiolarian fossils from the Japanese Islands (Kikuchi, 1883; Nagai & Shiraki, 2010). Naumann (1885), however, considered that the radiolarian remains were included in the Paleozoic strata from his study on structural geology in Shikoku. Thus, unfortunately the first report of Cretaceous radiolarians in Japan by Kikuchi has not been properly estimated for over a hundred years.

In June 1884, Miura Soujirou submitted his graduation thesis entitled “A brief Report on the Geology of Eastern Tosa” to Dr. Harada Toyokichi of the University of Tokyo. Miura (1884) found the occurrence of radiolarian quartzites from Kishimoto in Kagamigori; he noticed that the quartzites were very similar to the Cretaceous radiolarian quartzites discovered by Kikuchi (1883). Miura also mentioned the occurrence of similar radiolarian quartzites in the Mino and Musashi Provinces (Miura, 1884; Nagai & Shiraki, 2011).

Mitsukuri Kakichi was one of the researchers who observed living Radiolaria first in Japan (Nagai & Shiraki, 2017). In 1887, he reported on the Marine Biological Station of the Imperial University of Tokyo established in December 1886 at Misaki, Miura Peninsula, Kanagawa Prefecture. He mentioned in the report, “Of the Radiolarians we have seen some mostly of the Acanthometridae.” (Mitsukuri, 1887). Observations of living Radiolaria were done nearly 130 years ago.

Mitsukuri went to the United States of America in 1873 and studied zoology. In June to September 1879, he participated in a marine biological school, which was held at Chesapeake Bay by William Keith Broocks, Professor of Johns Hopkins University. In February 1881 he visited Europe (United Kingdom, France, Belgium, the Netherlands, Germany, Austria, Italy) and went back to Japan in December. In 1882, Mitsukuri became the first Japanese Professor of Zoology of the University of Tokyo (Unknown, 1910). He contributed to the establishment of the Marine Biological Station and performed the seaside practical training and education for students there. The Marine Biological Station served as a base for marine zoological studies including Radiolaria in Japan.

Mitsukuri visited USA and Europe again in 1897-1898. In the course of his American and European inspection journey, he got the radiolarian models. Later, the models of six radiolarian species were on sale for educational use. At that time Japanese names for radiolarian species were given first by Oka Asajiro, Professor of Tokyo

Higher Normal School (Unknown, 1901a). The radiolarian models were used not only for zoological education but also for the licensing examination of zoology (Nagai & Shiraki, 2017).

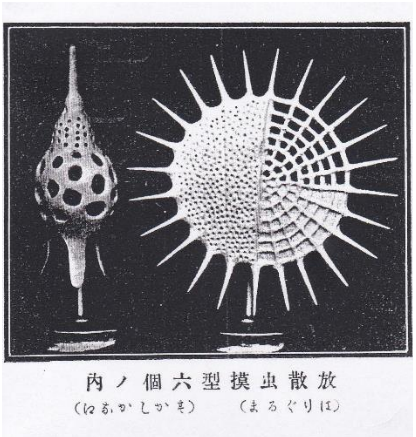

Figure 1. Radiolarian models (Tow of six species). Copy of the frontispiece from “The Magazine of Natural History”, 1901, Vol. 3, No. 30. (Unknown, 1901b). Right: Stylodictya multispina Haeckel はりぐるま (丘 Oka) Dim. 0.2 mm. Left: Podocyrtis schombourgii Ehrenberg ずかしかなえ（丘 Oka）

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Keywords: Radiolarian study in Japan, Radiolarian models, Kikuchi Yasusi, Mitsukuri Kakichi

How to present diversity of geologic entities? – Proposal of Radiolarian age Diversity IndeX (RADIX)

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Diversity is one of keywords in presenting features in nature. Species richness is a common criterion in evaluating diversity in ecological sciences. How can we recognize or describe diversities in geological sciences? Diversity may include numbers of rock types, mineral species, and a variety of fossils. We propose an index presenting age diversity of geologic entities in certain areas. This is referred as Radiolarian Age Diversity Index (RADIX).

RADIX is shown as a fraction. The denominator is 12, the number of the Periods from the Cambrian to the Quaternary. The numerator is presented by the total number of Periods evidenced by radiolarian fossils. The numerator may include the number of Periods which will be proved in the future. This can make the motivation to find out new radiolarian fossil evidence higher.

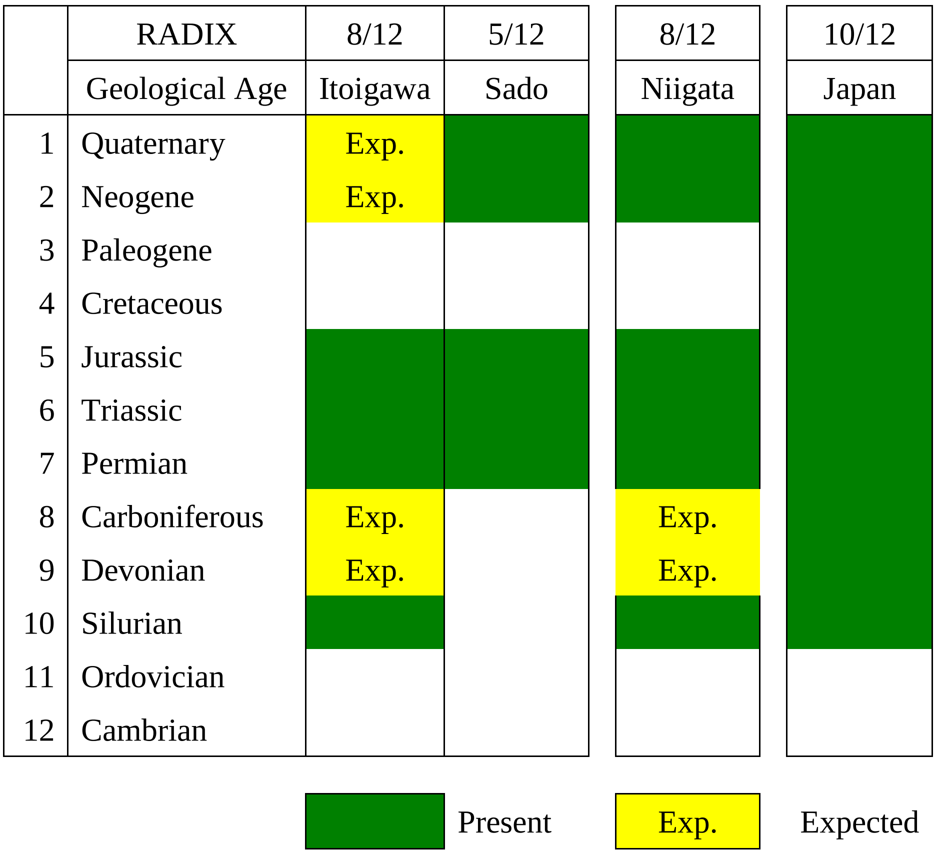

Figure 1. RADIX for Itoigawa City, Sado City, Niigata Prefecture, and Japan.

The entire area of Itoigawa City in Niigata Prefecture, central Japan is assigned to the UNESCO Global Geopark in 2009. The geopark is said to be characterized by highly diverse nature in geology. Figure 1 shows RADIX of the Itoigawa UNESCO Global Geopark for example. Silurian, Permian, Triassic, and Jurassic radiolarians were reported from the Itoigawa area (Ito et al., 2012, 2014, 2017; Kumazaki & Kojima, 1996; Tazawa et al., 1984; Ujihara, 1985). Devonian, Ordovician, Neogene, and Quaternary are categorized as expected periods. Therefore, RADIX of Itoigawa City is 8/12.

For comparison, RADIXs of Sado City in Niigata Prefecture, Niigata Prefecture, and Japan are also depicted in Figure 1. Because Niigata Prefecture includes Itoigawa, Sado and other cities, RADIX of Niigata Prefecture must be the same as or greater than that of any cities in Niigata Prefecture. Itoigawa City and Niigata Prefecture exhibit the same RADIX, 8/12, indicating that Itoigawa City has a quite high value of RADIX.

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Keywords: diversity, geological age, radiolaria, Itoigawa UNESCO Global Geopark

How good are we at inventorying the biodiversity of radiolarian species?

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Databases have gained increased importance over the last decade as archives for biodiversity studies. Approximately 236 radiolarian species are known from tropical-subtropical water column surveys and sediment core tops based on Takahashi (1991) and Boltovskoy *et al.* (2010). However, the extent to which these taxa are preserved in deep sea sediments and furthermore reported in fossil databases, such as Neptune (NSB), a database containing the fossil occurrences in DSDP-IODP publications, remains unclear. It is also unknown whether widely accessed taxonomic catalogues, such as radiolaria.org, adequately capture our current knowledge of both living and fossil species. Therefore, we test the fidelity of NSB to the living species inventory, and of radiolaria.org to all living and fossil species.

Modern species occurrence data were cross-checked against taxa appearing in the NSB taxonomic list from deep sea drill cores within 20 degrees of the equator and 0-2 Ma. A list comprised of all species described from deep sea sediments in NSB and as living tropical species in Takahashi (1991) and Boltovskoy *et al.* (2010), was compared to the radiolaria.org catalogue. An 8% Pacman trim (Lazarus *et al.*, 2012) was applied to the NSB species listings to remove outliers and problematic occurrences. Synonymous species were combined whenever possible to avoid inflating either fossil or living diversity.

Preliminary results indicate that of the 236 living species, only 40 (17%) match fossil taxa in NSB. In addition, of the 68 recent tropical taxa listed in NSB only 28 are found in either living species database. This may be at least partially attributable to extinctions in the last 2 m.y., and even more to synonyms that we have not yet recognized. Therefore, this low percentage of living species in NSB is expected to rise as we resolve additional synonyms. Compared to to NSB, a notably higher percentage of living taxa appears in radiolaria.org (47-58%, depending on how species are synonymized). Radiolaria.org also includes between 42% and 52% (depending on synonymies) of a combined list of tropical recent taxa from NSB, Takahashi (1991), and Boltovskoy *et al.* (2010). This is likely due to the site's inclusion of both living and fossil specimens from a diverse set of data sources.

Overall, our initial analyses show that living species are only listed in the fossil database 17% of the time, and approximately half of known species are listed in the radiolarian.org species catalogue. A myriad of processes may contribute to this discrepancy, including the failure of delicate species to preserve in sediments. Another probable cause is the practice in most deep-sea drilling studies of selectively identifying biostratigraphically relevant species in an assemblage while not fully cataloging all species present in the core sample (Lazarus, 2011). A comparison of taxa lists between Southern Ocean radiolarian plankton (Abelmann, 1992) and comprehensive biodiversity surveys of Southern Ocean Pleistocene sediments (Renaudie and Lazarus, 2013) suggest that most of the discrepancy seen in the tropical sediment data is not preservational but simply failure to report 'non-useful' species in applied studies. A forthcoming biodiversity census based on comprehensive taxonomic counts of recent taxa in tropical sediments will be used in this presentation to formally assess the ultimate sources of bias in the radiolarian fossil record. This will help unravel the relative contributions of taphonomy and recording practices to database gaps. These results have strong implications for a wide range of radiolarian studies, as they demonstrate the extent to which the fossil record and our databases represent past biodiversity.

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Keywords:

■ MEMO ■

GENERAL SYMPOSIUM SESSION 21

Oceanography

Poster Core time (inc. lunch):

26/Oct (Thu), 12:00–14:00; 27/Oct (Fri), 11:30–13:00

Multi-purpose Space of TOKIMATE, Eki-nan Campus, Niigata Univ.

P21-01	Bole, M. et al.	Oxygen isotopes and trace element stratigraphy of the Middle Jurassic radiolarite section at Colle di Sogno, Lombardy Basin, N-Italy
P21-02	Kamikuri, S. & Moore, T.C.	Reconstruction of oceanic circulation patterns in the tropical Pacific across the early/middle Miocene boundary as inferred from radiolarian assemblages
P21-03	Rogers, J.	A new species of *Spongodiscus* (Radiolaria: Spongodiscidae): its description and occurrence
P21-04	Umeda, M.	Devonian and Carboniferous Radiolarians from the Deep-Sea Pelagic cherts of the New England Fold Belt, Eastern Australia

Oxygen isotopes and trace element stratigraphy of the Middle Jurassic radiolarite section at Colle di Sogno, Lombardy Basin, N-Italy

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Trace elements are commonly used to evaluate productivity and redox conditions in sediments associated with organic matter (c.f. Tribovillard et al. 2006). In sediments, trace elements are mainly associated with clays, with organic matter or with precipitates due to redox conditions. To discard the influence of the clay content, they are usually expressed as enrichment factor relative to post Archean shales. Under oxic conditions, organic matter is degraded by organisms using normal aerobic respiration. When oxygen becomes limited, anaerobic organisms replace the aerobic organisms. Anaerobic respiration is less efficient and involves redox reactions. Low oxygen availability thus increases the preservation of organic matter. A high flux of organic matter can lead to anoxic conditions if all oxygen is consumed by the aerobic decomposition of organic matter.

We measured trace element concentrations in radiolarites of the Sogno section (Lombardian Basin) which were deposited in a restricted basin and we observed that trace elements covary with the $\delta^{18}O$. This relation suggests that the oxygen restriction in this basin was influenced by the productivity of radiolarians which.in turn, was driven by climate.

The Torre de Busi section is directly in the southward continuity of the Sogno section (c.f. Baumgartner, 1995). The siliceous strata of this section start with about 16m of Bajocian-Bathonian dark greenish-grey radiolarites (Basal Radiolarites). They grade upsection into red radiolarites (Knobby Radiolarites). The Knobby Radiolarites measure about 24m and they progressively pass upsection to Oxfordian ribbon bedded limestones (Rosso Ad Aptici formation). The greenish color of the Basal Radiolarites suggests that they were deposited under reducing conditions. The Mo/U ratios clearly indicate that these radiolarites were deposited in a restricted basin. Stratigraphic observations on these radiolarites by Ikeda et al. (2016) have revealed that dark layers generally co-occur with high chert abundance in the first 8m of the Basal Radiolarites. This relation suggests that during their sedimentation, the radiolarian productivity was responsible of the oxygen depletion. In the remaining 8m of the Basal Radiolarites, the dark layers do not coincide with high chert abundance. This observation may indicate that times of stratified waters, responsible for the reducing conditions, alternated with periods of mixing, favorable to radiolarian productivity.

In the Basal Radiolarites, the enrichment of trace elements increases up to a maximum at about 4m and then decreases in the following 8m before restarting to rise on the remaining 4m. These variations of our trace elements are positively correlated to the variations of the $\delta^{18}O$ measured in radiolarites, suggesting a coupling between them. The peak of the enrichment factors at 4m supports that productivity was responsible of the oxygen depletion in first part of the Basal Radiolarites. It is interesting to note that the change of the relation between the chert abundances and the dark layers occurrences takes place at 8m which is a potential inflection point based on the variations of trace elements. For us, it is clear that the relation between the chert abundances and the dark layer occurrences was forced by the productivity associated with radiolarians and that this productivity is recorded in trace elements. Moreover, the TOC and Sulphur content continuously increase in the Basal Radiolarites indicating that the restriction persisted and probably became stronger through time. The decrease of the Mo_{Ef}/TOC ratios in the Basal Radiolarites supports this conclusion. Regarding the $\delta^{18}O$, we believe that the peak of productivity at 4m is due to more humid conditions around the Tethys driven by a cooling. In contrast, the minimal productivity at 12 m probably occurred during a warmer and dryer period, occasionally disturbed by Monsoons. These Monsoons can explain the occasional mixing of the generally stratified water column resulting in less dark layers associated with high chert abundance.

The passage to the Knobby Radiolarites is quite abrupt on the field but we unfortunately lack geochemical data to characterize this passage. Nevertheless, we observed in the Torre de Busy section (24-40 m) a global decline of trace elements, of TOC, of Al and potentially of silicon isotopes and a gradual increase in carbonates. The decreases are interpreted as a decline of radiolarian productivity. In the Knobby radiolarites, trace elements are no longer correlated to the $\delta^{18}O$ of radiolarites. The $\delta^{18}O$ stays more or less constant at the same value than the topmost of the Basal Radiolarites. This observation may support that the restriction in the Sogno Basin was in part driven by climate. The progressive increase of carbonates suggests a tendency toward more oligotrophic conditions during cooler climate favouring calcareous nanoplankton and periplatform ooze. The decrease of Al can indicate either a dilution by these carbonates, or an increase of the distance from continents associated with the opening of the Alpine Tethys. In this frame, the opening up of this ocean may be responsible of a better oceanic circulation and of the disappearance of restriction in the marginal basins surrounding the Tethys.

The relation of trace elements and oxygen isotopes in the Basal Radiolarites is particularly interesting to evaluate environmental factors affecting the restriction in the Sogno basin. At the exception of one sample reaching 10%, the TOC in our cherts was generally less than 0.1%. Our study thus also confirms that trace elements can be used in radiolarites with low TOC content and not only when these rocks are associated with high TOC content.

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Keywords: Traces elements, Oxygen Isotopes, Jurassic Radiolarites, Sogno, Lombardy Basin

Reconstruction of oceanic circulation patterns in the tropical Pacific across the early/middle Miocene boundary as inferred from radiolarian assemblages

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Although there have been attempts to infer oceanic circulation patterns in the tropical Pacific on the basis of multiple marine proxies covering the Neogene, it is still poorly understood despite significant changes to the paleoclimate that occurred over this interval. In this study, we reconstruct the changes in tropical oceanic circulation patterns in the Pacific across the early/middle Miocene boundary based on radiolarian assemblages obtained at Integrated Ocean Drilling Program Site U1335 in the eastern tropical Pacific.

The relative sea surface temperature based on the radiolarian temperature index (RTI) was slightly high from 16.8 to 16.0 Ma and gradually decreased from 16.0 to 14.6 Ma. Subsequently, the temperature decreased stepwise at 13.9 and 13.4 Ma and became relatively low from 13.4 to 12.7 Ma. Comparison of the RTI record in the eastern tropical Pacific to the climatic index based on the benthic foraminiferal $\delta^{18}O$ record shows that variability in the two records follows a roughly similar trend from the early to the middle Miocene. However, the sea surface temperature record does not indicate a sharp increase in warmth in the eastern tropical Pacific during the mid-Miocene climatic Optimum-1 (MMCO-1). This is likely because of increased upwelling of cool, nutrient-rich water at this time.

Beginning in the latest early Miocene (~17 Ma) radiolarian assemblages were dominated by different taxa in the eastern and western tropical Pacific. This pattern is interpreted as indicating a shallower thermocline in the east and a deeper thermocline in the west, based on the relative abundance of the upwelling taxa. There is an overall increasing trend in this difference since the latest early Miocene. We tie these events to the effective closure of the Indo-Pacific gateway and the development of a substantial western Pacific warm pool along with the development of a strong Equatorial Undercurrent.

Keywords: radiolarian assemblage, tropical Pacific, east-west thermocline gradient, MMCO

A new species of *Spongodiscus* (Radiolaria: Spongodiscidae): its description and occurrence

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The test of this previously undescribed ***Spongodiscus*** is a spongy disc of approximately uniform thickness with a large V-shaped notch reaching close to the disc's centre (Figure 1). Radiating from the apex of the notch and following the edges of the notch are three or four large conical spines. The rim of the disc (apart from the notch edge) is slightly irregular with occasional short spines protruding. The disc is typically 170-250 µm across although much smaller specimens (60 µm) have been observed. The major spines protrude around 30 µm beyond the perimeter of the disc.

This *Spongodiscus* has, to date, only been observed in four southern Indian Ocean cores – MD88-769 [46°04′S 90°06′E], MD88-770 [46°01′S 96°27′E], MD94-102 [43°30′S 79°50′E], and MD94-103 [45°35′S 86°31′E] – and no more recently than 7.4 ka. The majority of the specimens found are in MD88-103, although the largest number in any one sample is from core MD88-769 which is nearer to MD88-103 than either of the other two cores. Almost all the specimens discovered are in samples from before 30 ka. Despite extensive searches, so few specimens appear since 30 ka that the species may be close to extinction, in this region at least.

It is concluded that conditions during MIS-3 favoured this *Spongodiscus* in the southern Indian Ocean near the Polar Front. Identification of the species in another area or in a different age range could provide additional information about the ocean environment.

Keywords: new *Spongodiscus* species; southern Indian Ocean; MIS-3; Polar Front

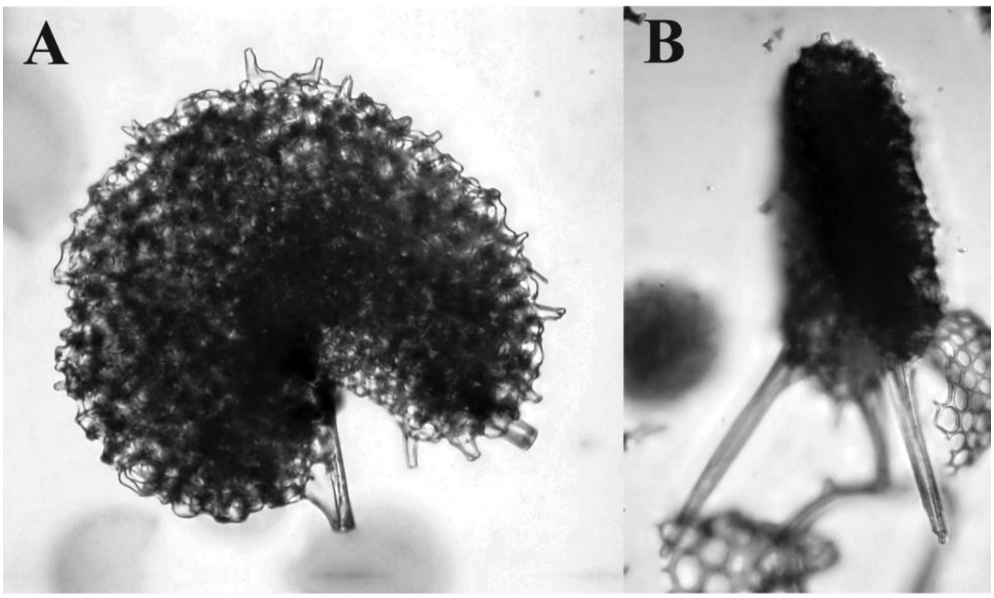

Figure 1. *Spongodiscus* sp. nov. – A: anterior view; B: lateral view

Devonian and Carboniferous Radiolarians from the Deep-Sea Pelagic cherts of the New England Fold Belt, Eastern Australia

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Global cooling has been widely considered as a likely agent of the Late Devonian mass extinction event (McGhee, 1982). Although studies of this extinction event have focused particularly on shallow-water sedimentary rocks which contain abundant megafossils, information of pelagic sediments is limited, and it is especially important to examine the climatic change at that time.

Radiolaria, a protozoan holoplanktonic organism as a primary consumer, is the best group for studying the age-determination of Paleozoic pelagic sediments due to the solid siliceous skeleton which has resistance to dissolution during diagenesis. In order to elucidate the environmental change of Devonian, deep-sea pelagic chert samples of the Brisbane, Bingara and Manilla areas of the New England Fold belt in eastern Australia were collected and radiolarian fossils were extracted.

As a result of the biostratigraphic study, Emsian-Eifelian (late Early to early Middle Devonian), Eifelian-Givetian (Middle Devonian), Frasnian (early Late Devonian), Famennian (late Late Devonian) and Early Carboniferous radiolarians were obtained from the deep-sea cherts. Lithological characteristics of the Late Devonian green to gray cherts show a remarkable contrast when compared to the Early to Middle Devonian and Early Carboniferous red cherts. The color of cherts reflects the ancient redox condition of the depositional environment.

Lithologic characteristics of the Late Devonian cherts suggest that this unique rock type was deposited under reducing condition in a broad sense. Late Devonian dark-color cherts were also reported from Thailand (Sashida, et al., 1993) and Nevada (Boundy-Sanders, et al., 1999). This may suggest that the reducing condition in deep-sea was recorded the global phenomena rather than a local signal at that time.

Early to Middle Devonian and Early Carboniferous red cherts of this belt were deposited under a well-mixed aerated condition which indicates a ventilated ocean. Late Devonian chert was deposited under a reducing condition which indicates a stratified stagnant ocean. Late Devonian would remain a period of global warming and the Late Devonian mass extinction event occurred in the stagnant warm ocean at that time.

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Keywords: Devonian, Mass extinction, New England Fold belt, Australia

GENERAL SYMPOSIUM SESSION 22

Biogeography

Poster Core time (inc. lunch):

26/Oct (Thu), 12:00–14:00; 27/Oct (Fri), 11:30–13:00

Multi-purpose Space of TOKIMATE, Eki-nan Campus, Niigata Univ.

P22-01	Ito, Y. et al.	Transitions in the Cretaceous radiolarian assemblages of the Yezo Group in the Niikappu area, Hokkaido, Japan: age constraints from U–Pb zircon dating of tuffaceous rocks
P22-02	Manchuk, N. et al.	Late Devonian radiolarians from the Hebukehe Formation, Northwestern Xinjiang, China
P22-03	Sashida, K. et al.	Upper Permian to Middle Triassic radiolarians from bedded cherts distributed in the Nong Prue area, western Thailand

Transitions in the Cretaceous radiolarian assemblages of the Yezo Group in the Niikappu area, Hokkaido, Japan: age constraints from U–Pb zircon dating of tuffaceous rocks

Yuki ITO[1], Kousuke HARA[1], Toshiyuki KURIHARA[1] & Hayato UEDA[2]

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The Yezo Group, distributed in the central part of Hokkaido, Japan, is composed of thick Cretaceous forearc-basin sediments that are rich in macro- and micro-faunas. In recent years, the foraminiferal biostratigraphy and the carbon isotope stratigraphy around the C/T boundary in Hokkaido have been studied and documented (e.g., Hasegawa, 1997; Takashima, 2011). The detailed radiolarian biostratigraphy in the Urakawa area of Hokkaido has been documented by Taketani (1982).

Cretaceous sediments in the Niikappu area consist of radiolarian-rich mudstones and turbidites of offshore facies, and these rocks are associated with beds of felsic tuff. We have now conducted detailed geological mapping of the area, recorded the radiolarian biostratigraphy, and performed U–Pb dating of zircons from several of the tuff beds with the aim of providing information about the transition of Albian to Coniacian radiolarian assemblages in the western Pacific, constrained by isotopic age data.

The strata in this area are subdivided into the Shunbetsugawa and Niikappugawa formations. The Shunbetsugawa Formation consists of a basal conglomerate, sandstones, and alternating sandstones and mudstones along with several tuff beds in the lower part and hemipelagic mudstones in the upper part. The Niikappugawa Formation is composed mainly of mudstone along with turbidites in its lower part. The mudstones contain abundant radiolarians, and often inoceramids.

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We obtained moderately to well-preserved radiolarians from nine mudstone samples, and recognized four assemblages (assemblages 1 to 4). Our age assignments are based on the works of Pessagno (1976) and O'Dogherty (1994). Assemblage 1 is characterized by *Crolanium triangulare* and *Hiscocapsa asseni* of late Albian to early Cenomanian age. Assemblage 2 consists of typical Cenomanian species such as *Dactyliosphaera silviae*, *Holocryptocanium barbui*, and *Pseudodictyomitra tiara*. Assemblage 3 is characterized by the dominance of *Stichomitra* species along with *Diacanthocapsa* sp. Assemblage 4 contains *Alievium superbum*, *Archaeospongoprunum bipartitum*, *Dictyomitra formosa*, and *Pseudotheocampe urna*, and this assemblage is considered to be late Turonian–Coniacian in age.

U–Pb ages were measured for zircons from four horizons of tuff (895, 931-02, 916-27, and 906) in the Shunbetsugawa and Niikappugawa formations. Approximately 100 grains were measured for each sample, and the cluster of the youngest peak was analyzed using the Unmix Ages routine of Isoplot/Ex 4.15 to obtain the depositional age. As a result, the ages of samples 895 and 931-02 collected from the lower part of the Shunbetsugawa Formation are ca. 100 Ma, corresponding more-or-less to the boundary between the Albian and Cenomanian. The age of the tuff in the lower part of the Niikappugawa Formation (sample 916-27) is 91.48 ± 0.78 Ma, and in the upper part (sample 906) it is 87.34 ± 0.52 Ma. The former age corresponds to the Turonian and the latter to the Coniacian. The biostratigraphic ages mentioned above are consistent with the numerical ages of the tuffs. In particular, this means that assemblage 3, which does not contain age-diagnostic species, can be assigned to the Turonian.

The species in our assemblages of Albian to Cenomanian and Coniacian age (assemblages 1, 2, and 4) are similar to those in assemblages reported from the Tethys and North America (e.g., Pessagno, 1976; O'Dogherty, 1994; Hara & Kurihara, 2017). In contrast, the Turonian assemblage of the Yezo Group (assemblage 3) has a very low diversity of species and does not contain typical Turonian species. This implies that the faunal connection between the western Pacific and Tethys was limited during the Turonian.

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Keywords: Yezo Group, Hokkaido, Albian, Cenomanian, Turonian, Coniacian, zircon, U–Pb age

Late Devonian radiolarians from the Hebukehe Formation, Northwestern Xinjiang, China

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The Late Devonian rocks in the Xinjiang-Uyghur Province, northwestern China, are part of the Central Asian Orogenic Belt (CAOB). The section near the Boulongour Reservoir is divided into four units: the Zhulumute, Hongguleleng, "Hebukehe" and Heishantou formations. Here, we will present radiolarian fossils from the "Hebukehe" Formation. This formation is 95.7 meters thick and consists mainly of siliceous shale, mudstone and red-brown calcareous mudstone. Some minor layers of limestone nodules are intercalated within the chert-dominated part in the lower horizon of this formation. According to conodont biostratigraphy (by Ruth Mawson and John A. Talent, unpublished data) and stable isotope record (Suttner et al. 2014, Carmichael et al. 2016), the interval of the "Hebukehe" Formation at Boulongour Reservoir is constrained to the late Famennian, ranging from the conodont, marginifera Biozone to ?praesulcata Biozone.

We obtained 48 radiolarians (Trilonche elegans, Trilonche echinata, Entactinia sp.?, Stigmosphaero stylus sp.?, Astroentactinia sp.?, Archocyrtium sp.?, Trilonche davidi and Polyentactinia polygonia), 4 conodont elements and 16 spicules of sponges from four chert and limestone samples beds (He/7, He/8, He/17, He/36c) This is the first systematic description of radiolarians from the "Hebukehe" Formation.

The paleoenvironment of the "Hebukehe" Formation will be refined via a combination of microfacies analysis, radiolarian bio-zonation, and stable isotope stratigraphy and whole rock geochemistry.

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Keywords: Devonian radiolarians, Xinjiang, China

■ MEMO ■

Upper Permian to Middle Triassic radiolarians from bedded cherts distributed in the Nong Prue area, western Thailand

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Quartzite, shale, chert, tuff, phyllite and thin crystalline limestone distributed in the Bo Phloi area, western Thailand have been regarded as the Silurian to Devonian Bo Phloi Formation by Bunopas (1991). Sashida et al. (1998) preliminary reported the occurrence of Triassic radiolarians from bedded cherts in this area and suggested to revise the stratigraphy. Saesaengserung (2009) identified Lower to Middle Triassic radiolarian faunas from several chert outcrops in this area, which are correlated to the *Parentactina nakatsugawaensis, Eptingium nakasekoi, Triassocampe coronate, T. deweveri,* Spine A2 and *Tritortis kretaensis* zones established by Sugiyama (1997) in the Mino area, central Japan. Recently we discriminated Upper Permian radiolarian faunas from bedded chert out cropping near the city of Nong Prue. We summarized herewith the occurrence of Upper Permian radiolarian fauna from the Nong Prue area and briefly mention the depositional environments of the Upper Permian to Middle Triassic cherts distributed in this area.

Upper Permian radiolarians were recovered from dark gray to black bedded chert from the newly constructed roadside outcrop. This radiolarian fauna is characterized by the occurrence of *Albaillella levis, Albaillella excelsa, Follicucullus* spp., *Latentifistula* sp., *Triplanospongos* sp., *Stigmosphaerostylus* sp. and others. Any species belonging to genus *Neoalbaillella* which represents the Upper Permian were not identified. According to the stratigraphic occurrence of *Albaillella levis* and *A. excels* examined at the Gujyo Hachiman section in the Mino Terrane by Kuwahara (1999), the co-occurrence of these two species is restricted to the boundary between the *Neoalbaillella ornithoformis* and *N. optima* zones which corresponds to Late Permian middle Changhsingian.

Middle Triassic bedded cherts in this area sometimes intercalate thin layers of fine to middle grained sandstone. Saesaengseerung (2009) classified the radiolarian-bearing cherts distributed in Thailand into two types, namely, pelagic chert and hemipelagic chert based on the sedimentological characteristics. Hemipelagic chert is characterized by presence of terrigenous grains larger than silt-sized particles, and radiolarian tests, sponge spicules and calcareous organisms such as foraminifers, thin bivalve shells and ostracods within matrix consisting of microcrystalline quartz and clays. The distribution of hemipelagic chert has an obvious N-S trend, in Mae Hong Son, Mae Sariang and Kanchanaburi areas, northwestern and western Thailand and Song Khla area, southern Thailand (Saesaengseerung, 2009). Hemipelagic cherts in Thailand are thought to have been deposited within the continental slope/shelf of passive continental margin in the Paleo-Tethys Ocean (Saesaengseerung, 2009).

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Keywords: bedded cherts, Permian, radiolarians, Triassic, western Thailand

■ MEMO ■

GENERAL SYMPOSIUM SESSION 23

Evolution and Stratigraphy

Poster Core time (inc. lunch):

26/Oct (Thu), 12:00–14:00; 27/Oct (Fri), 11:30–13:00

Meeting Room A of TOKIMATE, Eki-nan Campus, Niigata Univ.

P23-01	Ariunchimeg, Y. & Uugantsetseg, B.	Devonian fossils of Mongolia and their stratigraphical significance
P23-02	Caulet, J.P. et al. (Presenter: O'Dogherty, L.)	An up-to-date catalogue of Cenozoic radiolarian genera and families: a review with illustrations of type species
P23-03	Hollis, C.J. et al. (Presenter: Kamikuri, S.)	Towards an integrated cross-latitude event stratigraphy for Paleogene radiolarians
P23-04	Hori, R.S. et al.	Triassic-Jurassic boundary of a bedded chert sequence from the Chichibu Belt, Shikoku, Japan
P23-05	Matsuda, M. et al.	Early Jurassic radiolarian fauna from a carbonate nodule in Northern Chichibu Belt, Shikoku, Southwest Japan
P23-06	Nakae, S.	Boundary age of the *Dictyomitra koslovae* and the *Amphipyndax tylotus* zones (Campanian radiolarian zones) constrained by detrital zircon U–Pb dating: an example of the Matoya Group (Shimanto belt) in Kii Peninsula, Southwest Japan
P23-07	Suzuki, H. & Gawlick, H.J.	Radiolarians from the lower–middle Oxfordian section in the Northern Calcareous Alps (Fludergraben, Austria)
P23-08	Takemura, A. & Takemura, S.	Radiolarian faunas from the Tanba Belt in Kita-Harima District, Hyogo Prefecture, Southwest Japan
P23-09	Toshiro, G. et al.	The ages of Early-Middle Jurassic radiolarians from the Tamba Terrane, central Japan
P23-10	Zhang, Z. et al.	Radiolarian faunas in Wufeng Formation from Yi Chang, Hubei Province and Lun Shan, Jiangsu Province, China

Devonian fossils of Mongolia and their stratigraphical significance

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The Devonian sediments of Mongolia contains a diverse fauna of invertebrates as well as plant fossils and remains of fish fragments.

Devonian based on the study of the brachiopods (Alekseeva, Mendbayar, 1981; Alekseeva, 1993; Erlanger, 1994; Oleneva, 2000; Alekseeva et al., 2001, 2006) subdivided into following regional stratigraphical units – horizons: Borteeg (Lochkovian), Biger (Pragian), Chuluun (Emsian), Tsagaankhaalga (Emsian-Eifelian) and Ulgii (Givetian-Frasnian). Alekseeva et al. (2006) and Lasarev S.S. ((Brunton & Lazarev, 1997) suggested the Frasnian and Famennian age for the some formations of the Baruunhuurai terrane based on brachiopods.

Except brachiopods bryozoans are one of the widespread and taxonomically diverse invertebrate fossils in Devonian deposits of Mongolia. The presence of characteristic bryozoan associations in different tectonic units makes it possible to trace and correlate eight bryozoa-bearing beds widely (Ariunchimeg, 2010).

Corals (Paleontology…, 2003) are widespread and some of them are important reef-building organisms. Based on tabulate corals the following zona established: Favosites favositiformis, Favosites socialis (Lochkovian); Riphaeolites zogtensis – Favosites admirabilis; Favosites kovechovi (Pragian); Oculipora angulata; Emmonsia taltiensis; Thamnopora nana (Emsian); Alveolites levis grandis (Eifelian) (Sharkova, 1981; 2003). Recently some late Devonian tabulate corals mentioned from the sections in the Baruunhuurai terrane (in Ruzhentsev, 2001, Sersmaa and Kido, 2015).

Rugosa are widespread in the Devonian of Mongolia. They are characteristic mainly of the Lower Devonian deposits, chiefly Emsian, becoming much more rare in the middle Devonian and being known in the Upper Devonian only from the Baruunhuurai area. Based on their study following beds with rugosa are established: Spongophylloides dubrovensis (Lochkovian), Martinophyllum latum, Lyrielasma aggregatum; Tabulophyllum major, Spongophyllum massivum (Emsian), Heliophyllum halli, Pseudozonophyllum versiforme (Eifelian), Cystiphylloides radugini (Givetian); Aulacophyllum exiguum, Temnophyllum ruzhentsevi (Frasnian);

Based on stromatoporoids in Lochkovian traced beds with Stromatopora racemifera and Gerronostroma concentricum and in the middle Devonian - beds with Idiostroma cumulus and Stromatopora colliculata.

Crinoids also are widespread but are less studied (Dubatolov et al., 1982, Webster & Ariunchimeg, 2003, Ariunchimeg and Kurilenko, 2016). The first Devonian crinoid caps are reported from the statotype section of Chuluun Formation in Shine Jinst area. They show affinity to Europian and north American Emsian faunas.

Radiolarians are present in siliceous rocks formed in deeper water (Kurihara et al., 2009). Four radiolarian assemblages that have a combined age range from the latest Silurian (Pridolian) to the late Devonian (Frasnian) are known from the Khangai-Hentei zone.

Recently the late Devonian phacopid trilobites Omegops. Trimerocephalus and Phacops were found from the Samnuur-Uul formation in the Baruunhuurai terrane (Munkhjargal, 2015).

Conodonts are the most important Devonian taxa for the correlation. The earliest Devonian conodont zonal fossil has been found from the "Gavuu Member" in Mandalovoo area (Wang et al., 2003). The latest Famennian conodonts were found in several sections in Mongolia (Kurimoto et al, 1997, Nyamsuren, 1998; Wang & Minjin, 2004), but the base and top of the Devonian still cannot be precisely defined at this time.

Tentaculites, ammonoids and ostracodes occasionally seen in some deposits.

The lowermost part of the Samnuur-Uul formation in the Baaruunhuurai terrane is characterized by a series of sandstones and conglomerates with interbedded siltstone and shales containing macroscopic plant fossils (Stephenson et al., 2015).

Mongolia has extensive Devonian marine and near-shore sequences which should yield vertebrate remains. Early Devonian deposits yield acanthothoracid placoderms and acanthodian remains. The Early-Middle Devonian yields a diverse assemblage of placoderms and osteichthyans. The Late Devonian has produced abundant Bothriolepis remains and rare osteolepidid material. Most significantly is a lack of jawless vertebrate macroremains (Brazeau et al., 2015).

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The references should be ordered alphabetically. (Times New Roman, 12 pt., regular)

Keywords: Mongolia, Devonian, fossils.

An up-to-date catalogue of Cenozoic radiolarian genera and families: a review with illustrations of type species

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Following the revision undertaken by the Paleozoic and Mesozoic Working Groups of InterRad (Danelian et al. 2017; O'Dogherty et al. 2009) we are currently focusing our interest on the Cenozoic era. This research is expected to be also published as a monography in Geodiversitas (a scientific publication of the Natural History Museum of Paris) by the end of 2019. The project started in 2012 but, for several healthy reasons, it has been in a latent state till the last InterRad meeting.

A thorough revision of Cenozoic radiolarian literature was performed during the past years. The first step in this research was to produce a complete list of described species from Cenozoic material (ca 6600 species and subspecies). This dataset was used to prepare a raw list of nominal Cenozoic genera. The species list consists on an objective record of all newly described taxa regardless their taxonomic status, that is to say, it includes all valid taxa, junior objective or subjective synonyms, *nomina dubia*, etc. At the present time, our taxonomic revision reports 1637 existing generic names for the Cenozoic (including valid and not valid). This huge number of genera largely surpasses the sum of Paleozoic and Mesozoic genera together (*ca* 1300 taxa). The reason for such impressive number of genera is mostly imposed by the legacy of the Haeckel's taxonomy, wo erected an artificial systematics with hundreds of genera and subgenera based exclusively on the geometry of the shell, the number of segments, the number of concentric shell, the presence or absence of appendices, among others.

All genera have been reviewed and their type species re-illustrated. These are presented on 410 plates (4 genera per plate) and arranged morphologically for quick recognition (an alphabetic list is available also). Each genus (even those corresponding to a junior synonym) is illustrated, sometime a support figure is presented for those taxa having a poor illustration (old drawing or bad photographic pictures). The basic information contains: genus name, author, year of publication and page of description; family (when possible); image of type species with scale bar; binomial combination for the type species with indication of original source (year, page, and plate-figure for the holotype).

Taking into account fruitful (sometimes heated) discussion, as well as existing published opinions, this revision allowed us to identify: 367 taxa described without illustration of the type species, 260 junior objective synonyms 532 junior subjective synonyms, 41 homonyms, 29 *nomen novum*, 80 *nomen nuda*, 400 *nomina dubia* and 21 genera originally described as radiolarians but belonging to other taxa (mostly sponge spicules or silicoflagellates). The final balance of valid genera for taxonomic and stratigraphic purpose is 405.

An important part of this work is paid to the taxonomic values of the genera and its usefulness in stratigraphy. For this reason, we summarize in our publication a revised opinion of the status and family assignment of all Cenozoic genera described so far, and providing an up-to-date evaluation of their currently known age range.

We intend for this atlas to serve as a useful taxonomic and biostratigraphic compendium for the new generations of micropaleontologists.

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Keywords: Taxonomy, Cenozoic

Towards an integrated cross-latitude event stratigraphy for Paleogene radiolarians

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Numerous studies have shown that the standard low-latitude radiolarian biozonation for the Cenozoic (Sanfilippo and Nigrini, 1998: Zones RP6 to RP22, RN1-RN17) is an effective and reliable tool for correlation in low-latitude and many mid-latitude Paleogene sedimentary successions (e.g. Norris et al., 2014). Most of the underpinning bioevents are now calibrated to the geomagnetic polarity timescale (GPTS) from latest early Eocene to early Miocene (Kamikuri et al., 2012: RP8 to RN2). However, because many low-latitude index species are absent or have shortened age ranges in high latitudes and some mid-latitude regions, regional zonations have been developed for local correlation. A Southern Ocean zonation that extends from late middle Eocene to earliest Miocene is calibrated to the GPTS using calcareous microfossil biostratigraphy and magnetostratigraphy (Funakawa and Nishi, 2005). A Southwest Pacific zonation that extends from earliest Paleocene to early Oligocene is calibrated to the GPTS using calcareous microfossil biostratigraphy (Hollis, 1997).

In this study, we integrate these three zonations with the aid of new radiolarian biostratigraphic data and new magnetostratigraphic calibrations for Southwest Pacific radiolarian bioevents (Dallanave et al., 2014; Pascher, 2017) and a new magnetobiochronology for latest Cretaceous to early Eocene radiolarian bioevents in the Southern Indian Ocean (ODP Site 752). The zonal schemes are calibrated to GPTS 2012 (Gradstein et al., 2012). We introduce new zonal codes to rectify current confusion surrounding use of "RP" zones. Southwest Pacific zones codified as "ZRP" zones, the "Z" referring to the southwest Pacific continent Zealandia (Mortimer et al., 2017). Southern Ocean zones are codified as ARP, the "A" referring to Antarctica.

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Keywords: Biostratigraphy, Paleogene, Tropical, Southwest Pacific, Antarctic

Triassic-Jurassic boundary of a bedded chert sequence from the Chichibu Belt, Shikoku, Japan

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The Triassic-Jurassic (T-J) boundary sequences of bedded chert have been documented firstly from the Inuyama area, Mino Belt, Southwest Japan by Matsuda et al. (1980) and Yao et al. (1982), where the Mesozoic accretionary complex are widely distributed. Succeeding to their pioneering works, numerous researches of Triassic and Jurassic radiolarian biostratigraphy have been conducted on the Mino-Tamba, Ashio, Chichibu Belt and also the other Japanese Mesozoic belts containing the similar age chert-clastic sequences in their accretionary complexes. Nishizono et al. (1982) and Ishida (1986) have documented radiolarian biostratigraphy of bedded chert sequences from Upper Triassic to Lower Jurassic possibly crossing the T-J boundary in the Chichibu Belt, however, there are no precise data closing up the boundary.

We have studied a bedded chert sequence from the southern part of the Chichibu Belt biostratigraphically and geochemically, and found a new continuous pelagic sequence of the T-J boundary, namely AY section, shikoku, Japan. The chert sequence of the AY section consists of 324cm in total thickness, which exhibits red to gray in color and overturned stratigraphically. Based on the Radiolarian fossils obtained, this section can be correlated to the interval from the Upper Triassic *Canoptum triassicum* Zone of Yao et al (1982) including the *Globlaxtorum tozeri* Zone of Carter (1993) to the lower part of the *Parahsuum simplum* Zone (Rhaetian to Hettangian). Spherical spumellarians are abundant in whole of this section, and species of genus *Livarella* and *Serilla* are obtained from the top part of this section. The topmost 50cm interval contains *Pantanellium* spp., and *Pantanellium* cf. *kluense* which is one of the characteristic taxa around the T-J boundary is identified. *Livarella* spp. occurred from the most part of this section except for the top. Above the disappearance of *Livarella valida,* Mesozoic type *Mesosaturnalis* sp. occurred, therefore, the T-J boundary could be located between the final occurrence of *Livarella* and the first occurrence of *Mesosaturnalis* sp.

The $\delta^{13}C$ values of bulk organic carbon of chert beds in the AY section also have been studied preliminary. The data shows a remarkable decrease during uppermost Triassic part and then a sharp positive spike around the T-J boundary. These excursion pattern of $\delta^{13}C$ values obtained is consistent with those from the Katsuyama section of Inuyama area, Mino Belt, Japan and from the Pakihi section, Waipapa Belt, New Zealand which were documented by Okada et al. (2015). The T-J boundary induced from the preliminary results of $\delta^{13}C$ study is well fit to the T-J boundary of radiolarian biostratigraphy. Based on the data of these $\delta^{13}C$ excursion pattern and radiolarian biostratigraphy, the sedimentation rate of AY section chert is faster than those of the Inuyama area, Mino Belt, Japan.

The age-corrected $^{187}Os/^{188}Os$ values of chert samples from the AY section have been studied, which show a gradual increasing after a negative peak during the upper Rhaetian interval. A positive spike is observed just below the T-J boundary and then decreases toward the T-J boundary. This fluctuation pattern is consistent with those of the Kurusu T-J boundary section documented from the Inuyama area, Mino Belt, Japan (Kuroda et al., 2010). The absolute values of $^{187}Os/^{188}Os$ from the AY section cherts are higher those from the Kurusu section. The results suggest the possibility that the Chichibu cherts deposited under much higher influx from continent and/or island arc than the Mino cherts. Future precise analyses on $\delta^{13}C$ and $^{87}Os/^{188}Os$ values are required to conform these possibilities and correlations.

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Keywords: Triassic-Jurassic boundary, chert, radiolarian biostratigraphy, Shikoku

Early Jurassic radiolarian fauna from a carbonate nodule in Northern Chichibu Belt, Shikoku, Southwest Japan

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Well-preserved Jurassic radiolarians occurred in a carbonate nodule at the outcrop near Nanogawa in Niyodogawa-cho, Kochi prefecture in Shikoku, Southwest Japan. This outcrop consists of Jurassic mélange with mudstone matrix of the Yusukawa Formation in the Northern Chichibu Belt. From this outcrop, while Takemura and Yamakita (1993) and Takemura et al. (2009) reported the Late Permian radiolarian fauna from a phosphatic nodule, Yamakita and Hori (2009) did Early Jurassic radiolarians from a carbonate nodule. Early Jurassic radiolarians occur also in the mudstones in which the nodules are included.

In this study, we report the well-preserved radiolarian fauna from another carbonate nodule newly found in this outcrop. This fauna is composed of more than 150 species including *Anaticapitula anatiformis*, *Ares armatus*, *Droltus sanignacioensis*, *Farcus asperoensis*, *Napora cerromesaensis*, *Pantanellium danaense*, *Parahsuum ovale*, *Parahsuum simplum*, *Thetis oblonga* and *Udalia plana*, as well as species belonging to Genera *Bagotum*, *Bipedis*, *Canoptum*, *Cuniculiformis*, *Katroma*, *Orbiculiformella*, *Paronaella* and *Saitoum*.

This radiolarian fauna is assigned to Subzones 1 to 3 of Hori's (1990) zonation and JR1 of Matsuoka's (1995) zonation, based on the occurrence of *Parahsuum ovale*, *Parahsuum simplum* and the absence of *Trillus elkhornensis*. It is also correlated with the Lower Pliensbachian zones by Cater et al. (2010), because *Droltus sanignacioensis*, *Katroma angusta* and *Pantanellium danaense* occurs in this fauna. The age of this radiolarian fauna, therefore, can be regarded as Early Pliensbachian.

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Keywords: radiolarian fauna, carbonate nodule, Early Jurassic, Pliensbachian, Northern Chichibu Belt, South West Japan

■ MEMO ■

Boundary age of the *Dictyomitra koslovae* and the *Amphipyndax tylotus* zones (Campanian radiolarian zones) constrained by detrital zircon U–Pb dating: an example of the Matoya Group (Shimanto belt) in Kii Peninsula, Southwest Japan

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Most part of the Upper Cretaceous has been divided into several (4 to 8) radiolarian zones respectively by major researches during the 1970s–1980s (*e.g.*, Riedel and Sanfilippo, 1974; Foreman, 1975, 1977; Pessagno, 1976; Sanfilippo and Riedel, 1985). Recently in Japan, detailed radiolarian zonation was proposed for the Coniacian to Maastrichtian, and each stage-boundary is defined as follows; boundaries of the Coniacian/Santonian and the Santonian/Campanian stages are respectively correlated with the top of lower and upper parts of the *Dictyomitra koslovae* Zone, and the Campanian/Maastrichtian stage-boundary coincides with the boundary between the *Amphipyndax tylotus* and *Pseudotheocampe abschnitta* zones (Hollis and Kimura, 2001). And further (in the case of a two-fold subdivision 'Lower/Upper' for the Campanian), the top of the *Dictyomitra koslovae* Zone is situated within the Lower Campanian (Hollis and Kimura, 2001; Hashimoto *et al*., 2015), however it has not been settled precisely yet.

Detrital zircon U–Pb dating is one of the most useful methods for constraining sedimentary age of coarse-grained clastic rocks such as sandstone (Shibata *et al*., 2008). If radiolarian fossils and detrital grains of zircon are simultaneously acquired from the same sample or samples from adjacent outcrops, the age of zone-boundaries as well as some other biohorizons can be determined by this method.

In the eastern Kii Peninsula, the Matoya Group (Upper Cretaceous accretionary complex in the Northern Shimanto belt of Southwest Japan) is widely exposed (Iizuka, 1929, 1932), and predominantly composed of sandstone and mudstone, accompanied by a minor amount of basalt and chert. The studied succession reaches approximately 300 m thick and consists of the lower part of fine-grained (clayey) to silty mudstones (170 m), the middle part of sandstone (30 m), and the upper part of silty mudstones (100 m). Mudstones from the lower and upper parts were collected for radiolarian extraction, and a sandstone from the middle part for U–Pb dating.

This succession yielded more than 30 radiolarian species that have ranged across the Campanian; *Archaeospongoprunum salumi*, *Archaeospongoprunum andersoni*, *Diacanthocapsa ovoidea*, *Hemicryptocapsa polyhedra*, *Hemicryptocapsa praepolyhedra* and *Theocampe urna* were obtained from the lower mudstones, and *Amphypindax tylotus*, *Amphypindax streckta*, *Amphypindax pseudoconulus*, *Stichomitra carnegiense*, *Cornutella californica* and *Dictyomitra torquata* were found in the upper mudstones. Mainly based on Pessagno (1973), Hollis (1997), Hollis and Kimura (2001), the lower and upper parts are respectively correlated with the *Dictyomitra koslovae* Zone and the overlying *Amphipyndax tylotus* Zone; so that means the boundary between these two zones comes to exist within the middle part of this succession.

On the other hand, for the U–Pb dating, 60 grains of detrital zircon were separated from the sandstone of the middle part and measured. The result included clearly distinctive five age-clusters, of which the youngest was 82.5 ± 0.5 Ma. This value constrains a possible oldest age for the middle part, demonstrating that the middle part deposited in 82.5 Ma or slightly later.

Considering that this age (82.5 Ma) is certainly included within the Campanian Stage and the boundary between the Lower and Middle Campanian substages (in the case of a three-fold subdivision 'Lower/Middle/Upper' for the Campanian) is set at approximately 81 Ma (Gradstein *et al*., 2012), it is thought that the sandstone of the middle part is situated at just or close to this Lower/Middle substage-boundary. Consequently, the boundary of the two zones (the *Dictyomitra koslovae* Zone and the *Amphipyndax tylotus* Zone), that is litho-stratigraphically correlated with the sandstone of the middle part, is presumed to be at the boundary between Lower and Middle substages of the Campanian.

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Keywords: Campanian, radiolaria, detrital zircon, U–Pb age, Kii Peninsula, Southwest Japan

Radiolarians from the lower–middle Oxfordian section in the Northern Calcareous Alps (Fludergraben, Austria)

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Radiolarian species, which mark the beginning of the Oxfordian are practically not well-known. With respect to the fact, radiolarite successions correlated with ammonoids are worldwide very rare. In the previously proposed radiolarian biozonations the time span from middle Callovian to early Oxfordian is united in one radiolarian zone (e.g. Unitary Association Zone 8; Baumgartner et al., 1995). A more precise radiolarian zonation for the time around the Callovian/Oxfordian boundary is therefore highly needed. We analyse well-preserved Oxfordian radiolarian faunas from more than 30 positive radiolarian samples of a thick radiolarite succession in the Northern Calcareous Alps, i.e. the Fludergraben section near Altaussee, Austria. In this section, red nodular limestone prevailed until the latest Callovian to the Callovian/Oxfordian boundary, as proven by the following ammonites (Mandl, 1982): *Euaspidoceras* sp., *Holcophylloceras zignodianum* and fragments of ?*Nebrodites*. Therefore the section provides the rare opportunity to search for Oxfordian marker species.

The radiolarite section in the Fludergraben valley starts almost instantaneously from the red nodular limestones dated with ammonoids. The basal red radiolarite is well-bedded and the beds are massive, partly completely silicified, but the preservation of the radiolarians is in cases rather good. The microfacies show radiolarian wackestones to packstones. After two to three metres, the colour of the red radiolarite changes from reddish to grey, and in the upper section grey cherty limestones and cherty mudstone prevail. This indicates basin inversion: several slumps of reddish radiolarite are intercalated in this lower grey laminated radiolarite part of the section; the grey radiolarites and the reddish radiolarites slumps are all of the same age and contain a similar radiolarian fauna. Upsection, the first fine-grained carbonate turbidites and thin-bedded coarse-grained mass-flow deposits occur. The components in these resediments are mostly older (Late Triassic to Middle Jurassic). At the base of most of the turbidites and mass flows, thin layers of volcanic ashes are preserved. The radiolarites are grey, slightly calcareous and laminated. Upsection, the deep-water sediments become more and more marly or calcareous; in some cases calcareous radiolarites occur. The occurrence of slump deposits and mass transport deposits increases.

Among the radiolaritic facies of Fludergraben, here we describe radiolarian species obtained especially from the basal red radiolarite within 1m thickness just above the ammonite horizon because of its stratigraphic importance: *Acanthocircus suboblongus* (Yao, 1972), *Archaeospongoprunum* cf. *imlayi* Pessagno, 1977, *Tritrabs exotica* (Pessagno, 1977), *Archaeodictyomitra apiarium* (Rüst, 1885), *Archaeodictyomitra minoensis* (Mizutani, 1981), *Archaeodictyomitra mirabilis* Aita, 1987, *Archaeodictyomitra rigida* Pessagno, 1977, *Cinguloturris carpatica* Dumitrica, 1982, *Dictyomitrella kamoensis* Mizutani & Kido, 1983, *Eucyrtidiellum circumperforatum* Chiari, Marcucci & Prela, 2002, *Eucyrtidiellum nodosum* Wakita, 1988, *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo, 1974), *Eucyrtidiellum unumaense* (Yao, 1979), *Gongylothorax favosus favosus* Dumitrica, 1970, *Gongylothorax favosus oviformis* Suzuki & Gawlick, 2009, *Helvetocapsa matsuokai* (Sashida, 1999), *Hsuum brevicostatum* (Ozvoldova, 1975) , *Hsuum maxwelli* Pessagno, 1977, *Loopus doliolum* Dumitrica, 1997, *Neorelumbra skenderbegi* Chiari, Marcucci & Prela, 2002, *Parahsuum* sp. S sensu Matsuoka, 1986, *Podobursa nodosa* (Chiari, Marcucci & Prela, 2002), *Protunuma lanosus* Ozvoldova, 1996, *Protunuma multicostatus* (Heitzer, 1930), *Pseudodictyomitra primitiva* Matsuoka & Yao, 1985, *Pseudoeucyetis reticularis* Matsuoka & Yao, 1985, *Ristola altissima* (Rüst, 1885), *Stichocapsa cicciona* Chiari, Marcucci & Prela, 2002, *Stichocapsa robusta* Matsuoka, 1984, *Stichomitra annibill* Kocher, 1981, *Stichomitra* sp. A sensu Baumgartner et al., 1995, *Striatojaponocapsa conexa* (Matsuoka, 1983), *Striatojaponocapsa naradaniensis* (Matsuoka, 1984), *Striatojaponocapsa riri* O'Dogherty et al., 2005, S*triatojaponocapsa synconexa* O'Dogherty et al., 2006, *Stylocapsa* cf. *spiralis* Matsuoka, 1982, *Tricolocapsa tetragona* Matsuoka, 1983, *Tricolocapsa undulata* (Heitzer, 1930), *Triversus hexagonatus* (Heitzer, 1930), *Triversus hungaricus* (Kozur, 1985), *Unuma gordus* Hull, 1997, *Unuma typicus* Ichikawa & Yao, 1976, *Williriedellum carpathicum* Dumitrica, 1970, *Williriedellum crystallinum* Dumitrica, 1970, *Williriedellum dierschei* Suzuki & Gawlick, 2004, *Williriedellum marcucciae* Cortese, 1993, *Williriedellum sujkowskii* Widz & De Wever, 1993, *Zhamoidellum ovum* Dumitrica, 1970, *Zhamoidellum ventricosum* Dumitrica, 1970.

Stratigraphic ranges of most these species are extended from the underlying Callovian, so that useful marker species for the base of the Oxfordian could not be easily determined. One possibility is *Stylocapsa spiralis* that occurs, however, very rare in the Northern Calcareous Alps. *Protunuma lanosus* which is the index species of the Callovian *Protunuma lanosus* subzone of the *Zhamoidellum ovum* zone of Suzuki & Gawlick (2003) extends also upwards into the Oxfordian. We make further taxonomic description besides already known species, which will define the marker species for the base of the Oxfordian.

This radiolarite succession will be presented by the authors beside a lot of important successions during a field trip through the Northern Calcareous Alps in the frame of the next INTERRAD (2021), held in Ljubljana and organized by. S. Goričan.

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Keywords: Northern Calcareous Alps, Oxfordian, ammonite, radiolarite

Radiolarian faunas from the Tanba Belt in Kita-Harima District, Hyogo Prefecture, Southwest Japan

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Mesozoic sedimentary complexes are distributed in the Kita-Harima District, Hyogo Prefecture, Southwest Japan. These complexes belong to the Tanba Belt, which consists of Triassic to Jurassic accretionary complexes, and are situated at the westernmost part of the belt. The Tanba Belt in this district is surveyed by Ozaki et al. (1995) and Yoshikawa et al. (2005), and are divided into the Kochi, Wakai and Yachigusa complexes, which are composed mainly of sandstone, mudstone, chert and greenstone. The geologic age of the belt in Kita-Harima was determined using radiolarians from the Wakai complex by Hori et al. (2004) and Shibutani and Hori (2008). According to these studies, the ages of radiolarian faunas from the shales of the complex range from Late Triassic to Early Jurassic.

We report radiolarian faunas from this district through the collaboration of many students of our institution in this study. Radiolarian fossils occurs in more than 40 localities of cherts, siliceous mudstones and mudstones, belonging not only to the Wakai complex but also to the Kochi and Yachigusa complexes. The age of radiolarians from cherts ranges from Permian to Early Jurassic, while that from siliceous mudstones does Late Triassic to Early Jurassic. The age of mudstones are mostly Early Jurassic, but one radiolarian fauna from mudstone of Wakai complex could be correlated with the *Laxtorum*(?) *jurassicum* Zone of earliest Middle Jurassic. Late Triassic mudstone was not observed, except for siliceous mudstones accompanying bedded cherts. Therefore, the three complexes of the Tanba Belt in this district were considered to be formed mosly in Early Jurassic.

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Keywords: Radiolaria, Jurassic, Tanba Belt, Hyogo Prefecture, Kita-Harima

■ MEMO ■

The ages of Early-Middle Jurassic radiolarians from the Tamba Terrane, central Japan

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In this study, we have conducted a geological investigation in the Ichihara area, northern Kyoto city, in which the Haiya complex of the Tamba terrane is distributed. We have collected sedimentary rocks of black mudstone, siliceous mudstone and chert from the outcrop along the Kurama River bed. These sedimentary rocks are not stratified, but mixed like mélange or olistostrome. Chert and siliceous mudstone occur in black mudstone as exotic block. The purpose of this study is to report the well-preserved Jurassic radiolarians extracted from these samples and to discuss their geologic ages by identified species.

From the black mudstone, we obtained following species: *Striatojaponocapsa plicarum* (Yao, 1979), *Eucyrtidiellum unumaense* (Yao, 1979), *Japonocapsa fusiformis* (Yao, 1979), *Cyrtocapsa kisoensis* Yao, 1979, *Hsuum brevicostatum* (Ozvoldova, 1975), *Stichocapsa* cf. *japonica* Yao, 1979, *Saitoum levium* De Wever, 1981. These species are assigned to the *Striatojaponocapsa plicarum* zone of Matsuoka (1983), indicating a Bajocian age. From the siliceous mudstone, we obtained following species: *Hsuum hisuikyoense* Isozaki & Matsuda, 1985, *Hsuum matsuokai* Isozaki & Matsuda, 1985, *Laxtorum jurassicum* Isozaki & Matsuda, 1985, *Parahsuum officerense* (Pessagno & Whalen, 1982), *Parahsuum parvum* Takemura, 1986, *Parahsuum levicostatum* Takemura, 1986, *Eucyrtidiellum disparile* Nagai & Mizutani, 1990. These species are assigned to the *Laxtorum jurassicum* zone of Matsuoka & Yao (1986), indicating an Aelenian age. From the chert, we obtained following species: *Eucyrtidiellum disparile* Nagai & Mizutani, 1990, *Parvicingula gigantocornis* Kishida & Hisada, 1985, *Dictyomitrella* aff. *kamoensis* Mizutani & Kido, 1983. These species are assigned to the *Mesosaturnalis hexagonus* zone of Hori (1990), indicating a Toarcian age.

Previous study reports that radiolarians from bedded chert, siliceous shale and silty mudstone in the Haiya complex indicate ages of Permian to Early Jurassic, middle of the Middle Jurassic and Jurassic, respectively (Kimura et al., 1998). However, only a small number of radiolarians were presented in the report, some of which were not identified to species level. Our result suggests precise age ranges based on lager number of species than that of Kimura et al. (1998). In comparison of ages of lithology with the results of Kimora et al. (1998), *Striatojaponocapsa plicarum* was reported from siliceous shale that is exposed 1.5 km east of the Ichihara area (Kimura et al., 1998). In the Ichihara area, black mudstone yields *S. plicarum,* and siliceous mudstone yields radiolarians of the *Laxtorum jurassicum* zone that predate the *S. plicarum* zone. On the basis of this difference in age, the Haiya complex should be reconsidered with its stratigraphy, or the complex of the Ichihara area should be separated from the Haiya complex.

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Keywords: Early Jurassic, Middle Jurassic, Tamba terrane, Haiya complex, Ichihara area

Radiolarian faunas in Wufeng Formation from Yi Chang, Hubei Province and Lun Shan, Jiangsu Province, China

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A few radiolarian fossils were extracted from black shale samples collected from the Wufeng Formation (late Ordovician) in the core of YiHunag-1 well, Yi Chang, Hubei Province and from the Lun Shan section, Nanjing, Jiangsu Province. More than six species belonging to two genera were recognized from the Lun Shan section. They include Inanigutta webbyi, Inanigutta jiangsuensis, Cessipylorum sp. and so on. Due to the poor preservation, the radiolarian from the core of YiHunag-1 well can only be classified to order Spumellaria.

A new cone-shape fossil, their systematic position has not been determined yet, were found co-occurred with both radiolarian faunas in Yi Chang and in Lun Shan. These special fossils maybe possess the significance for the potential biostratigraphy correlation in south China.

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Keywords: Wufeng Formation, black shale, Radiolarian, south china

■ MEMO ■

GENERAL SYMPOSIUM SESSION 24

Tectonics

Poster Core time (inc. lunch):

26/Oct (Thu), 12:00–14:00; 27/Oct (Fri), 11:30–13:00

Meeting Room A of TOKIMATE, Eki-nan Campus, Niigata Univ.

P24-01	Hara, K. & Kuriahra, T. (Presenter: Kurihara, T.)	Radiolarian biostratigraphy of Late Cretaceous pelagic sediments within the Suhaylah and Zabyat formations of the Oman Ophiolite in the Wadi Jizzi area, northern Oman Mountains
P24-02	Sharav, D. et al.	Radiolarians from the Khooltiin davaa area, eastern Mongolia
P24-03	Sugamori, Y.	Radiolarian biostratigraphy studies of the Permian strata in the Tanto area, southeastern part of Hyogo Prefecture, Southwest Japan
P24-04	Yamagata, T.	Gravity-flow deposits on the slope to the foot of the Permian seamount in the Deadman Bay terrane, the San Juan Island, Washington State, USA

Radiolarian biostratigraphy of Late Cretaceous pelagic sediments within the Suhaylah and Zabyat formations of the Oman Ophiolite in the Wadi Jizzi area, northern Oman Mountains

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A detailed radiolarian biostratigraphy of middle–late Cenomanian to Coniacian pelagic sediments overlying basaltic extrusive lavas (V1 and V2 lavas) of the Oman Ophiolite was studied in the Wadi Jizzi area, about 40 km west of Sohar, northern Oman Mountains, aimed at understanding the nature of pelagic sedimentation, history of volcanic activity of the ophiolite, and radiolarian faunal transition in this time period. Pelagic sediments including metalliferous sediments (umbers) commonly occur on lavas and at the boundaries between different volcanic units. Thickly accumulated metalliferous and pelagic sediments, which rest directly on the V1 lava formed by ridge magmatism at Suhaylah and the V2 lava as primitive arc-like volcanism at Zabyan and Lasail, were named the Suhaylah Formation (Fleet & Robertson, 1980; Tippit et al., 1981; Hara & Kurihara, 2017). This formation consists mainly of lower metalliferous sediments that grade into overlying red mudstone intercalated with radiolarian chert, which is in turn overlain by upper micritic limestone. The uppermost part of this formation is composed of red mudstone. All lithologies contain moderately to well-preserved radiolarians. The Suhaylah Formation is overlain by the Zabyat Formation (Woodcock & Robertson, 1982; Robertson & Woodcock, 1983) that consists of ophiolite debris, redeposited sandstone- to siltstone-sized volcaniclastic rocks, and pelagic red mudstone.

From the occurrence patterns and stratigraphic ranges of radiolarians, the species clearly make up four distinct assemblages. Based on the occurrences, we defined the following four biostratigraphic zones (interval zones): *Guttacapsa gutta* Zone (basal part of the Suhaylah Formation; middle–late Cenomanian to latest Cenomanian), *Rhopalosyringium scissum* zone (lower part of the Suhaylah Formation; early Turonian), *Foremanina schona* Zone (upper part of the Suhaylah Formation; Turonian), and *Eostichomitra perapedhia* Zone (uppermost part of the Suhaylah Formation and the Zabyat Formation; Coniacian). In previous studies (e.g., Tippit et al., 1981), the Suhaylah Formation was dated as early Cenomanian to Coniacian–Santonian. We revised the age of this formation to middle–late Cenomanian to Coniacian. The age of the Zabyat Formation is Coniacian.

The radiolarian age of the basal part of the Suhaylah Formation (*G. gutta* Zone: ca. 96.5–93.9 Ma) that directly overlies the V1 lava is consistent with the high-precision U–Pb zircon age of crustal rocks formed by ridge magmatism (96.12–95.50 Ma) (Rioux et al., 2016). The sediments on the V2 lava can be also correlated with the middle–late Cenomanian, based on the occurrence of the zonal fauna of the *G. gutta* Zone. These findings reveal that the activities of both the V1 and V2 lavas were terminated in late Cenomanian. In other words, the change of the tectonic setting from mid-ocean ridge through subduction zone to oceanic thrusting occurred in a very short period of late Cenomanian.

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Keywords: Cenomanian, Turonian, Coniacian, ophiolite, Oman

Radiolarians from the Khooltiin davaa area, eastern Mongolia

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Our study area is located near Khooltiin Davaa area in the southeastern part of the Khangai-Khentey orogenic system, Central Asian orogenic belt (CAOB), and main focus is stratigraphic units. Based on stratigraphy, petrology and structural geology, we newly classified five different type geological units with Paleozoic tectonic boundary.

We represent some results for biostratigraphy of Upper Silurian volcano-siliceous (Sergelen formation) and Middle-Upper Devonian sedimentary sequences (Gorkhi formation).

Upper Silurian Sergelen formation is composed metabasalts, basaltic tuffs with thin-layers of the white-grey color chert. Middle-upper Devonian Gorkhi formation is mainly consist black shale and sandstone with thin-bedded red cherts. During the fieldwork, 12 chert samples have been collected and totally 30 radiolarians were determined. Our study is classified totally four species from the two formations. These genera *Futobari*, *Zadrappolus* is belonged to from Sergelen formation, but *Trilonche*, *Stigmosphaerostylus* is belonged to Gorkhi formation. Sergelen formation have previously been assigned to an age upper Silurian but now have ranged from upper Silurian-lower Devonian and radiolarians of Gorkhi formation have presented middle-upper Devonian age.

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Keywords: Radiolarian, Sergelen formation, Gorkhi formation

Radiolarian biostratigraphy studies of the Permian strata in the Tanto area, southeastern part of Hyogo Prefecture, Southwest Japan

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The Shimomidani Formation, distributed in the northern part of Kyoto Prefecture, Southwest Japan is tectonically underlain by the Oeyama Ophiolite and Granite and metamorphic rocks of the Maizuru Terrane. The tectonic implications of the formation are unclear, which makes it complicate to understand the Paleozoic to early Mesozoic tectonic evolution of the Innner Zone of Southwest Japan. The author examined the litostratigraphy and biostratigraphy of Permian strata in the Tanto area, northeastern part of the Hyogo Prefecture, Southwest Japan, correlated with the Shimomidani Formation to clear evolution of the basin forming the formation and Permian strata in the study area (Shimomidani basin).

As a result of examination, the Permian strata in the study area consist mainly of alternating of mudstone and felsic tuffaceous mudstone, with sandstone, felsic tuff, chert (including red siliceous tuff) and basalt. Apparently thickness of this strata is estimated 1000 m at least. Those strata often are dismembered and folded.

Sugamori (2013) reported the yielding of *Pseudoalbaillella* aff. *longicornis* Ishiga and Imoto from mudstone. As a result of re-examination, the author found that the mudstone, felsic tuff, and chert of the Permian strata contain Middle Permian radiolarians (*Pseudoalbaillella* aff. *longicornis* Ishiga and Imoto, *Follicucullus monacanthus* Ishiga and Imoto, and, *Follicucullus scholastics* Ormiston and Babcock)., late Early Permian radiolarians (*Albaillella asymmetrica* Ishiga and Imoto), and middle Early Permian radiolarians (*Pseudoalbaillella sakumarensis* (Kozur), *Pseudoalbaillella postscalprata* Ishiga, and *Pseudoalbaillella scalprata* Holdsworth and Jones), respectively.

The depositional age of mudstone and felsic tuff of the Permian strata in the study area on the basis of those radiolarian biostratigraphy corresponds to the restored stratigraphy of the Shimomidani Formation (Ishiga and Suzuki, 1984, 1988). This indicates that the deposition of felsic tuff and mudstone deposited from late Early Permian and Middle Permian in the Shimomidani basin, respectively.

On the other hand, chert or red siliceous felsic tuff of the Shimomidani Formation contains the *Pseudoalbaillella bulbosa* assemblage (Latest Carboniferous to Earliest Permian) (Ishiga and Suzuki, 1984, 1988). The radiolarian assemblage of chert in this study is correlated with middle Early Permian (upper part of *Pseudoalbaillella lomentaria* Range Zone to *Pseudoalbaillella scalprata* m. *rhombothoracata* Assemblage Zone). This suggests that a sedimentation of siliceous deposits such as chert and red siliceous felsic tuff in the Shimomidani basin occurs from Latest Carboniferous or Earliest Permian to middle Early Permian.

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Keywords: Shimomidani Formation, Shidaka Terrane, Akiyoshi Terrane, Maizuru Terrane

Gravity-flow deposits on the slope to the foot of the Permian seamount in the Deadman Bay terrane, the San Juan Island, Washington State, USA

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The Deadman Bay terrane is the Mesozoic accretionary complex in the San Juan Islands, Washington State, USA (Brandon et al., 1988). The terrane is divided into three major coexistent stratigraphic units: the Permian volcanics unit, the Permian shallow-marine limestone unit, and the chert unit. The Permian volcanics unit comprises basalt lava, hyaloclastite, and basaltic volcaniclastic rocks intercalating Permian limestone-basalt breccia. The Permian shallow-marine limestone unit consists mainly of fossiliferous micritic limestone and is accompanied by basaltic rocks at the bottom. This limestone yields Middle Permian fusulines (Ota et al., 2009). This unit is accompanied by The chert unit is composed of Permian to Triassic bedded radiolarian chert. The Triassic chert intercalates clastic rocks containing grains of Permian shallow-marine limestone, basalt, and Permian to Triassic chert.

The limestone-basalt breccia in the Permian volcanics unit is composed of unsorted, angular lithoclasts of shallow-marine limestone and basalt, which are chaotically embedded in a basaltic volcaniclastic fine matrix. The limestone clasts yield Middle Permian fusulines. It is stressed that no coarse terrigenous clastic grains are contaminated in the Permian rocks.

The clastic rocks in the chert unit include volcaniclastic rocks, chert-sandstone, and chert-conglomerate. The volcaniclastic rocks contain variously-sized blocks of Permian shallow-marine limestone and Triassic chert. The blocks are chaotically embedded in and supported by the surrounding matrix of unsorted basalt fragments.
On the other hand, the chert-sandstone and the chert-conglomerate are graded sediments, which are composed of a siliceous mud matrix and angular clasts of Triassic chert, siliceous shale, basalt, and Permian shallow-marine limestone. The matrix contains a little amount of detrital quartz grains.

These rocks of the Deadman Bay terrane are reconstructed as the Permian basaltic seamount and sediments on the top, the slope, and the foot of a seamount. The Permian limestone-basalt breccia and the clastic rocks in the Triassic chert are considered to be gravity-flows deposits related to the collapse of a seamount. In the Permian period, the clasts of shallow-marine limestone and basalt were emplaced by gravity-flows from the top to the upper slope of the seamount in a pelagic realm. In the Triassic period, the seamount was approaching toward a continent and reached a hemi-pelagic realm. Then a larger collapse occurred and the collapse products were transported down onto the foot of the seamount by debris flows and turbidity currents, where chert had accumulated.

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Keywords: gravity-flow deposits, seamount, USA

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