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THE INTERNATIONAL ASSOCIATION OF RADIOLARISTS

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Hacettepe University

Chamber of Geological Engineers
of Turkey

General Directorate of
Mineral Research And Exploration

Turkish Association
of Petroleum Geologists

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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) and is affiliated to The Micropaleontological Society (TMS). Since 1978 members of INTERRAD meet every three years to present papers and exchange ideas and materials.

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.

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RADIOLARIA

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VOLUME 35 **March 2015**

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The 14th Meeting of
the International Association
of Radiolarists

A conference on Fossil and Recent Radiolarians

March 22-26, 2015

Antalya, Turkey

Programme and Abstracts

Host

Hacettepe University, Department of Geological Engineering, Ankara, Turkey

Supporting Institutions

Chamber of Geological Engineers of Turkey

General Directorate of Mineral Research and Exploration

Turkish Association of Petroleum Geologists

Turkish Petroleum Corporation

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Halil YUSUFOĞLU (Gen. Direc. of Min. Research and Exploration, Ankara, Turkey)

Conference Secretariat

Asterya Congress & Events Management (www.asterya.com)

Sessions & Conveners

Session 1.Taxonomy, systematics and phylogeny of radiolarians

(Conveners: Paula NOBLE & Nikita BRAGIN)

Session 2. Recent advances in radiolarian biostratigraphy

(Conveners: Rie S. HORI & Taniel DANELIAN)

Session 3. Radiolarians in geodynamics

(Conveners: Peter O. BAUMGARTNER & Marco CHIARI)

Session 4. Reconstruction of paleoenvironmental conditions and detection of climate changes through time using radiolarians

(Conveners: Giuseppe CORTESE & Qinglai FENG)

Session 5. Biological and ecological characteristics of recent radiolarians

(Conveners: Demetrio BOLTOVSKOY & Atsushi MATSUOKA)

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Antalya Havalimanı
Altıntaş Mh.
Muratpaşa
Gazi Blv.
Antalya
Namık Kemal Blv.
Dumlupınar Blv.
Crowne Plaza

SYMPOSIUM CALENDAR

March 19-22, 2015

Pre-Conference Excursion: Four day field trip to the Karakaya Complex and the Izmir-Ankara Suture Belt in central and western Turkey

Sunday March 22, 2015

10:00-18:00 Registration for congress at Crown Plaza Hotel, Antalya
19:00-22:00 Icebreaking Party

Monday March 23, 2015

08:40-12:20 Oral Session 1 with coffee break (S-3. Radiolarians in Geodynamics)
12:20-13:40 Group Photo & Lunch
13:40-17:20 Oral Session 2 with coffee break (S-2. Recent Advances in Radiolarian Biostratigraphy)
17:20-18:40 Poster Session 1 (S-3. Radiolarians in Geodynamics)
18:40-20:00 Paleozoic, Mesozoic & Cenozoic Workshops
20:00-22:00 Dinner

Tuesday March 24, 2015

08:40-10:00 Oral Session 3 (S-3. Radiolarians in Geodynamics)
10:00-10:20 Coffee Break
10:20-12:20 Oral Session 4 (S-1. Taxonomy, Systematics and Phylogeny of Radiolarians)
12:20-13:40 Lunch
13:40-17:00 Oral Session 5 with coffee break (S-1. Taxonomy, Systematics and Phylogeny of Radiolarians)
17:00-17:20 Coffee Break
17:20-18:20 Oral Session 6 (S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians)
18:20-20:00 Poster Session 2 (S-1. Taxonomy, Systematiabelacs and Phylogeny of Radiolarians & S-2. Recent Advances in Radiolarian Biostratigraphy)
20:00-22:00 Dinner

Wednesday March 25, 2015

09:00-12:30 Mid-Conference Excursion (Field trip to west of Antalya: Cenomanian/Turonian Anoxic Event in Antalya Nappes: The Doyran Section)
12:30-14:00 Lunch at hotel
14:00 Departure from hotel to visit Aspendos Antique Theatre
20:00-22:00 Gala Dinner

Thursday March 26, 2015

09:00-12:00 Oral Session 7 with coffee break (S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians)
12:00-12:20 Special Talk
12:20-13:40 Lunch
13:40-15:00 Oral Session 8 (S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians)
15:00-15:20 Coffee Break
15:20-17:40 Oral Session 9 (S-5. Biological and Ecological Characteristics of Recent Radiolarians)
17:40-19:00 Poster Session 3 (S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians & S-5. Biological and Ecological Characteristics of Recent Radiolarians)
19:00-20:00 Business Meeting
20:00-22:00 Farewell Dinner & Closure

March 27-30, 2015

Post-Conference Excursion: Four day field trip to the Antalya Nappes, southern Turkey

14th INTERRAD PROGRAMME

MONDAY, March 23

08:40-09:00 Welcome

Oral Session 1
(S-3. Radiolarians in Geodynamics)
Session Chairs: Luis O'DOGHERTY & Sergei V. ZYABREV

09:00-09:20 Goran ANDJIC & Peter O. BAUMGARTNER
Discovery of Late Cretaceous Radiolaria in the Loma Chumico Formation stratotype (Nicoya Peninsula, Costa Rica). New constraints on the tectonostratigraphic evolution of terranes in the Nicoya Peninsula

09:20-09:40 Maria Isabel SANDOVAL, Peter O. BAUMGARTNER, Franco URBANI & Walter REATEGUI
New paleontological insights for the Siquisique Ophiolite (northern Venezuela) using radiolarians

09:40-10:00 Nevenka ĐERIĆ, Špela GORIČAN, Nataša GERZINA, Renata JACH & Duje KUKOČ
Jurassic – Early Cretaceous radiolarian stratigraphy of the Danubian nappes (eastern Serbia)

10:00-10:20 Duje KUKOČ & Špela GORIČAN
Jurassic–Early Cretaceous pelagic succession of the eastern Southern Alps (NW Slovenia) and its correlation with the central Dinarides (Bosnia and Herzegovina, Montenegro)

10:20-10:40 Coffee Break

10:40-11:00 Marco CHIARI, Mensi PRELA, Marta MARCUCCI, Atsushi MATSUOKA & Emilio SACCANI
Radiolarian biostratigraphy and geochemistry of the ophiolites in the northern Albania

11:00-11:20 Patrice MOIX, Paulian DUMITRICA, Péter OZSVÁRT & Alexandre HUNGERBÜHLER
Huğlu-Pindos remnants in the Kopría (Rhodes, Greece) and in the Mersin (southern Turkey) mélanges: evidence from exceptionally preserved lower Tuvalian (upper Carnian) radiolarian fauna

11:20-11:40 Dishu CHEN & Hui LUO
New discovery of the Triassic radiolarians from Yarlung Zangbo Suture Zone in the Jinlu area, Zetang, southern Tibet

11:40-12:20 KEY-NOTE TALK
M. Cemal GÖNCÜOĞLU, U. Kağan TEKIN, Kaan SAYIT, Yavuz BEDI & Seda UZUNÇIMEN
Opening, evolution and closure of the Neotethyan Oceanic Branches in Anatolia as inferred by radiolarian research

12:20-13:40 Group Photo & Lunch

Oral Session 2

(S-2. Recent Advances in Radiolarian Biostratigraphy)
Session Chairs: Yoshiaki AITA & Paulian DUMITRICA

13:40-14:00 Jörg MALETZ
The earliest radiolarians: The race is still open

14:00-14:20 Noritoshi SUZUKI, Mayuri TAKEMOTO, Emi WATANABE, Satoshi YAMAKITA, Satoshi TAKAHASHI, Shun MUTO, Yoichi USUI & Masayuki IKEDA
Reexaminaton of conodonts and radiolarians from type sections of the Upper Carboniferous–Lower Permian radiolarian biozones in Japan

14:20-14:40 Kiyoko KUWAHARA & Hiroyoshi SANO
Upper Permian radiolarian biostratigraphy of deep sea Panthalassic chert sections from the Mino Terrane, Japan

14:40-15:00 Valentina S. VISHNEVSKAYA
Mesozoic Radiolaria of Crimea

15:00-15:20 Sarah KACHOVICH, Jonathan C. AITCHISON, Aliba AO, Santanu BHOWMIK & Tara ROEDER
Well-preserved Jurassic radiolarians from the Naga Hills ophiolite, Indo-Myanmar Range; constraints on intra-oceanic island arc development within eastern Tethys

15:20-15:40 Coffee Break

15:40-16:00 Luis O'DOGHERTY, Peter O. BAUMGARTNER, Sébastien BRUCHEZ & Špela GORIČAN
Carbon isotope correlation of Middle–Upper Jurassic radiolarian-bearing rocks across the Atlantic-western Tethys gateway

16:00-16:20 Bo XU & Hui LUO
Early Cretaceous Radiolaria from the Baergang section in southern Tibet and its significance

16:20-16:40 Peter O. BAUMGARTNER & Paulian DUMITRICA
Revision of some Late Cretaceous multicyrtid Nassellaria: Biometrics and lineages

16:40-17:00 Dmitry V. KOCHERGIN & Yuriy V. AGARKOV
First radiolarian records in the Paleocene of the southern slope of the western Caucasus

17:00-17:20 Yuxi JIN, Tim van PEER, Chuang XUAN & Christopher J. HOLLIS
Late Oligocene to early Miocene radiolarian events recorded in the mid-latitude North Atlantic

17:20-18:40 Poster Session 1

Monday Posters
(S-3. Radiolarians in Geodynamics)

P-1. Yoshiaki AITA, Hayato TAMURA, Satoshi YAMAKITA, Rie S. HORI, Atsushi TAKEMURA, Satoshi TAKAHASHI, K. Bernhard SPÖRLI & Hamish J. CAMPBELL
Microfacies and biogenic sedimentation processes by using high-resolution SEM revealed in the Middle Triassic bedded chert from Motutapu Island, New Zealand

P-2. Yoshiaki AITA, Ayaha SASAKI, Satoshi YAMAKITA, Rie S. HORI, Atsushi TAKEMURA, Satoshi TAKAHASHI, K. Bernard SPÖRLI & Hamish J. CAMPBELL
Middle Triassic Radiolaria from the manganese carbonate lens from the Motutapu Island, North Island, New Zealand

P-3. Jonathan C. AITCHISON, Sarah KACHOVICH, Peter G. FLOOD & Solomon BUCKMAN
δ age dating: combining new and traditional techniques to inform 4D models for understanding ancient ocean basin evolution

P-4. Alexandre N. BANDINI-MAEDER, Jonathan C. AITCHISON, Kathleen M. MARSAGLIA, Sébastien MEFFRE, Ivan P. SAVOV, Sev KENDER, Rodrigo DO MONTE GUERRA, Mohammed H. ALJAHDALI, Richard J. ARCULUS, Andrew P. BARTH, Kara A. BOGUS, Philipp A. BRANDL, Laureen DRAB, Michael GURNIS, Morihisa HAMADA, Li HE, Rosemary HICKEY-VARGAS, Osamu ISHIZUKA, Fuqing JIANG, Kyoko KANAYAMA, Yuki KUSANO, Lorne C. LOUDIN, Marco MAFFIONE, Anders MCCARTHY, Antony MORRIS, Martin NEUHAUS, Clara SENA, Frank J. TEPLEY, Cees VAN DER LAND, Gene M. YOGODZINSKI & Zhaohui ZHANG
Preliminary result of the radiolarian biochronological study of the basal sediments at IODP Site U1438 (Amami Sankaku Basin, Northern Philippine Sea)

P-5. Peter O. BAUMGARTNER & Daniel BERNOULLI
Diachronous Middle-Late Jurassic ophiolite obduction and exposure along the eastern Pelagonian Margin (Hellenides, Greece)

P-6. Valerio BORTOLOTTI, Marco CHIARI, M. Cemal GÖNCÜOĞLU, Marta MARCUCCI, Gianfranco PRINCIPI, Emilio SACCANI, U. Kağan TEKIN & Renzo TASSINARI
Radiolarian biostratigraphy and geochemistry of the ophiolitic complexes of the Izmir-Ankara Mélange (Turkey)

P-7. Nikita Yu. BRAGIN & Liubov G. BRAGINA
Lower and Middle Jurassic Radiolaria from cherts of the Kiselevka-Manoma accretionary complex (lower flow of Amur River, eastern Russia)

P-8. Marco CHIARI, Daniela HUNZIKER, Asghar DOLATI, Paulian DUMITRICA, Jean-Pierre BURG & Daniel BERNOULLI
Late Cretaceous and early Eocene radiolarian faunas from the internal Makran Accretionary Wedge (southeast Iran)

P-9. Taniel DANELIAN, Gayane ASATRYAN, Ara AVAGYAN, Ghazar GALOYAN, Lilit SAHAKYAN & Marc SOSSON
Deciphering geodynamic clues from radiolarian biochronology in the Lesser Caucasus and NW Iran

P-10. Tsuyoshi ITO, Yusuke SAKAI, Qinglai FENG & Atsushi MATSUOKA

Denudation history of mid-Mesozoic accretionary complexes in East Asia: compilation of microfossil-bearing clasts within the Upper Mesozoic strata

P-11. Yoshihito KAMATA & Kazuki GOTO

Lithology and geochemistry of chert-argillaceous rock sequences in the Inthanon Zone, northern Thailand: implications for accretionary ages in the Paleo-Tethys subduction zone

P-12. Satoshi NAKAE

Cretaceous radiolarians from chert-clastic rock sequence of the Matoya Group (Northern Shimanto belt), Kii Peninsula, southwest Japan

P-13. Hathaithip THASSANAPAK, Mongkol UDCHACHON & Clive BURRETT

Early Permian radiolarians from the west of Cambodia

P-14. Mongkol UDCHACHON, Hathaithip THASSANAPAK, Qinglai FENG & Clive BURRETT

Rare earth geochemistry of Late Devonian radiolarian chert/shale sequences from the Truongson Foldbelt, Indochina Terrane; implication to basin evolution

P-15. Satoshi YAMAKITA, Yoshiaki AITA, Atsushi TAKEMURA, Rie S. HORI & Noritoshi SUZUKI

Space-time distribution of Radiolaria-bearing carbonate nodules in Jurassic accretionary complexes in Japan and its tectonic interpretation

P-16. Sergei V. ZYABREV

Radiolarian biostratigraphy solves the tectono-stratigraphic relationships of the Amursky and Kiselevsko-Manominsky accretionary complexes in the eastern Russia

18:40-20:00 Paleozoic, Mesozoic & Cenozoic Workshops

20:00-22:00 Dinner

TUESDAY, March 24

Oral Session 3

(S-3. Radiolarians in Geodynamics)
Session Chair: Qinglai FENG

08:40-09:00 Xueheng WANG & Hui LUO
Paleocene radiolarians from the Sangdanlin Section, southern Tibet

09:00-09:20 Hathaithip THASSANAPAK, Mongkol UDCHACHON & Clive BURRETT
Silurian radiolarians from the Indochina Terrane

09:20-09:40 Tatiana N. PALECHEK, Dmitrii P. SAVELYEV, Alexei V. SOLOVIEV & Nikolai V. TSUKANOV
Radiolarian biostratigraphy of the Southern Kronotskii paleoarc (eastern Kamchatka)

09:40-10:00 Kenji KASHIWAGI & Kaori SANO
Radiolarian assemblages from the continental shelf sediments of the Middle Jurassic Kaizara Formation and the Late Jurassic Ikenoue Formation in Japan

10:00-10:20 Coffee Break

Oral Session 4

(S-1. Taxonomy, Systematics and Phylogeny of Radiolarians)
Session Chair: Špela GORIČAN

10.20-10.40 Wenchao CAO & Qinglai FENG
Early Cambrian radiolarians from Hubei, China

10.40-11.00 Shan CHANG & Qinglai FENG
Radiolarians from the Cambrian Terreneuvian in South China

11.00-11.20 Paula NOBLE, Martin TETARD, Taniel DANELIAN & Claude MONNET
Taxonomy and biodiversity analysis of a Gorstian radiolarian fauna from the Cape Phillips Formation, Canadian Arctic

11.20-11.40 Paulian DUMITRICA
On the status of the Triassic family Tetraspinocyrtidae Kozur & Mostler (Radiolaria) *and description of some new related taxa*

11.40-12.20 KEY-NOTE TALK
Taniel DANELIAN, Martial CARIDROIT, Luis O'DOGHERTY, Paula NOBLE, Jonathan C. AITCHISON, Paulian DUMITRICA, Noritoshi SUZUKI, Lauren POUILLE, Jessie CUVELLIER, Kiyoko KUWAHARA, Jörg MALETZ & Qinglai FENG
An up-to-date catalogue of Paleozoic radiolarian genera

12:20-13:40 Lunch

Oral Session 5

(S-1. Taxonomy, Systematics and Phylogeny of Radiolarians)
Session Chairs: Kiyoko KUWAHARA & Jonathan C. AITCHISON

13.40-14.00 Yoshiaki AITA, Rei KUKI, Atsushi TAKEMURA & Naoko KISHIMOTO
Three-dimensional images of morphology and internal structure of the genus Glomeropyle by using a micro X-ray CT

14.00-14.20 Nikita Yu. BRAGIN
Two radiolarian assemblages from the upper Norian (Triassic) of Kotel'nyi Island (Arctic, Russia)

14.20-14.40 Atsushi MATSUOKA, Takashi YOSHINO, Naoko KISHIMOTO, Naoto ISHIDA, Toshiyuki KURIHARA & Katsunori KIMOTO
How to define fossil radiolarian species? – A case study of the Mesozoic spumellarian Pantanellium

14.40-15.00 Sergei ZYABREV & Atsushi ANDO
Earliest Cretaceous radiolarians from the TAMU Massif on Shatsky Rise, North Pacific, Leg IODP 324: stratigraphic, taxonomic and paleobiogeographic issues

15.00-15.20 Liubov G. BRAGINA
Stratigraphic distribution and phylogeny of the Family Pseudodictyomitridae Pessagno, 1977 (Radiolaria) in Late Cretaceous

15:20-15:40 Coffee Break

15:40-16:00 Girish Kumar SHARMA, Deepak DAYAL & Umesh C. MAINALI
New species and evolution of Saturnalis and Saturnulus during the Neogene time in the Southern Ocean region

16:00-16:20 David LAZARUS & Johan RENAUDIE
Reconstructing radiolarian diversity: what we don't know; and a new analysis of the Cenozoic

16:20-16:40 Anders K. KRABBERØD, Russell ORR, Kjell BJØRKLUND & Kamran SHALCHIAN-TABRIZI
Single cell transcriptomics of two radiolarian species

16.40-17.00 Tristan BIARD, Loïc PILLET, Johan DECELLE, Camille POIRIER, Noritoshi SUZUKI & Fabrice NOT
Morpho-molecular classification of the Collodaria: Toward an integrative taxonomy?

17:00-17:20 Coffee Break

Oral Session 6

(S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians)
Session Chair: Hui LUO

17:20-17:40 Qiangfen MA & Qinglai FENG
Paleoenvironmental implication of radiolarian fauna and geochemical variation from the Gufeng Formation (Middle Permian) in western Hubei Province, south China

17:40-18:00 Tsuyoshi ITO, Qinglai FENG & Atsushi MATSUOKA
Distribution and provincialism of Pseudotormentus De Wever & Caridroit

18:00-18:20 Špela GORIČAN, Tea KOLAR-JURKOVSEK & Bogdan JURKOVSEK
Paleoecology of Middle Triassic low-diversity radiolarian fauna from Mt. Svilaja (External Dinarides, Croatia)

18:20-20:00 Poster Session 2

Tuesday Posters

(S-1. Taxonomy, Systematics and Phylogeny of Radiolarians &
S-2. Recent Advances in Radiolarian Biostratigraphy)

P-17. Tsuyoshi ITO, Atsushi MATSUOKA & Qinglai FENG
Dimorphism of Permian Albaillellaria: biometrical analysis of swollen type

P-18. Luis O'DOGHERTY, Patrick DE WEVER, Peter O. BAUMGARTNER & Špela GORIČAN
Radiolarian diversity in the Mesozoic: evolution and driving mechanisms

P-19. Mahin RAMI, Seyed Hamid VAZIRI, Atsushi MATSUOKA & Mahmoud Reza MAJIDIFARD
Lithostratigraphy and radiolarian biostratigraphy in the Halashi 01 section of the Kermanshah area, west Iran

P-20. Jiani SHENG, Sarah KACHOVICH & Jonathan C. AITCHISON
Silurian radiolarians from the Jenolan Caves region, New South Wales, Australia

P-21. Emine TÜRK ÖZ
New radiolarian records from pelagic red limestones in the eastern Black Sea Region (Giresun), NE Turkey

P-22. Emine TÜRK ÖZ, Ludmila KOPAEVICH & Valentina VISHNEVSKAYA
Finding of planktonic foraminifera and radiolarians of Upper Cretaceous from the Eastern Black Sea region (Trabzon, Turkey)

P-23. Liubov G. BRAGINA & Nikita Yu. BRAGIN
Radiolarian biostratigraphy of the Cretaceous (Albian–Coniacian) deposits of the Kelevudag section (northeastern Azerbaijan)

P-24. Sébastien BRUCHEZ, Luis O'DOGHERTY, José SANDOVAL, Peter O. BAUMGARTNER, Špela GORIČAN & Roque AGUADO
Radiolarian and carbon-isotope stratigraphy dating the onset of siliceous deposits in pelagic seamounts of the Subbetic

P-25. Kousuke HARA & Toshiyuki KURIHARA
Radiolarian biostratigraphy of the Suhaylah Formation (Upper Cretaceous) in the Oman ophiolite

P-26. Atsushi MATSUOKA & Seyed Hamid VAZIRI
Mesozoic radiolarian biostratigraphy in pelagic sediments in the Kermanshah area, west Iran

P-27. Luis O'DOGHERTY, Peter O. BAUMGARTNER, Sébastien BRUCHEZ & Špela GORIČAN
Callovian–Oxfordian Carbon isotope stratigraphy of Site 534A DSDP, Leg 76: facies evolution and revision of radiolarian occurrences

20:00-22:00 Dinner

WEDNESDAY, March 25

09:00 Departure from hotel to Mid-Conference Excursion

12:30-14:00 Lunch at hotel

14:00 Departure from hotel to visit Aspendos Antique Theatre

20:00-22:00 Gala Dinner

THURSDAY, March 26

Oral Session 7

(S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians)

Session Chairs: Yoshihito KAMATA & David LAZARUS

09:00-09:20 Manuela CASACCI, Angela BERTINELLI, Thomas J. ALGEO & Manuel RIGO
Norian/Rhaetian radiolarian assemblages related to paleoenvironmental conditions of the Lagonegro Basin (southern Apennines, Italy)

09:20-09:40 Qun YANG & Kuei-yu YEH
Radiolarian faunal transition in the Triassic-Jurassic boundary strata, Nadanhada Terrane, NE China

09:40-10:00 Naoto ISHIDA
Low-diversified earliest Jurassic (Hettangian) radiolarian assemblages from the Hashirimizu Complex in the Outer zone of southwest Japan

10:00-10:20 Xin LI, Atsushi MATSUOKA, Yalin LI & Chengshan WANG
Radiolarian biostratigraphic research near Zhongba county, along the Yarlung-Tsangpo Suture Zone and its applications in paleogeographic significance and Neo-Tethys evolution

10:20-10:40 Coffee Break

10:40-11:00 Yuriy V. AGARKOV & Andrey Yu. AGARKOV
Universal paleontological system and analysis of species diversity of radiolarians and diatoms

11:00-11:20 Kristina PASCHER, Steven M. BOHATY, Christopher J. HOLLIS, Robert M. MCKAY & Giuseppe CORTESE
Expansion of Southern Ocean radiolarian fauna linked to a late Eocene cooling event

11:20-11:40 Alexandre N. BANDINI-MAEDER, Michael J. ELLWOOD, Sébastien MEFFRE, Fuqing JIANG, Clara SENA, Ivan P. SAVOV, Sev KENDER, Rodrigo DO MONTE GUERRA, Mohammed H. ALJAHDAL, Richard J. ARCULUS, Andrew P. BARTH, Kara A. BOGUS, Philipp A. BRANDL, Laureen DRAB, Michael GURNIS, Morihisa HAMADA, Li HE, Rosemary HICKEY-VARGAS, Osamu ISHIZUKA, Kyoko KANAYAMA, Yuki KUSANO, Lorne C. LOUDIN, Marco MAFFIONE, Kathleen M. MARSAGLIA, Anders MCCARTHY, Antony MORRIS, Martin NEUHAUS, Frank J. TEPLEY, Cees VAN DER LAND, Gene M. YOGODZINSKI & Zhaohui ZHANG
Discussion on the preservation of Miocene radiolarians and sponge spicules at IODP Site 1438 (Amami Sankaku Basin, Northern Philippine Sea)

11:40-12:00 Johan RENAUDIE & David B. LAZARUS
Radiolarians, diatoms and the Cenozoic Si and C cycles

12:00-12:20 SPECIAL TALK
Patrick DE WEVER
Microscopic jeweleries: Chronometers for geologists and palace builders

12:20-13:40 Lunch

Oral Session 8
(S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians)
Session Chair: Kjell BJØRKLUND

13:40-14:00 Takuya ITAKI
Middle to late Pleistocene changes of radiolarian assemblages in the Japan Sea: Their response to global climate and sea-level variations

14:00-14:20 Ligia PÉREZ-CRUZ, Laura GÓMEZ, Jaime URRUTIA-FUCUGAUCHI & Konstantine CHOUMILINE
Climatic changes during Mid-Late Holocene in the southern Gulf of California

14:20-14:40 Giuseppe CORTESE & Joe PREBBLE
A radiolarian-based modern analogue dataset for paleoenvironmental reconstructions in the southwest Pacific

14:40-15:00 John ROGERS
The environment of the southern Indian Ocean over the last 40ka from radiolarian proxies

15:00-15:20 Coffee Break

Oral Session 9
(S-5. Biological and Ecological Characteristics of Recent Radiolarians)
Session Chairs: John ROGERS & Qun YANG

15:20-15:40 Rie S. HORI
Living Phaeodaria from surface water offshore Kashiwajima, southwestern Shikoku, Japan

15:40-16:00 Takahito IKENOUE, Kjell R. BJØRKLUND, Svetlana B. KRUGLIKOVA, Jonaotaro ONODERA, Katsunori KIMOTO & Naomi HARADA
Seasonal and annual flux changes of Radiolaria under the seasonally sea-ice covered conditions in the western Arctic Ocean

16:00-16:20 Kenji M. MATSUZAKI, Takuya ITAKI & Katsunori KIMOTO
Living radiolarian vertical distribution in the northern East China Sea

16:20-16:40 Yasuhide NAKAMURA, Ichiro IMAI, Fabrice NOT, Akihiro TUJI & Noritoshi SUZUKI
Morpho-genetic phylogeny and distribution pattern of phaeodarians (Cercozoa)

16:40-17:00 Kaoru OGANE, Noritoshi SUZUKI, Atsushi YAMAGUCHI & Akihiro TUJI
Improved method for collecting and culturing live polycystine cells

17:00-17:20 Kozo TAKAHASHI, Jonaotaro ONODERA & Seiji TANAKA
Significance of radiolarians in the middle Eocene Arctic basin for determining the degree of the connection to the Atlantic Ocean

17:20-17:40 Takashi YOSHINO & Atsushi MATSUOKA
Turing patterns on the spherical surface as an initial construction of skeletal structure of spherical radiolarians

17:40-19:00 Poster Session 3

Thursday Posters
(S-4. Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians & S-5. Biological and Ecological Characteristics of Recent Radiolarians)

P-28. Peter O. BAUMGARTNER, Marco CHIARI, Masayuki IKEDA & Rie S. HORI
Possible causes of a Lower Jurassic oceanic chert gap in Neotethys

P-29. Maximilien BÖLE & Peter O. BAUMGARTNER
Middle Jurassic radiolarite facies of Tethys as a function of paleoproductivity

P-30. Nikita Yu. BRAGIN & Liubov G. BRAGINA
Taxonomic composition of some Boreal radiolarian assemblages of Mesozoic

P-31. Liubov G. BRAGINA & Nikita Yu. BRAGIN
Radiolaria from lower Aptian deposits of the Shilovka section (Middle Volga Region, Eastern European Platform)

P-32. Christopher J. HOLLIS, Kristina PASCHER & Giuseppe CORTESE
Using radiolarian paleobiogeography to validate model- and proxy-based climate reconstructions for the early Paleogene of the southwest Pacific

P-33. Renata JACH, Nevenka ĐERIĆ & Špela GORIČAN
Nassellaria/Spumellaria ratio vs. palaeoproductivity proxies in the Middle–Upper Jurassic radiolarian-bearing deposits of the western Tethys Fatricum Domain (Poland and Slovakia)

P-34. Kenji M. MATSUZAKI, Noritoshi SUZUKI & Hiroshi NISHI
Radiolarian assemblage changes across the mid-Pleistocene Transition in southern Japan (IODP Exp. 314/315 Site C0001 Holes E & F)

P-35. Alexander MATUL, Andrea ABELMANN & Svetlana KRUGLIKOVA
Radiolarian Cycladophora davisiana and the last glacial ventilation of the intermediate water in the Subarctic Pacific

P-36. Akiko NISHIMURA
On the Cenozoic radiolarian assemblages from different environments

P-37. John ROGERS
The palaeoenvironment of the tropical eastern Indian Ocean

P-38. Maria Isabel SANDOVAL & Peter O. BAUMGARTNER
Neogene Radiolarian biostratigraphy and palaeoceanographic interpretations of the Costa Rican eastern equatorial Pacific offshore

P-39. Rujian WANG, Wenshen XIAO & Lei WANG
Millennial-scale paleoceanographic records based on radiolarian assemblages in the Northern Bering Sea since the Last Glacial Maximum

P-40. Qiang ZHANG, Muhong CHEN & Lanlan ZHANG
Variations in radiolarian assemblages in the Bering Sea since the Pliocene and their implications for paleoceanography

P-41. Tristan BIARD, Lars STEMMANN, Marc PICHERAL, Nicolas MAYOT, Rainer KIKO, Pieter VANDROMME, Helena HAUSE, Gabriel GORSKY, Tara Ocean Consortium & Fabrice NOT
Rhizaria, the elusive stars of the ocean

P-42. Lanlan ZHANG, Weifen HU, Muhong CHEN, Lili ZENG, Weihua ZHOU, Rongyu CHEN, Rong XIANG & Qiang ZHANG
Living and dead radiolarians in spring in the South China Sea and their responses to environmental factors

P-43. Martial CARIDROIT, Carine RANDON, Benjamin MUSAVU-MOUSAVOU with the support of some his numerous friends of the University of Lille 1 (France): Elisabeth LOCATELLI, Taniel DANIÉLIAN, Alain BLIECK, Daniel VACHARD, Thomas SERVAIS, Sébastien CLAUSEN, Régine NETTER
In honor of Nutthawut Wonganan, a friend, a geologist, a radiolarist who left us too early!

19:00-20:00 Business Meeting

20:00-22:00 Farewell Dinner & Closure

Session 1
Taxonomy, Systematics and Phylogeny of Radiolarians

Conveners
Paula NOBLE & Nikita BRAGIN

Three-dimensional images of morphology and internal structure of the genus *Glomeropyle* by using a micro X-ray CT

Yoshiaki AITA[1], Rei KUKI[1], Atsushi TAKEMURA[2] & Naoko KISHIMOTO[3]
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The radiolarian genus *Glomeropyle* has a large, globular to pyriform thick-walled shell with a rounded aperture and pylome. The genus, including seven species, was first described from the Middle Triassic of New Zealand and NE Siberia, Russia by Aita & Bragin (1999). Although the initial assignment to Spumellaria was suggested, subsequent studies revealed that the genus belonged to the Order Entactinaria due to the presence of a distinct internal spicule (Aita et al., 2000, 2009). Since then, two species, *Glomeropyle bispinosa* and *G. campbelli*, have been reported from the Lower Triassic (upper Olenekian) at Kaka Point, New Zealand (Hori et al., 2003). Recently, five new species of *Glomeropyle* including *G. clavatum, G. insulanum, G. cuneum, G. algidum* and *G. aculeatum* have been described; the first two species are from the Middle Triassic (Anisian) and the last three species occur in the Upper Triassic (lower Carnian) of Kotel'nyi Island, Arctic (Bragin, 2011). Another new species, *G. saccum*, was reported from the Middle Triassic (upper Anisian) of Kotel'nyi Island, New Siberian Islands (Bragin, 2014). The latest occurrence of *Glomeropyle* sp. from the Upper Triassic (lower Carnian) of Kotel'nyi Island was indicated by Bragin et al. (2012). Therefore, high species diversity and dominance of the genus *Glomeropyle* are very significant during the Early to Middle Triassic in higher latitudes of the southern and northern hemisphere and reinforce the bipolar nature of the genus and species (Spörli et al., 2007; Aita et al., 2009; Bragin et al., 2012; Bragin & Bragina, 2013).

In terms of the internal structure of the *Glomeropyle*, there is an initial spicule consisting of three Apical Rays (AR), four Basal Rays (BR) and a median bar (MB), with several inter-connecting arches (Ach). The initial spicule is obliquely set in the upper off-center position within the thick-walled shell. Such a general understanding of the internal structure was so far firsthand knowledge from the stereo-photos observation of partly broken specimens by using SEM. Recent cutting-edge technology like a micro X-ray CT can allow us to obtain the clear detailed internal structure of the radiolarian shell without any destruction. We have examined the three species of *Glomeropyle*, which are G. *aurora, G. mahinepuaensis* and *G. grantmackiei* by using a micro X-ray CT (Skyscan Micro-CT in SEM). The obtained 3-D images of the overall shell as well as internal structures on the three species are revealed and those data can allow us to describe and compare exact differences within species and generic common features.

Based on the 3-D images, the detailed morphology and arrangement of the initial spicule of these three species are presented. In particular, alignment of Apical Rays (ARs), Basal Rays (BRs) and Arches between Basal Rays demonstrates direct connection between Apical and Basal spines, and internal ARs and BRs. We found a special empty space secured within the *Glomeropyle* shell.

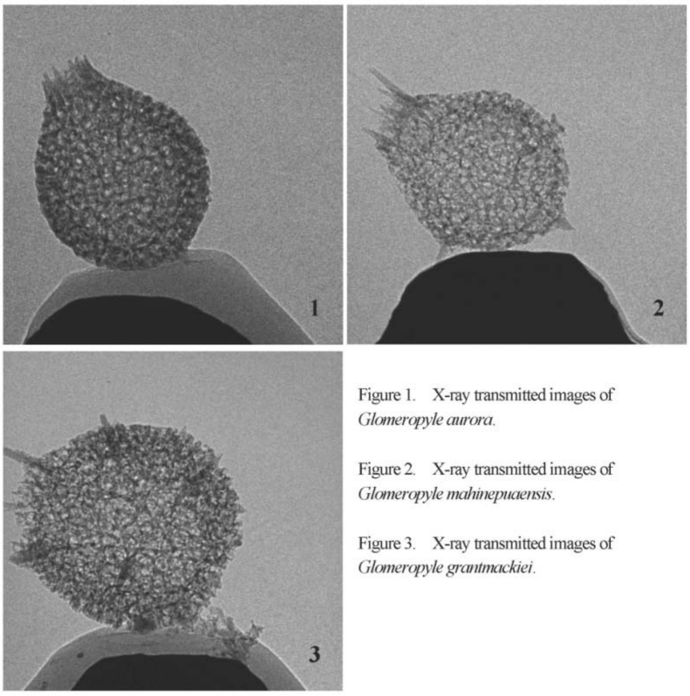

Figure 1. X-ray transmitted images of *Glomeropyle aurora*.

Figure 2. X-ray transmitted images of *Glomeropyle mahinepuaensis*.

Figure 3. X-ray transmitted images of *Glomeropyle grantmackiei*.

References

Aita, Y. & Bragin, N. Yu., 1999. Non-Tethyan Triassic Radiolaria from New Zealand and northeastern Siberia. Geodiversitas 21, 4, 503-526.

Aita, Y., Takemura, A. & Yamakita, S., 2000. Middle Triassic pylomate Spumellaria with an initial spicule from manganese carbonate layers at Arrow Rocks, Waipapa Terrane, New Zealand. Program with Abstract of Ninth Meeting, the International Association of Radiolarian Paleontologists, 14.

Aita, Y., Suzuki, N., Ogane, K. & Sakai, T., 2009. Bipolar distribution of Recent and Mesozoic Radiolaria. Fossils, The Palaeontological Society of Japan 85, 25-42.

Bragin, N. Yu., 2011. Triassic radiolarians of Kotel’nyi Island (New Siberian Islands, Arctic). Paleontological Journal 45, 7, 711-778.

Bragin, N. Yu., 2014. Stratigraphic significance of Middle Triassic radiolarians from the central part of Kotel’nyi Island (New Siberian Islands). Stratigraphy and Geological Correlation 22, 2, 62-76.

Bragin, N. Yu. & Bragina, L.G., 2013. Morphological characteristics of Boreal radiolarians from the Triassic and Late Cretaceous: Comparative Analysis. Paleontological Journal 47, 4, 351-362.

Bragin, N. Yu., Konstantinov, A.G. & Sobolev, E.S., 2012. Upper Triassic stratigraphy and paleobiogeography of Kotel’nyi Island (New Siberian Islands). Stratigraphy and Geological Correlation 20, 6, 541-566.

Hori, R.S., Campbell, J.D. & 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.

Spörli, K.B., Aita, Y., Hori, R.S. & Takemura, A., 2007. Results of multidisciplinary studies of the Permian-Triassic ocean floor sequence (Waipapa terrane) at Arrow Rocks, Northland, New Zealand. The Oceanic Permian/Triassic boundary sequence at Arrow Rocks (Oruatemanu), Northland, New Zealand. GNS Science Monograph 24, 219-229.

Key words: 3-D image, morphology, internal structure, *Glomeropyle*, micro X-ray CT.

Morpho-molecular classification of the Collodaria: Toward an integrative taxonomy?

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While most previous studies have investigated past diversity and paleo-environmental signatures via the fossil record, less is known about the diversity and ecology of living radiolarians. Among polycystine radiolarians, Collodaria are worldwide-distributed marine protists, and are particularly abundant in temperate, calm and oligotrophic surface waters (Swanberg, 1979). They occur as either large colonies or solitary specimens, and unlike most radiolarians, some taxa lack silicified structures. Almost all colonial collodarians are known to harbour hundreds of thousands of endosymbiotic microalgae, which make them important contributors to the primary production in oligotrophic surface waters (Michaels et al., 1995). Even though collodarians are known to play an important role in the oceanic food webs through high predation activity and symbiotic association with photosynthetic dinoflagellates, very little is known about their diversity and evolution. Taxonomic delineation is challenging and only a few species are currently genetically characterized. With only 24 reference genetic sequences (22 for the 18S ribosomal RNA gene and two for the 28S rRNA gene) and without unambiguous associated morphological characters, relationships between collodarian families, genera and species remain poorly resolved.

We investigated collodarian diversity through the phylogenetic analyses of both small (18S) and large (28S) subunits of the ribosomal DNA, which the concatenated dataset included 124 new sequences from 75 collodarians sampled worldwide. Resulting molecular phylogenies were compared to morphology-based classifications. Our analyses separated the monophyletic clade of skeleton-less and spicule-bearing Sphaerozoidae from the sister clades Collosphaeridae (skeleton-bearing) and Collophiidae (skeleton-less), while the Thalassicollidae (solitary specimens) was not retrieved as a monophyletic clade. Detailed morphological examination combined with molecular analyses revealed many discrepancies, such as a mix between solitary and colonial species, the existence of skeleton-less specimens in the skeleton-bearing clade Collosphaeridae, as well as complex intra- and interspecific variability in silicified structures. Such observations challenge the validity of a purely morphology-based classification and strengthen an integrative taxonomic approach to study the diversity of Collodaria. Besides pure taxonomic perspectives, this study contributes to improve the understanding of marine environmental genetic surveys, and more specifically the implications of collodarians in global ecology of the oceans.

References

Michaels, A.F., Caron, D.A., Swanberg, N.R., Howse, F.A. & Michaels, C.M., 1995. Planktonic sarcodines (acantharia, radiolaria, foraminifera) in surface waters near Bermuda - abundance, biomass and vertical flux. Journal of Plankton Research 17, 131–163.

Swanberg, N.R., 1979. The ecology of colonial radiolarians: their colony morphology, trophic interactions and associations, behavior, distribution, and the photosynthesis of their symbionts. Ph. D. Thesis. Woods Hole Oceanographic Institution and Massachusetts Institute of Technology.

Key words: Collodaria, phylogeny, integrative taxonomy.

Two radiolarian assemblages from the upper Norian (Triassic) of Kotel'nyi Island (Arctic, Russia)

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The first upper Norian (Triassic) Radiolaria from Kotel'nyi Island (New Siberian Islands, Arctic, Russia) were obtained and are reported in this paper. The Triassic of this region is represented by a fine-grained clastic sequence containing numerous phosphatic and carbonate concretions, with a total thickness of several hundred meters. The Triassic faunal assemblages of Kotel'nyi Island (ammonoids, nautiloids, bivalves and radiolarians) display boreal affinity but some stratigraphic intervals (especially upper Carnian and lower Norian) are marked by the penetration of southern (even Tethyan) taxa (Konstantinov et al., 2003; Bragin et al., 2012). Triassic Radiolaria was studied in detail by Bragin (2011), but late Norian assemblages remained unknown until two years ago.

Two radiolarian assemblages were recovered. The first, from the *Monotis zabaikalica* Subzone (bivalves, lower part of upper Norian), contains 24 species, including *Archaeocenosphaera lasekeensis* Pessagno & Yang, *Betraccium inornatum* Blome, *Crucella* sp. cf. *C. theokaftensis* Baumgartner, *C.* sp. cf. *C. angulosa* Carter, *Dumitricaella* (?) *parva* Sugiyama, *Ferresium titulense* Blome, *Parahsuum* sp. aff. *P. hashimotoi* Yeh & Cheng, *Pseudohagiastrum* sp. cf. *P. parvum* (Kozur & Mostler), *P. sandspitensis Blome*, *Praenanina* sp. aff. *P. veghae* Kozur, and additional species belonging to the genera *Acanthotetrapaurinella*, *Cantalum*, *Droltus*, *Kahlerosphaera*, *Laxtorum*, *Plafkerium*, *Relindella*. The second assemblage, from *Monotis subcircularis* Subzone (bivalves, upper part of upper Norian), contains 11 species, including *Archaeocenosphaera lasekeensis* Pessagno & Yang, *Crucella* sp. cf. *C. angulosa* Carter, *C.* sp., *Droltus* ? sp., *Kahlerosphaera acris* Bragin, *K.* sp. cf. *K. parvispinosa* Kozur & Mostler, *Parahsuum* ? sp., *Parasepsagon* ? sp., *Pseudohagiastrum crassum* (Carter), *P.* sp., *Triassospongosphaera* sp.. Both assemblages have taxa in common with upper Norian and Rhaetian of British Columbia (Blome, 1984; Carter, 1993), and possess clear features of high-latitude origin: low taxonomic diversity, presence of characteristic taxa unknown or very rare in low-latitude regions (like *Ferresium titulense* and *Pseudohagiastrum crassum*), absence of numerous forms common and abundant in low-latitude regions (like *Betraccium deweveri* Pessagno & Blome or *Lysemelas olbia* Sugiyama). In comparison with older radiolarian assemblages from Kotel'nyi Island (Bragin, 2011, 2014), the low-latitude elements are very rare here.

The presence of early representatives of the nassellarian genera *Droltus* and *Parahsuum* is very distinctive. The genus *Droltus* was previously known from Rhaetian of British Columbia (Carter, 1993). *Droltus* is very common taxon in Jurassic strata of various regions including sub-Boreal (Pessagno & Whalen, 1982), Tethyan (Tekin, 2002), sub-Austral (New Zealand) (Hori et al., 1996), Antarctic (Kiessling, 1999). The oldest known representatives of this taxon are *Droltus gelidus* and *D. niveus*, described from upper Carnian of Kotel'nyi Island (Bragin, 2011). *Droltus gelidus* is present also in the upper Carnian and lower Norian of Queen Charlotte Islands (Haida Gwaii), Canada (Carter & Orchard, 2013). Our late Norian representatives could be descendants of *D. gelidus* group and may represent phylogenetic lineage. The absence of *Droltus* in the Tethyan Upper Triassic gives opportunity to suppose that this taxon appeared in the Boreal Realm during the Late Triassic and became widespread in the Jurassic.

The genus *Parahsuum* was described from Lower Jurassic of Japan (Yao, 1982), is well- known in the Liassic, and some authors indicate that *Parahsuum* s.l. appears in the lowest Hettangian (Carter & Hori, 2005). Despite this point of view, representatives of this genus were indicated in Rhaetian of the Philippines (Yeh & Cheng, 1996). Our specimens have affinity with those of the Philippines, and may be the oldest representatives of the genus. Thus, the Boreal realm may be the center of appearance and further radiation of some multicyrtoid nassellarians that become typical for Jurassic.

References

Blome, C.D., 1984. Upper Triassic Radiolaria and radiolarian zonation from western North America. Bulletin of American Paleontology 85, 318, 1–88.

Bragin, N.Yu., 2011.Triassic radiolarians of Kotel'nyi Island (New Siberian Islands, Arctic). Paleontological Journal 45, 7, 711-778.

Bragin, N.Yu., 2014. Stratigraphic significance of Middle Triassic radiolarians from the central part of Kotel'nyi Island (New Siberian Islands). Stratigraphy and Geological Correlation 22, 2, 175–189.

Bragin, N.Yu., Konstantinov, A.G. & Sobolev, E.S., 2012. Upper Triassic stratigraphy and paleobiogeography of Kotel'nyi Island (New Siberian Islands). Stratigraphy and Geological Correlation 20, 6, 541–566.

Carter, E.S., 1993. Biochronology and paleontology of uppermost Triassic (Rhaetian) radiolarians, Queen Charlotte Islands, British Columbia, Canada. Mémoires de Géologie (Lausanne) 11, 1–175.

Carter, E.S. & Hori, R.S., 2005. Global correlation of the radiolarian faunal change across the Triassic–Jurassic boundary. Canadian Jour. Earth Sci. 42, 777–790.

Carter, E.S. & Orchard, M.J., 2013. Intercalibration of conodont and radiolarian faunas from the Carnian-Norian boundary interval in Haida Gwaii, British Columbia, Canada. In: The Triassic System (Tanner, L.N., Spielmann, J.A. & Lucas, S.G., Eds.), New Mexico Museum of Natural History and Science, Bull. 61. 67-92.

Hori, R. S., Aita, Y. & Grant-MacKie, J.A., 1996. Preliminary report on Lower Jurassic radiolaria of Gondwana origin from the Kawhia coast, New Zealand. The Island Arc 5, 104-113.

Kiessling, W., 1999. Late Jurassic Radiolaria from the Antarctic Peninsula. Micropaleontology 45(S1), 1-96.

Konstantinov, A.G., Sobolev, E.S. & Klets, T.V., 2003. New Data on Fauna and Biostratigraphy on Norian Deposits in the Kotel'nyi Island (New Siberian Islands), Stratigraphy and Geological Correlation 11, 3, 231–243.

Pessagno, E.A., Jr. & Whalen, P. A., 1982. Lower and Middle Jurassic Radiolaria (multicyrtid Nassellariina) from California, east-central Oregon and the Queen Charlotte Islands, B. C. Micropaleontology 28, 2, 111-169.

Tekin, U.K., 2002. Lower Jurassic (Hettangian-Sinemurian) radiolarians from the Antalya Nappes, Central Taurids, Southern Turkey. Micropaleontology 48, 2, 177-205.

Yao, A., 1982. Middle Triassic to Early Jurassic radiolarians from the Inuyama area, central Japan. Journal of Geosciences, Osaka City University 25, 53-70.

Yeh, K.-Y. & Cheng, Y. N., 1996. An Upper Triassic (Rhaetian) radiolarian assemblage from Busuanga Island, Philippines. Bulletin of the National Museum of Natural Science, Taiwan 7, 1-43.

Key words: Radiolaria, Triassic, upper Norian, Arctic.

Stratigraphic distribution and phylogeny of the Family Pseudodictyomitridae Pessagno, 1977 (Radiolaria) in Late Cretaceous

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The stratigraphic distribution and proposed phylogenetic relationships of taxa in the family Pseudodictyomitridae Pessagno, 1977 is discussed. This family is present from the early Bathonian to Late Cretaceous and supposedly in the early Paleocene. The oldest genus of this family is *Loopus* Yang, 1993 the range of which is Early Bathonian-Early Aptian (unknown in Late Cretaceous). The genus *Pseudodictyomitra* Pessagno, 1977 is known from the early Kimmeridgian to Late Cretaceous. Fourteen species of the genus *Pseudodictyomitra* are present in the Late Cretaceous. Only five species have their first appearance in Late Cretaceous (Fig. 1).

The species *Dictyomitra sagitafera* Aliev was described and illustrated only by drawing (Aliev, 1965). Due to absence of photo image this species was regarded as junior synonym of *P. pseudomacrocephala* (Squinabol) (Petrushevskaya & Kozlova, 1972; O'Dogherty, 1994). During reinvestigations of Albian-Cenomanian Radiolaria of the Greater Caucasus, the first photos of *Dictyomitra sagitafera* Aliev were done. It allowed to validate this species and assign it to *Pseudodictyomitra* genus (Bragina in Bragina & Bragin, 2015).

A new genus *Cyprodictyomitra* Bragina is assigned to the family Pseudodictyomitridae. This genus is represented by two species: *C. elegantissima* Bragina and *C. longa* Bragina that are present in middle Coniacian-uppermost Santonian of Cyprus (Bragina, 2013). Representatives of this genus were previously figured as Nassellaria, gen. and sp. indet. (Wakita et al., 1994, text-fig. 6.6) from Coniacian-middle Campanian of Jawa, Indonesia. The new genus differs from *Pseudodictyomitra* by the usual development of the apical horn and by the necessary presence of a terminal tube with a multilayered wall. Similar tubes (cylindrical neck) with a single thin layer and small pores can be present among some forms of *Pseudodictyomitra pseudomacrocephala* (Squinabol) (Pessagno, 1977, pl. 8, figs. 3, 7, 10, 24). This work was supported by RFBR grant 13-05-00447 A.

References

Aliev, K. S., 1965. Radiolyarii nizhnemelovykh otlozhenii severo-vostochnogo Azerbaidzhana i ikh stratigraficheskoe znachenie. Izdatel'stvo Akademii Nauk, Azerbaidzhanskoi SSR, Baku, 125p. (in Russian).

Bragina, L.G., 2013. New Radiolaria of the Family Pseudodictyomitridae from the Coniacian–Santonian of the Perapedhi Formation of southern Cyprus. Paleontological Journal 47, 5, 457–462.

Bragina, L.G. & Bragin, N.Yu., 2015. New data on Albian–Coniacian Radiolaria of the Kelevudag Section (northeastern Azerbajdzan). Stratigraphy and Geological Correlation 23, 1, 1–12.

O'Dogherty, L., 1994. Biochronology and paleontology of mid-Cretaceous radiolarians from northern Apennines (Italy) and Betic Cordillera (Spain). Mém. Géol. Lausanne 21, 1–413.

Pessagno, E.A., Jr., 1977. Lower Cretaceous radiolarian biostratigraphy of the Great Valley Sequence and Franciscan Coast Ranges. Cusman Found. Foraminiferal Res. Publ. 15, 1–87.

Petrushevskaya, M.G. & Kozlova, G.E., 1972. Radiolaria. Initial Report of the Deep Sea Drilling Project. Washington: U.S. Goverment Printing Office 14, 495–648.

Wakita, K., Munasri & Bambang, W., 1994. Cretaceous radiolarians from the Luk-Ulo Melange Complex in the Karangsambung are, central Java, Indonesia. Journal of Southeast Asian Earth Sciences 9, 1/2, 29–43.

Yang, Q., 1993.Taxonomic Studies of Upper Jurassic (Tithonian) Radiolaria from the Taman Formation, east-central Mexico. Palaeoworld 3, 1–164.

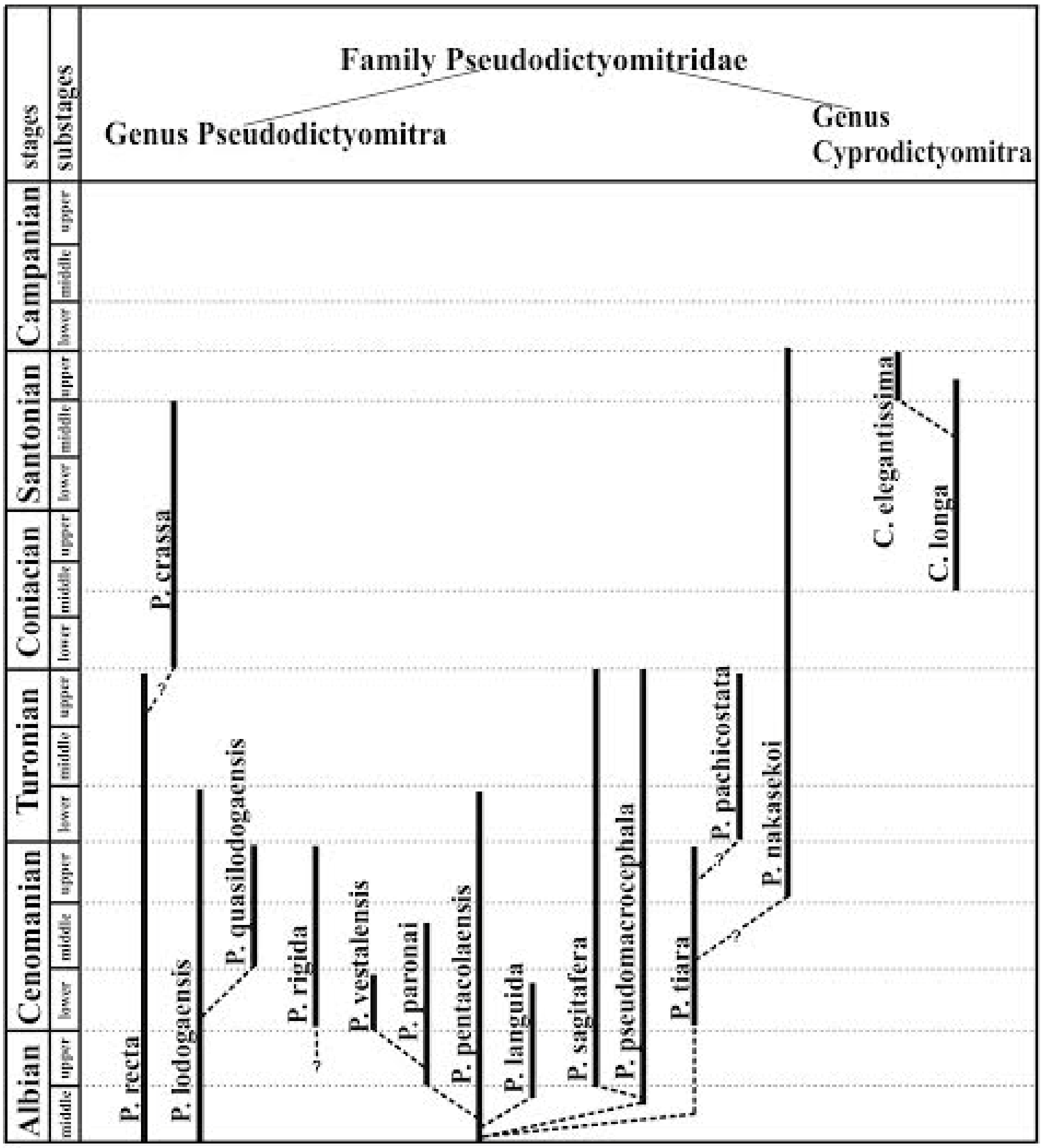

Fig. 1. Stratigraphic ranges of Late Cretaceous Pseudodictyomitridae and their possible phylogenetic relations.

Key words: Radiolaria, Late Cretaceous, evolution, phylogeny.

Early Cambrian radiolarians from Hubei, China

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Due to the absence of definite radiolarian records in the Early Cambrian and late Pre-Cambrian time, the origin of radiolarians and their early evolution are poorly understood. We surveyed the Cambrian in South China and collected radiolarian specimens including *Kalimnasphaera* sp. and some spherical radiolarians with latticed shells from limestone concretions at the bottom of the Shuijingtuo Formation in Zigui, Hubei Province, China (Cao et al., 2014). Based on the trilobite fauna containing *Sinodiscus*, *Tsunyidiscus*, and *Hupeidiscus* in the middle part of the formation (Wang et al., 1987; Dai & Zhang, 2011), the Shuijingtuo Formation is correlated to the Qiongzhusian Stage, corresponding to the basal part of the Cambrian Series 2 (Wang et al., 2002; Peng, 2009; Zhu, 2010). Recently, we reexamined the materials for further study. As a result, we obtained *Antygopora* sp. and some similar spherical latticed radiolarians. Here we report these new radiolarians and discuss the radiolarian records in the early stage.

Among our materials, some specimens can be assigned to *Antygopora* Maletz & Bruton according to the characters of several plate shells pierced by pores with elevated rims and a honeycomb pattern inner shell. However, these individuals cannot be identified with any known *Antygopora* species, therefore, they are left in open nomenclature provisionally. This genus was formerly reported only from the Early and Middle Ordovician. It is described from the Cambrian Series 2 for the first time herein. Some spherical radiolarians with latticed shells are rediscovered in our study. They were previously discovered from the Cambrian Terreneuvian in Shaanxi Province, China by Braun et al. (2007) and from the same location with this paper (Cao et al., 2014).

The needle-like or spicular construction of radiolarians represented by Order Archaeospicularia from the Middle Cambrian has been considered as the ancestor of radiolarians (Dumitrica et al., 2000). However, Braun et al. (2007) and Cao et al. (2014) discovered that some radiolarians from the Early Cambrian of China have latticed shells, but not be composed of spicules. The materials of this study, in addition to these previous discoveries, do not support the hypothesis that the Order Archaeospicularia is the representative of the oldest radiolarian group. The oldest known radiolarian fauna does not belong to Order Archaeospicularia. Besides, as can be known from these materials, two distinct types of shell structure of radiolarians including latticed test and perforate plate shell appeared in the Early Cambrian. Our materials combined with previous data show that the known Early Cambrian radiolarian fauna was complex in structure and diverse in morphological expression. It also indicates radiolarians might go through rapid diversification in this period. Therefore, it is necessary to investigate simpler and more original radiolarian faunas in older strata.

References

Braun, A., Chen, Y., Waloszek, D. & Maas, A., 2007. First Early Cambrian Radiolaria.Geological Society, London, Special Publications 286, 143-149.

Cao, W.C., Feng, Q.L., Feng, F.B. & Ling, W.L., 2014. Radiolarian *Kalimnasphaera* from the Cambrian Shuijingtuo Formation in south China. Marine Micropaleontology 110, 3-7.

Dai, T. & Zhang, X.L., 2011. Ontogeny of the ecodiscoid trilobite *Tsunyidiscus acutus* from the Lower Cambrian of south China. Palaeoecology 54, 6, 1279-1288.

Dumitrica, P., Caridroit, M. & De Wever, P., 2000. Archaeospicularia, ordre nouveau de radiolaires: une nouvelle étape pour la classification des radiolaires du Paléozoïque inférieur. Comptes Rendus de l'Académie des Sciences. Series IIA: Earth and Planetary Science 330, 8, 563-569.

Peng, S.C., 2009. The newly-developed Cambrian biostratigraphic succession and chronostratigraphic scheme for South China. Chinese Science Bulletin 54, 22, 4161-4170.

Wang, X.F., Chen, X.H. & Zhang, R.J., 2002. Precious geological relics preservation of the Three Gorges region and the Archean-Mesozoic multiple stratigraphic division and eustatic sea level change. Beijing: Petroleum Industry Press, 1-341 (in Chinese).

Wang, X.F., Xiang, L.W., Ni, S.Z., Zeng, Q.L., Xu, T.H., Zhou, T.M., Lai, C.G. & Li, Z.H., 1987. Biostratigraphy of the Three Gorges region (2)-Early Palaeozoic Volume. Beijing: Petroleum Industry Press, 1-714 (in Chinese).

Zhu, M.Y., 2010. The origin and Cambrian explosion of animals: fossil evidences from China. Acta Palaeontologica Sinica 49, 3, 269-287 (in Chinese with English Abstract).

Key words: Early Cambrian, Radiolaria, China.

Radiolarians from the Cambrian Terreneuvian in South China

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Radiolarians form an important part of the planktonic realm in the ocean of Early Palaeozoic, but their origin and evolutionary processes has long been enigmatic. The ancestor of radiolarians has been considered to belong to the order Archaeospicularia, whose unquestionable fossil records were dated back to the Middle Cambrian (Dumitrica et al., 2000). However, the earlier history of radiolarians is obscured by dubious or mistaken reports and poor stratigraphic documentations (Pickett & Jell, 1983; Maletz, 2011).

Here we report *Blastulospongia*, an enigmatic siliceous microfossil genus, and unnamed spherical radiolarians from the Yanjiahe Formation in South China. The Yanjiahe Formation belongs to early to middle Meishucunian in age (Steiner et al., 2007), corresponding to the Terreneuvian (Early Cambrian) internationally. More specifically, based on small shelly fossils (Guo & Li, 2014), the horizon is between *Anabarites trisulcatus–Protohertzina anabarica* assemblage zone and the *Aldanella yanjiaheensis* zone. The tests of *Blastulospongia* in this report are the earliest occurrence known so far, and we make comparisons between specimens reported formerly (e.g., Bengtson, 1986; White, 1986; Conway Morris & Chen, 1990) with those in this study. The results indicate that this genus had evolved to a larger size. Oxygen concentration has long been recognized as a critical trigger for evolution of life (Zhang et al., 2014), and Payne et al. (2010) concluded that increased oxygen availability leads to increased sizes (primarily in aerobic heterotrophs). Compatibly our study shows that oxygen availability is an important factor for the size increase of *Blastulospongia*. As for the unnamed radiolarians, in morphology they possess latticed shell and spherical shape, which are similar to the tests reported by Braun et al. (2007) from the Terreneuvian and Cao et al. (2014) from the Cambrian Series II. Our finding indicates that this spherical radiolarian is a very ancient group; it has appeared as early as the Terreneuvian. However, they show neither needle-like morphology nor spicular constructions postulated to be characteristic for ancestral radiolarians (Archaeospicularia), the hypothesis that the oldest radiolarians belong to the order Archaeospicularia needs to be reexamined. A phylogenetic analysis concerning these oldest radiolarians must await more investigations.

References

Bengtson, S., 1986. Siliceous microfossils from the Upper Cambrian of Queensland. Alcheringa 10, 3, 195-216.

Braun, A., Chen, Y., Waloszek, D. & Maas, A., 2007. First Early Cambrian Radiolaria. Geological Society, London, Special Publications 286, 143-149.

Cao, W., Feng, Q., Feng F., et al., 2014. Radiolarian *Kalimnasphaera* from the Cambrian Shuijingtuo Formation in South China. Marine Micropaleontology 110, 3-7.

Conway Morris, S. & Chen, M., 1990. *Blastulospongiapolytreta* n. sp., an enigmatic organism from the Lower Cambrian of Hubei, China. Journal of Paleontology 64, 26-30.

Dumitrica, P., Caridroit, M. & De Wever, P., 2000. Archaeospicularia, ordre nouveau de radiolaires: une nouvelle etape pour la classification des radiolaires du paleozoique inferieur. Comptes Rendues, Academie des Sciences, Paris, Sciences de la Terre et des Planetes 330, 8, 563-569.

Guo, J., Li, Y. & Li, G., 2014. Small shelly fossils from the Early Cambrian Yanjiahe Formation, Yichang, Hubei, China. Gondwana Research 25, 999-1007.

Maletz, J., 2011. Radiolarian skeletal structures and biostratigraphy in the Early Palaeozoic (Cambrian–Ordovician). Palaeoworld 20, 2, 116-133.

Payne, J.L., Mc Clain, C.R., Boyer, A.G., et al., 2010. The evolutionary consequences of oxygenic photosynthesis: a body size perspective. Photosynth Res. 107, 1, 37-57.

Pickett, J.W. & Jell, P.A., 1983. Middle Cambrian Sphinctozoa (Porifera) from New South Wales. Memoirs of the Association of Australasian Paleontologists 1, 85–92.

Steiner, M., Li, G.X., Qian, Y., Zhu, M.Y. & Erdtmann, B.D., 2007. Neoproterozoic to Early Cambrian small shelly fossil assemblages and a revised biostratigraphic correlation of the Yangtze platform (China). Palaeogeography, Palaeoclimatology, Palaeoecology 254, 67–99.

White, R.D., 1986. Cambrian Radiolaria from Utah. Journal of Paleontology 60, 778-780.

Zhang, X., Shu, D., Han, J. et al., 2014. Triggers for the Cambrian explosion: Hypotheses and problems. Gondwana Research 25, 3, 896–909.

Key words: Radiolarian, Terreneuvian, *Blastulospongia*, South China, oxygen concentration.

An up-to-date catalogue of Paleozoic radiolarian genera

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The first ever Paleozoic radiolarian genus was described by Hinde (1890) from Ordovician cherts of Scotland (U.K.). Only few additional genera were erected for the following 60 years, till the milestone publication of Deflandre (1952), which clearly established the substantial evolutionary character of the Radiolarian fossil record. The extensive use of the Scanning Electron Microscope, since the 1970s, gave undoubtedly a new impetus to the study of Paleozoic Radiolaria, and resulting in a present day total of 341 genera being described in the literature.

In order to achieve taxonomic clarity and a sound appreciation of Paleozoic radiolarian genus diversity, we have undertaken the preparation of an illustrated taxonomic catalogue, which will include all known Paleozoic genera. We have been greatly inspired by the Mesozoic radiolarian genus catalogue and have used the same template and preparation procedure. Thus the holotype of the type species of each genus will be re-illustrated. The type material of Deflandre was re-photographed. Additional plates will be prepared to illustrate some genera with better preserved material than the holotype.

In our publication we shall present a revised opinion of the status and family assignment of all Paleozoic genera described so far, and shall provide an up-to-date evaluation of their currently known age range. A taxonomic revision of the 341 existing generic names was conducted, taking into account existing published opinions; this revision allowed us to identify 84 junior synonyms, 6 homonyms, one *nomen nudum* and 38 *nomina dubia*. We present also a complete list of ca. 2,200 Paleozoic species described till today. The list provides only an objective record without revision of taxonomic status, and thus includes invalid taxa, junior objective or subjective synonyms, *nomina dubia* and *nomina nuda*.

Finally, 17 genera can no longer be considered as radiolarians, most of them being re-interpreted already in the literature as Porifera. We intend for this atlas to serve as a useful taxonomic and biostratigraphic compendium in the micropaleontology community.

References

Deflandre, G., 1952. *Albaillella* nov. gen., Radiolaire fossile du Carbonifère inférieur, type d'une lignée aberrante éteinte. Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences (Paris), Série D : Sciences Naturelles 234, 8, 872-874.

Hinde, G. J., 1890. Notes on Radiolaria from the Lower Palaeozoic Rocks (Llandeilo-Caradoc) of the South of Scotland. Annals and Magazine of Natural History 6, 31, 40-59.

Key words: Radiolaria, Paleozoic, catalogue, taxonomy.

On the status of the Triassic family Tetraspinocyrtidae Kozur & Mostler (Radiolaria) and description of some new related taxa

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Twenty years ago, in one of their monograph on the Middle Triassic Radiolaria, Kozur & Mostler (1994, p. 129-131, pl. 40) described, among other new suprageneric taxa, the family Tetraspinocyrtidae based on a single genus with four new species: *Tetraspinocyrtis laevis* (type species), *T. anisica*, *T. fassanica*, and *T. annuloporata*. The diagnosis of the family and of the genus mentions that: a) the test is multicyrtid, subcylindrical to subconical; b) the cephalis is large, partly fused with the thorax to a large cephalothorax; c) the cephalic spicular system has MB, A, V, 2L, D, and 2l; d) the spine V is sometimes missing; e) on the lower part of the joints D, 2l, A with MB, and (V) 2L with MB a distinct node is present; f) the thorax is large, hoop-like or subcylindrical, sometimes united with cephalis to globular cephalothorax; g) the abdomen and postabdominal segments are hoop-like, strongly elevated to almost flat; h) the apical horn is moderately large to large, round to tricarinate; and I) the other three horns, representing prolongations of D and 2L, and situated on the thorax or cephalothorax, are large to moderately large, tricarinate to vertically oval with lateral grooves. The genus is compared with the genera *Planispinocyrtis* Kozur & Mostler, *Spinotriassocampe* Kozur, and *Yeharaia* Nakaseko & Nishimura.

The detailed study under optical microscope I made on the species mentioned above and on other related species from the faunas of Anisian, Ladinian and Carnian age has demonstrated that they are not only congenerical but also that they belong even to different nassellarian families. In order to prove this statement and to make an order in this group of nassellarians I shall describe accurately the four species and almost all the related species, based on their study in transmitted light microscopy and sometimes in electron microscopy. This is the best way to do with the Fassanian fauna and with other Anisian and Ladinian faunas because, due to their very good preservation, under the light microscope one can see their internal characters very difficult to see normally in scanning electron microscopy, such as the hollow or massive structure of spines and the structure of the initial spicule, which are ones the most important taxonomical characters for radiolarians.

The results of this study show that:

1) Only the type species, *T. laevis* Kozur & Mostler, belongs to the family Tetraspinocyrtidae. The family is emended accordingly and restricted to nassellarians consisting of cephalis and a cylindrical postcephalis segment that can be a simple tube or segmented. The initial spicule has MB, A, V, L, l and D. A, L and sometimes D are prolonged outside into spines. Usually rays l are dissimilar outside, one being longer and downwardly directed. The family comprises two genera: *Tetraspinocyrtis* Kozur & Mostler (late Anisian – middle Carnian) and *Sifunculovum* n. gen. (middle to late Anisian). The species *Spinotriassocampe alata* Kozur & Mostler is transferred to the same genus.

2) *Tetraspinocyrtis fassanica* Kozur & Mostler is the type species of the genus *Gradinarium* n. gen., which is the type species of the family Gradinariidae n. fam. that comprises Triassic nassellarians with cylindrical or slightly conical two- to four-segmented test, bulbous, commonly poreless cephalis bearing a conical, hollow apical horn, and three-bladed horns corresponding to V and l rays. Apical horn is with one or more pores at the boundary between the internal cavity and the massive terminal spine. Rays D and 2L are

present inside the cephalic cavity but not extended outside. MB is approximately in the middle of cephalis, not at its base. The family is known from the middle Anisian to lower Carnian of Arctic region [*Gradinarium kotelniense* (Bragin, 2011)].

3) The species *Tetraspinocyrtis anisica* Kozur & Mostler is transferred to the genus *Pseudotetraspinocyrtis* n.gen. that comprises cylindrical multicyrtid nassellarians with a globular cephalis, a wide open postcephalic part divided or not into two or more segments separated by circumferential constrictions. Initial spicule without D, with MB, and rays A, V, 2L, and 2l extended outside into spines, of which A and 2L are longer.

4) *Tetraspinocyrtis annuloporata* Kozur & Mostler is transferred to the genus *Turrinasus* n. gen., type species *T. nasutus* n. sp., a genus belonging to the family Planispinocyrtiidae Kozur & Mostler and characterized by having a multisegmented, cylindrical to conical shell with hollow, but apically closed conical apical horn, relatively long V horn, which is laterally or downwardly directed and partly hollow sometimes, initial spicule without D, with l prolonged outside into conical spines and L stopped in the cephalic wall. Cephalis fused generally with thorax forming a cephalothorax, postthoracic segments scalariform or more or less inflated with pores disposed usually in a single circumferential row, and last segment not flared. To the same genus is transferred *Planispinocyrtis* ? *annulata* Kozur & Mostler.

5) Several other new genera and many new species, more or less related to the four species initially included under *Tetraspinocyrtis*, are also described.

References

Bragin, N. Yu., 2011. Triassic radiolarians of Kotel’nyi Island (New Siberian Islands, Arctic). Paleontological Journal 45, 7, 1-68.

Kozur, H. & Mostler, H., 1994. Anisian to middle Carnian radiolarian zonation and description of some stratigraphically important radiolarians. Geologisch-Paläontologische Mitteilungen Innsbruck, Sonderband 3, 39-255.

Kozur, H.W. & Mostler, H., 2006. Radiolarien aus dem Longobard der Dinariden. Hallesches Jahrbuch für Geowissenschaften 28, 23-91.

Key words: Radiolaria, Nassellaria, Triassic, taxonomy, Tetraspinocyrtidae.

Single cell transcriptomics of two radiolarian species

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The phylogenetic relationship between the major groups of living radiolarians has been continually debated and revised during the last decade. Molecular data now shows that the four groups originally assigned to Radiolaria (Phaeodaria, Nassellaria, Spumellaria and Acantharia), are not monophyletic. Recent phylogenies based on ribosomal genes place Phaeodaria within Cerocozoa, and the previously heliozoan group Taxopodida, as well as Foraminifera should be included in Radiolaria (Yuasa et al., 2004, 2006; Krabberød et al., 2011). Ribosomal genes alone cannot resolve the deeper relationship between groupings within the Radiolaria. However, very few genetic sequences other than 18S rDNA have so far been generated from radiolarian cells. This is partly due to the fact that radiolarians have been impossible to cultivate. In addition, protocols for molecular work with single cells are yet to be developed and applied to radiolarian cells. Some progress has been made in recent years, but no study has yet inferred a phylogeny with representatives from all radiolarian groups (Ishitani et al., 2011; Sierra et al., 2012; Burki, 2014). Therefore the true relationships between the major groups of radiolarians remains unresolved, with then continued lack of molecular data representing an “Achilles heal” for the study of Radiolaria.

In this talk we will present some recent advances in the methodological developments allowing for the amplification of genomes and transcriptomes from single cells. Together with the advances in next generation sequencing, single-cell-omics will bring a revolution to the molecular studies of not only radiolarians, but all unculturable protists. Here we focus on two selected radiolarian species in testing the power of single cell transcriptomics for phylogenomic analyses, functional analyses of single cells and their symbionts. In this talk, we will present the used methods and show phylogenetic results from these studies.

References

Burki, F., 2014. The eukaryotic tree of life from a global phylogenomic perspective. cold Spring Harb Perspect Biol 6. Available: http://www.ncbi. nlm.nih.gov/pubmed/24789819

Ishitani,Y., Ishikawa, S., Inagaki, Y., Tsuchiya, M. & Takishita, K., 2011. Multigene phylogenetic analyses including diverse radiolarian species support the “Retaria” hypothesis - the sister relationship of Radiolaria and Foraminifera. Marine Micropaleontology 81, 32–42.

Krabberød, A.K., Bråte, J., Dolven, J.K., Ose, R.F., Klaveness, D. et al., 2011. Radiolaria Divided into Polycystina and Spasmaria in Combined 18S and 28S rDNA Phylogeny. PLoS One 6: e23526. Available: http://dx.doi.org/10.1371/journal.pone.0023526.

Sierra, R., Matz, M. V., Aglyamova, G., Pillet, L., Decelle, J. et al., 2012. Deep relationships of Rhizaria revealed by phylogenomics: a farewell to Haeckel’s Radiolaria. Mol Phylogenet Evol. 67, 53–59.

Yuasa, T., Takahashi, O. & Mayama, S., 2004. PCR primers for the amplification of the nuclear small subunit ribosomal DNA sequences from polycystine radiolarians. Jpn. J. Protozool 37, 133–138.

Yuasa, T., Takahashi, O., Dolven, J.K.K., Mayama, S., Matsuoka, A. et al., 2006. Phylogenetic position of the small solitary phaeodarians (Radiolaria) based on 18S rDNA sequences by single cell PCR analysis. Marine Micropaleontology 59, 104–114.

Key words: Transcriptomics, multigene phylogeny.

Reconstructing radiolarian diversity: what we don't know; and a new analysis of the Cenozoic

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Diversity change in biotas over geologic time contains important information on evolutionary processes and, when compared to appropriate data, the sensitivity of biodiversity to environmental change. Paleobiologists have attempted to reconstruct diversity for the entire Phanerozoic fossil record (e.g., with databases such as the Paleobiology Database PBDB), with results that are still in dispute after nearly 40 years of effort.

Radiolarians provide an unusually good opportunity to study and compare evolution and biodiversity-environment controls using the same taxonomic group over the entire Phanerozoic. Current thinking is that radiolarians were fairly low in diversity in the Paleozoic, reached peak diversities in the Mesozoic, and declined to more moderate diversity levels in the Cenozoic. These beliefs are based on comparison of sample pairs from different time intervals, changes in relative diversity seen in individual short sections, and compilations from the literature.

Radiolarian studies have however only very rarely (e.g. Kiessling & Danelian, 2011; Kocsis et al., 2014) taken into account the numerous challenges that paleobiologists have identified in estimating diversity change over time, e.g. the effect on diversity estimates of sample size, stratigraphic resolution, differences in taxonomic rank, taxonomist's practice, changing biogeography and shifts in the degree of preservation. Comparison of Phanerozoic radiolarian diversity estimates by different authors shows in fact very little agreement, and radiolarian data from PBDB suggests most observed diversity change is due simply to changing sample size. Sample pair comparisons, after taking into account taxonomic practice (Kiessling, 2002) and sample size effects show little difference between Mesozoic and Cenozoic diversity or (including biogeography) relatively higher Cenozoic diversity. We conclude that very little is known yet about radiolarian diversity change over time, and new studies are needed.

We have carried out such a new study of Cenozoic radiolarian diversity, using contemporary paleobiologic subsampling methods on species occurrence data at 1 my or better stratigraphic resolution, and the new version of the Neptune database (NSB in Berlin) which contains a fully revised, comprehensive species names list (Lazarus et al., submitted). We find that Cenozoic radiolarian diversity shows a very strong, several fold increase, not decline, clearly contradicting previous interpretations. Tropical diversity is approximately static over most of the Cenozoic, dropping in the early Oligocene and recovering gradually by the late Neogene. Global diversity increase is instead driven by major diversity increase in polar regions - from the latest Eocene in the Southern Ocean, and from the mid-Miocene in the north polar provinces.

Comparison of these patterns to those available for other marine plankton groups suggests possible general controls on plankton evolution, both extrinsic (environmental) and internal (biologic).

References

Kiessling, W. 2002. Radiolarian diversity patterns in the latest Jurassic-earliest Cretaceous. Palaeogeography, Palaeoclimatology, Palaeoecology 187, 179-206.

Kiessling, W. & Danelian, T. 2011. Trajectories of Late Permian-Jurassic radiolarian extinction rates: no evidence for an end-Triassic mass extinction. Fossil Record 14, 95-101.

Kocsis, A. T., Kiessling, W. & Palfy, J. 2014. Radiolarian biodiversity dynamics through the Triassic and Jurassic: implications for proximate causes of the end-Triassic mass extinction. Paleobiology 40, 625-639.

Lazarus, D., Suzuki, N., Caulet, J.-P., Nigrini, C., Goll, I., Goll, R., Dolven, J. K., Diver, P. & Sanfilippo, A., submitted. An evaluated list of Cenozic-Recent radiolarian species names, based on those used in the DSDP, ODP and IODP Deep-Sea Drilling Programs.

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.

Key words: Diversity, evolution, Cenozoic.

How to define fossil radiolarian species? – A case study of the Mesozoic spumellarian *Pantanellium*

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Defining fossil species is one of fundamental issues in paleontology. A general consensus can be as follows: the definition of fossil taxa should be consistent with that of extant taxa. We show our opinion how to define fossil radiolarian species through our examination using micro-CT techniques (Matsuoka et al., 2012). As a case study, species belonging to the Mesozoic spumellarian *Pantanellium* are treated.

The genus *Pantanellium* is one of the most prolific genera among Mesozoic radiolarians. *Pantanellium* and its allied forms commonly have a spherical or subspherical cortical shell with bipolar primary spines. The cortical shell is covered with polygonal, mostly pentagonal and hexagonal, pore frames. As many as 80 species have been described since Pessagno (1977) established the genus.

3D models of earliest Cretaceous *Pantanellium* from a single rock sample were produced from real fossil specimens by applying X-ray micro-CT and layered manufacturing technology. This enables us to elucidate the exact number of polygonal pore frames and their configuration on the cortical shell, which is difficult to recognize from scanning electron microscopic or light microscopic images. The pore frame number and the configuration are important criteria in the taxonomy of *Pantanellium*. We propose a practical definition applicable for this genus.

References

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.

Pessagno, E.A.Jr., 1977. Upper Jurassic Radiolaria and radiolarian biostratigraphy of the California Coast Ranges. Micropaleontology 23, 56-113.

Key words: Species definition, micro-CT, *Pantanellium.*

Taxonomy and biodiversity analysis of a Gorstian radiolarian fauna from the Cape Phillips Formation, Canadian Arctic

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Well-preserved Gorstian radiolarians recovered from the *Lobograptus progenitor* graptolite zone in the Cape Phillips Formation, Arctic Canada were examined with the goal of first re-evaluating the taxonomy of *Inanihella tarangulica* Nazarov & Ormiston and related species, and secondly, determining the extent of facies-controlled differences in faunal composition between two of the Arctic localities. The material was collected from Twilight Creek (TWC) on Bathurst Island, located ~100 km from the paleo-shelf margin, and from Snowblind Creek (SB) on Cornwallis Island, located more proximally to the paleo-shelf margin (~1 km). Both TWC and SB are composed of calcareous shales rich in graptolites, however TWC is shalier, and concretions are finer-grained. SB contains a higher proportion of bioclastic beds rich in shelfal debris, including a higher diversity sponge spicule assemblage. A total of four radiolarian-bearing samples were recovered; one from TWC and three from SB. Species occurrence was noted and abundance counts were made on fine and coarse fractions (100 specimens per fraction). From a taxonomic standpoint, the fauna contains 27 species largely dominated by specimens assignable to either *I. tarangulica* group (*I. tarangulica, I. duroacus, I. macroacantha, I. perarmata, I. leguincula, F. osobudaniensis* and a new species), *Gyrosphaera, Zadrappolus, Ceratoikiscum*, or palaeoscenidiids. Examination of interspecific and intraspecific variation in the *I. tarangulica* species group indicates that there is a sufficient morphological gradient to make discrimination of several species arbitrary and unworkable. *I. tarangulica, I. duroacus, I. perarmata* and *I. leguincula* are treated as a single highly variable morphospecies. Furthermore, we agree with previous workers (i.e. Furutani, 1990; Amon et al., 1995) that these Silurian species are more properly assigned to *Fusalfanus* Furutani than to *Inanihella* Nazarov and Ormiston. From a comparative biodiversity standpoint, the taxonomic composition of all samples is relatively similar, despite facies differences. Samples from both localities are immediately recognizable as belonging to the same biozone. Despite this strong similarity, there were slight but statistically significant differences between localities. Species richness was slightly higher at TWC (22 species), than at SB (18 species). Diversity indices run on the genus-level abundance data also yielded very slight but statistically significant differences in taxonomic composition. Differences in species composition also exist between the topotype locality from the Tarangul Mountains in Asia and the Arctic localities. *Helenifore speciosus* is present in the topotype material, but its last appearance predates the Gorstian in the Arctic, and *Secuicollacta* is a common component in the topotype material but its occurrence is highly variable among Arctic localities. Lastly, separate counts on fine and coarse fractions from the two Arctic sites allowed for a quantitative analysis of the effects of size fraction on biodiversity. There was a strong taxonomic separation in size fractions that exceeded the separation between samples and sites. As a cautionary note, biodiversity comparisons between localities must take into account processing and sieving techniques to allow for meaningful results.

References

Amon, E.O., Braun, A. & Ivanov, K.S., 1995. Upper Silurian radiolarians from the southern Urals. Geologica et Palaeontologica 29, 1–17.

Furutani, H., 1990. Middle Paleozoic radiolarians from Fukuji Area, Gifu Prefecture, central Japan. Journal of Earth Sciences, Nagoya University 37, 1–56.

Nazarov, B.B. & Ormiston, A.R., 1984. Tentative system of Paleozoic Radiolaria. In. Morphology, Ecology and Evolution of Radiolaria. (Eurorad IV Symposium, Petrushevskaya, M.G. & Stepanjants, S.D., Eds.), Akademiia NAUK SSSR Ecologieskiya Instiytut, Leningrad, 64–87.

Key words: Silurian biodiversity, taxonomy.

New species and evolution of *Saturnalis* and *Saturnulus* during the Neogene time in the Southern Ocean region

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The study area Leg 119 Site 745B is located on a large sediment drift at the base of the southern slope of the Kerguelen Plateau and lies at longitude 59^0 35.71’ S and latitude 85^0 57.60’E in the Southern ocean region. The samples were collected at a water depth of 4082.5 m. The 284 samples are used to carry out this study. 10 new species of *Saturnalis* and 13 taxa of *Saturnulus* are identified from the long core of 214.05 m of Neogene period.

Based on radiolaria, six zones are proposed namely Tau, Upsilon, Phi, Chi, Psi and Omega from Miocene to Pleistocene. It is observed that *Saturnalis circularis* showed its presence throughout the core and new species *Saturnalis* sp. A of having single medullar shell but different morphological characters evolved from the sample 745B-19H-6, 86-88 at a depth of 166.37 mbsf. It is diversified further into various new taxa at different samples and depth into *Saturnalis* sp. B to sp. J till the sample no. 745B-6H-4,12-14 at a depth of 47.62mbsf (Fig. 1). Whereas, *Saturnulus* sp. a of having two medullar shells and different morphological characters showed its occurrence from sample no. 745B-23H-7,13-15 at a depth of 203.6 mbsf. This new species goes upto *Saturnulus* sp. m till the sample no. 745B-6H-7,4-6 at a depth of 52.04 mbsf (Fig. 1). They might have also evolved from *Saturnalis circularis*.

It is observed that the maximum diversification of the *Saturnalis* sps. take place in the Phi and Chi zones of Pleistocene and evolution was started in the Upsilon zone of Pliocene. Whereas, *Saturnulus* sp. a is evolved in the late Miocene and goes upto chi zone of early Pleistocene.

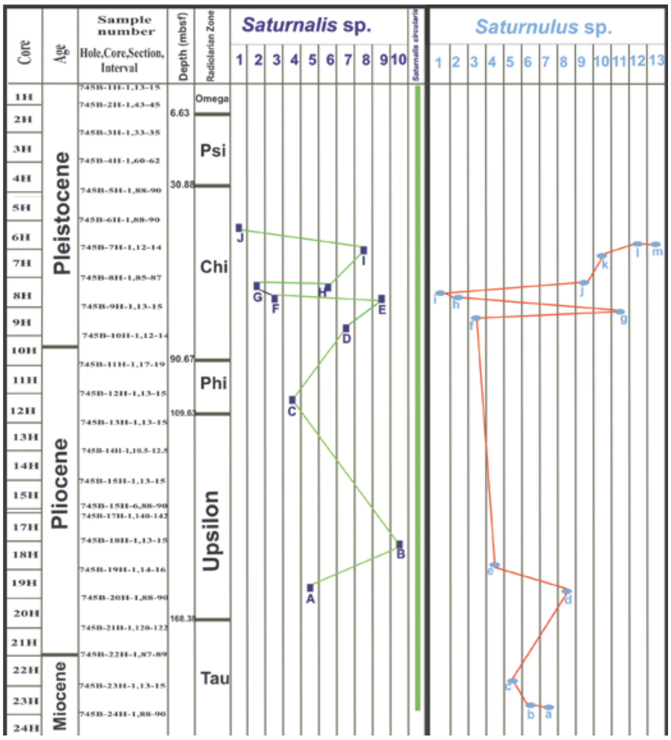

Figure 1. Showing the distribution and evolution of new species of *Saturnalis* and *Saturnulus* in the Leg 119 Site 745B.

Saturnalis:
A. *Saturnalis* sp. 5– 745B-19 H-6,86-88;Depth – 166.37 mbsf
B. *Saturnalis* sp. 10 –745B-18H -1,13-15;epth – 148.63 mbsf
C. *Saturnalis* sp. 4 – 745B- 12H -3,88-90;epth – 103.88 mbsf
D. *Saturnalis* sp. 7– 745B- 9H-6,7-9;epth – 79.07 mbsf
E. *Saturnalis* sp. 9 – 745B- 8 H -7,11.5-13.5 ;depth – 71.11 mbsf
F. *Saturnalis* sp. 3 – 745B- 8H-6,88-90;Depth – 70.38 mbsf
G. *Saturnalis* sp. 2 – 745B- 8H-2,88-90;Depth – 64.38 mbsf
H. *Saturnalis* sp. 6 – 745B- 8H -3,86.5-88.5;Depth – 65.86 mbsf
I. *Saturnalis* sp. 8 – 745B- 7H-1,88-90;Depth – 53.38 mbsf
J. *Saturnalis* sp. 1 – 745B- 6H-4-12-14;Depth – 47.62 mbsf

Saturnulus:
a. *Saturnulus* sp. 7– 745B- 23 H -7,13-15;Depth – 203.63 mbsf
b. *Saturnulus* sp. 6 – 745B-23 H -6,13-15;Depth – 203.63 mbsf
c. *Saturnulus* sp. 5 – 745B- 22 H-6,87-89;Depth – 194.87 mbsf
d. *Saturnulus* sp. 8– 745B-19H-6,86-88;Depth – 166.37 mbsf
e. *Saturnulus* sp. 4 – 745B-18H -7,16-18;Depth – 157.66 mbsf
f. *Saturnulus* sp. 3 – 745B-9H -3,13-15;Depth – 74.63 mbsf
g. *Saturnulus* sp. 11 – 745B-9 H -1,88-90;Depth – 72.38 mbsf
h. *Saturnulus* sp. 2 – 745B- 8H -7,11.5-13.5;Depth – 71.11 mbsf
i. *Saturnulus* sp. 1 – 745B-8H -6,13-15;Depth -69.63 mbsf
j. *Saturnulus* sp. 9 – 745B-8H-1,85-87;Depth – 62.85 mbsf

Key words: Phylogeny, new taxa, southern Ocean Region.

Earliest Cretaceous radiolarians from TAMU Massif on Shatsky Rise, North Pacific, Leg IODP 324: stratigraphic, taxonomic and paleobiogeographic issues

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The Shatsky Rise oceanic plateau, North Pacific is a large igneous province thought to have been emplaced during the latest Jurassic-earliest Cretaceous (~150-135 Ma). It consists of three large edifices, the largest and oldest of which is TAMU Massif located at the southwest end of the plateau. TAMU Massif is interpreted as a single immense shield volcano, the largest known on Earth (Sager et al, 2013).

IODP Expedition 324 recovered basaltic basement and basal sediments from five sites (U1346-U1350) on Shatsky Rise. ^{40}Ar/^{39}Ar ages for lavas from Hole U1347 on TAMU Massif have recently become available (Geldmacher et al, 2014). Lavas from the lower and middle portions of the cored section, Units XV and X yielded ages within ~143-144 Ma, whereas a sample from the uppermost lava, Unit IV, Core 13R-4 produced a significantly younger age of ~134 Ma.

Abundant radiolarians were recovered from inter-basalt and basal sediments in Hole U1347 on TAMU Massif. Basal sediments are dark-coloured, radiolarian-bearing volcanoclastic siltstones. The best preservation and great taxonomic diversity is characteristic to the radiolarian assemblage from sample U1347A-13R-7, 19.5-21.5 cm, collected from the inter-basalt, Unit V/Unt IV radiolarite at 174.45 mbsf ~17 m below the top of the basaltic basement. Some other samples from the basal clastic sediments of Unit III (157.55-100.80 mbsf) also yielded abundant, diverse, and well-preserved radiolarians.

Although abundant and diverse, radiolarian assemblages allow for quite broad age constraints due to the lack of some well-known and widespread taxa characteristic to the Early Cretaceous. The other problem related to age assignment is the co-occurrence of species that are not known to co-occur. The narrowest age constraint, earliest Berriasian (UA 5 of Jud, 1994) or latest Tithonian-earliest Berriasian (UAZ-95 13) is obtained for sample U1347A-13R-7, 19.5-21.5 cm. Ages of samples from the basal clastic sediments, Unit III are constrained to the early-mid Berriasian (UA 7-9 of Jud, 1994) or latest Tithonian-earliest Berriasian to late Berriasian-earliest Valanginian (UAZ-95 13-15) intervals.

Exceptional preservation of radiolarians in sample U1347A-13R-7 grants a very fresh and sometimes surprising vision of some known species and reveals numerous details of their structural design. Some fine sculptural features are likely related to silica dissolution and Cc-replacement processes prior to or during sediment diagenesis. Morphologies of some species are similar to their holotypes but differ in few details. These clearly observed aberrations make species diagnostic and age assignment somewhat troublesome. Some species demonstrate a wide and continuous range of morphological variations, so that the end members on either side of this row could hardly be considered as the very same species. Particularly abundant and diverse Parvicingulidae exhibits numerous morphologies that differ from one another and known species. They are not clearly clustered, which makes it difficult to discriminate among them and clearly distinguish and classify new species.

The lack of some well-known/widespread species together with abundance of new species and numerous morphological aberrations of the known species makes these radiolarian assemblages fairly specific. This possibly indicates their accumulation within a circum-Pacific oceanic gyre in the Early Cretaceous central Pacific Realm, or on a shallow ocean floor, or during some ecological excursion.

References

Geldmacher, J., van den Bogaard, P., Heydolph, K., & Hoernle, K., 2014. The age of Earth's largest volcano: Tamu Massif on Shatsky Rise (northwest Pacific Ocean). International Journal of Earth Sciences 103, 8, 2351-2357.

Sager, W. W., Zhang, J., Korenaga, J., Sano, T., Koppers, A. A., Widdowson, M., & Mahoney, J. J., 2013. An immense shield volcano within the Shatsky Rise oceanic plateau, northwest Pacific Ocean. Nature Geoscience 6, 976-981.

Key words: Radiolaria, the Shatsky Rise, IODP 324.

Dimorphism of Permian Albaillellaria: biometrical analysis of swollen type

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Some taxa of Albaillellaria Deflandre have dimorphism: normal and swollen types (Ishiga, 1991). The swollen type is characterized by having a swollen apical portion. Observation and quantitative analysis are necessary for characterizing the dimorphism. However, it is difficult to recover swollen type specimens because of their extremely-low population in general (Ishiga, 1991).

Ito & Matsuoka (in pres.) reported a Cisuralian (Early Permian) radiolarian assemblage including a swollen type of *Albaillella sinuata* Ishiga & Watase from the Waji section in Ie-jima Island, Okinawa Prefecture, Japan. This study analyzes biometrically 26 specimens of normal and swollen types of *A. sinuata* from the Waji section (Fig. 1.1). Three points (P1, P4, and P5) were plotted: P1 (top of the apical cone), P4 (ventral end of the basal part of shell body), and P5 (dorsal end of the basal part of shell body). We then drew two external tangents to apical cone, which are parallel to P1–P4 and P1–P5, respectively. Ventral and dorsal spines were not used to draw the external tangents. The contact points in ventral and dorsal sides are called P2 and P3, respectively. We drew vertical line to P4–P5 from P1. Angles of A1 (P1–P2 to P1–P3), A2 (P2–P1 to P2–P4), and A3 (P3–P1 to P3–P5) were measured. Here, we use to A2+A3-A1 to show swollenness and call it the S-value.

A specimen with low S-value is a swollen type, while a specimen with high S-value is a normal type. Distributions of the S-value are bimodal (Fig. 1.2). Swollen type specimens are smaller in total length (L1) than normal type specimens (Fig. 1.3). Bimodal distributions of S-value and inverse relation between swollenness and length of the shell indicate that the swollen type and the normal type are dividable.

In this study, we propose four tentative mechanisms as possible causes of radiolarian dimorphism: individual difference, appositional growth, convergent evolution, and reproductive generation. Based on currently-known rizharian biological knowledge in addition to our biometrical results, we then evaluate these mechanisms as a cause of the dimorphism of Albaillellaria. In the simple model of individual difference and appositional growth, the size distribution should be unimodal. Consequently, the bimodal distribution in *A. sinuata* size rejects these possibilities. Swollen-type specimens have also been recognized in Albaillellaria taxa other than *A. sinuata* (e.g., Ishiga, 1991), indicating the possibility that convergent evolution caused the dimorphism of Albaillellaria. However, the similarity in sedimentary environment in some geologic bodies yielding swollen type specimens is indiscoverable. At present, there is a little positive evidence to support convergent evolution as a cause of the dimorphism. Based on observation of living foraminifers, an alternation of sexual and asexual generations in their life cycles has been demonstrated (e.g., Leutenegger, 1977). Ishiga (1991) pointed out the possibility that the dimorphism is caused by alternating generations. In the case of foraminifers, the populations of individuals of sexual generations are extremely lower compared with those of asexual generations in nature (e.g., Fujita et al., 2000), which is consistent with the case of the dimorphism of Albaillellaria. This mechanism can explain the bimodal distribution in *A. sinuata* size. Thus, we concluded that reproductive generation is the most likely mechanism producing the dimorphism of Albaillellaria amongthe proposed mechanisms. The conclusion implies the presences of the alternating generation in Permian planktonic microorganisms.

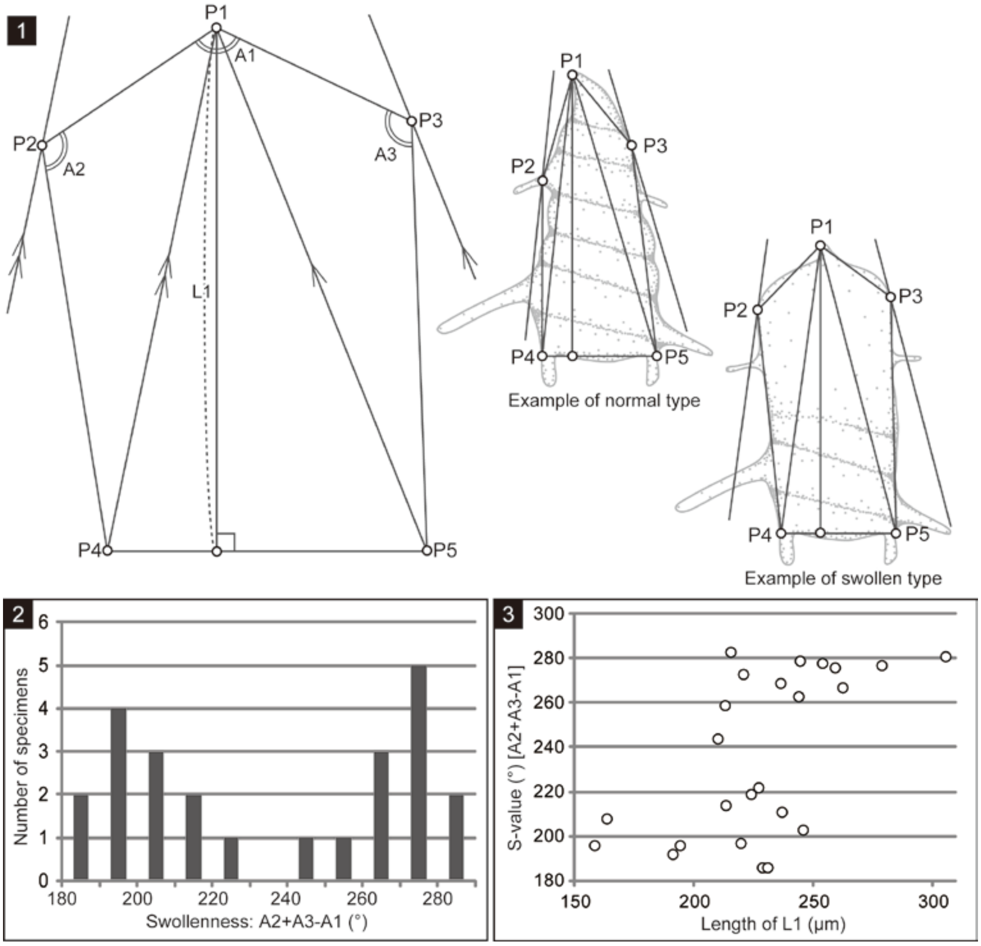

Figure 1. 1: Plotted landmarks and measured parameters for biometrical analyses. **2:** Frequency diagram of the S-value. **3:** Scatter diagram of length of L1 and the S-value.

References

Fujita, K., Nishi, H. & Saito, T., 2000. Population dynamics of *Marginopora kudakajimensis* Gudmundsson (Foraminifera: Soritidae) in the Ryukyu Islands, the subtropical northwest Pacific. Marine Micropaleontology 38, 267–284.

Ishiga, H., 1991. “Dimorphic pairs” of Albaillellaria (Late Paleozoic Radiolaria), Japan. Memoir of the Faculty of Science, Shimane University 25, 119–129.

Ito, T. & Matsuoka, A., in press. Swollen type of *Albaillella sinuata* Ishiga & Watase (Permian Radiolaria) from a chert boulder in Ie-jima Island, Okinawa Prefecture, Japan. News of Osaka Micropaleontologists (NOM), Special Volume 15.

Leutenegger, S., 1977. Reproductive cycles of larger foraminifera and depth distribution of generations. Utrecht Micropaleontological Bulletins 15, 27–34.

Key words: Dimorphism, Permian Radiolaria, paleoecology, swollen type, life cycle, reproduction generation.

Radiolarian diversity in the Mesozoic: evolution and driving mechanisms

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This paper analyses the diversity and evolution of Polycystine radiolarians during the 185 My long history through the Mesozoic and is based on a refined global data set of genera. The data set considered all radiolarian genera and species described as new since 1876 and summarized quantitatively the progress made on the taxonomy of Mesozoic radiolarians over the last 145 years. Although species counts are theoretically more objective than genus richness, difficulties related to the high intraspecific variability and possibly a considerable number of synonyms (the dataset contains 6296 species but their taxonomic status has not been revised) make radiolarian genera obviously a more stable taxonomic category.

Sampled genus diversity in each time interval (substage) was estimated using the genera database compiled and updated by the InterRad Mesozoic Working Group. The taxonomic homogeneity in the data set allows to interpiret the evolution of the biodiversity by analyzing curves of generic diversity for the three orders of Mesozoic radiolarians: Spumellaria, Entactinaria and Nassellaria. The pattern and general trends of these curves are similar; especially they show comparable patterns at the main turnover points. The dynamics of evolutionary change is either well-illustrated by the pattern in the rate of turnover-diversification, or by the extinction-origination per-genera rates. Although some extinction-origination peaks seem to be protracted over a longer period, the extinction-origination rates (as well as any other metrics analyzed in this contribution) are not normalized at substage duration because there is no linear relationship between stage duration and extinction-origination rate (Spearman rank-order correlation $Rs = 0.11$, $P = 0.3$)

The average genus lifespans in Mesozoic radiolarians range from 15.3 Ma for Triassic genera to 30.1 Ma for Jurassic–Cretaceous ones (we consider only genera that first occur in the Mesozoic). In order to illustrate the longevity of Polycystine genera we present the stratigraphic distribution of taxa as a time duration matrix (Fig. 1). Each point represents the lifetime interval of one or more genera that share the common first and last appearance datum, in other words, the same stratigraphic intervals. Thus, the vertical distance from a point to the diagonal is the duration time, or lifetime, of the corresponding genus or genera. It is noticeable that the Triassic genera exhibit shorter duration than those of the Jurassic–Cretaceous. This graphical representation also shows the net extinction event at the end of the Triassic. Another noticeable aspect is the sudden increase of genera longevity between the 150–100 Ma (late Tithonian–Albian) denoted by the absence of dots close to the diagonal. This emptiness results from the negative diversification rates through the Early Cretaceous. The genera longevity analysis among orders shows a positive correlation between the two principal groups of radiolarians (Nassellaria *vs* Spumellaria).

Examination of the evolutionary rates at the taxonomic level of families might unravel whether group membership was controlling evolutionary rate. In this sense we have also plotted the age ranges of genera grouped in higher taxonomic units. The genera are grouped by order, then by family and sorted by taxonomic affinities. The pattern of genus first and last occurrence within families reveals better correlations between sets of genera that are more closely related.

In order to understand what forcing factors were behind the evolution of radiolarian diversity through the Mesozoic we compare our set of curves against several paleoceanographic proxies (Carbon isotopes, Strontium isotopes, Temperatures and Sea level). Two signals, the Strontium and Carbon isotopes fluctuations, keep a striking relationship with the diversity. For instance, the most prominent extinctions occur during periods of major perturbation in the Carbon cycle, but the fluctuation of diversity shows an opposite trend with the Strontium isotopes. This suggests that diversity appears to be greatest when there were large amounts of open marine habitats and moderate levels of productivity. The taxonomic diversity in Mesozoic radiolarians seems to have kept a common direct response to the extent of continental inundation by seawater.

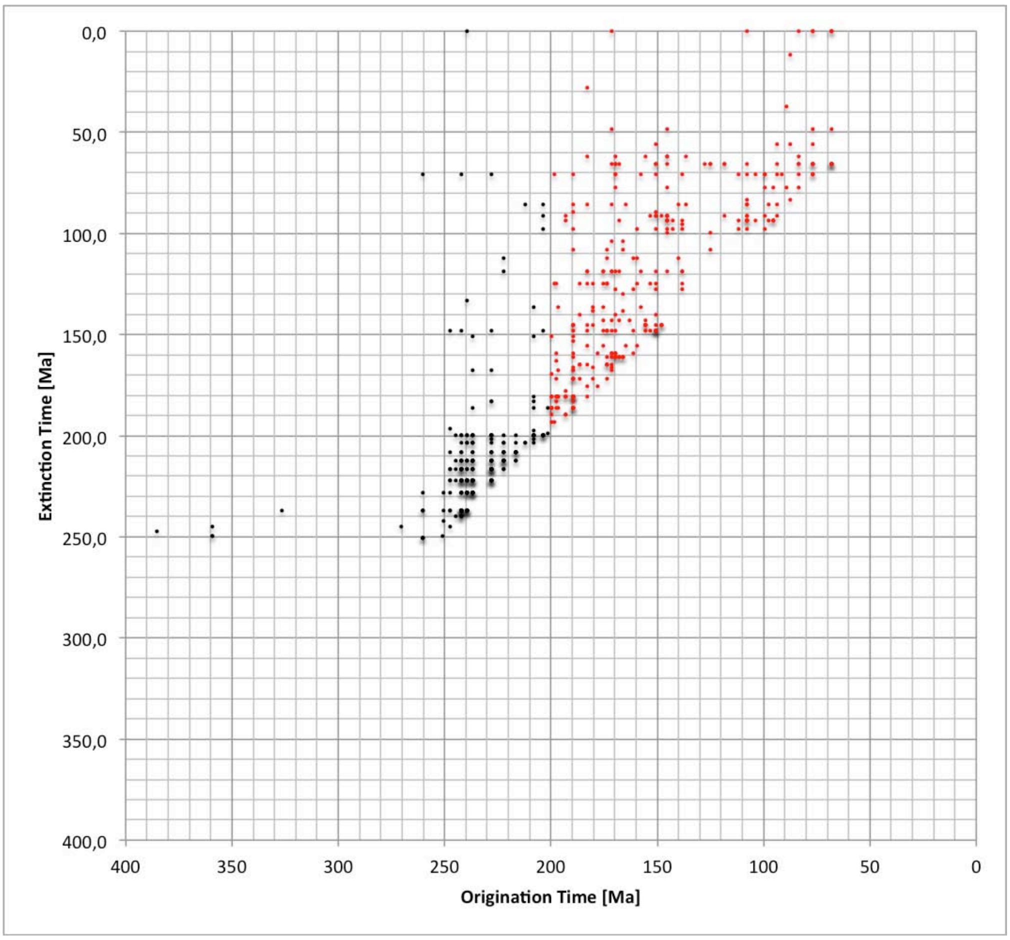

Figure 1. Stratigraphic distribution of Mesozoic genera as a time duration matrix. Black dots represent longevity of Polycystines during Triassic occurrences, and red dots the longevity during the Jurassic–Cretaceous.

Key words: Mesozoic, evolution, diversity.

Lithostratigraphy and radiolarian biostratigraphy in the Halashi 01 section of the Kermanshah area, west Iran

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In order to study the biostratigraphy and paleoecology of Mesozoic deposits in the range of the Kermanshah (Kermanshah Province) region, a stratigraphic section (the Halashi 01) in the west Kermanshah area was selected. The section consists mainly of chert, siliceous mudstone, marlstone, limestone and mudstone. A total of 143 rock samples were collected from the Halashi 01 section. Identified taxa include 57 genera and 165 species from this section; 50 genera and 155 species of radiolarians, 4 genera and 6 species of sponges, 2 genera and 3 species of planktonic foraminifera, and 1 genus and 1 species of benthic foraminifera. These fossil records indicate that the study section is Tithonian (Late Jurassic) to early Valanginian (Early Cretaceous) in age.

High diversity and abundant occurrence of radiolarians in the study section indicate that a favorable condition was prevailed during the deposition of the strata in Tithonian to early Valanginian time. Nassellarians are generally more abundant than spumellarians, which may suggest the sediments were accumulated in a great depth.

Key words: Radiolarian, biostratigraphy, Iran, Tithonian, early Valanginian, Late Jurassic, Early Cretaceous.

Silurian radiolarians from the Jenolan Caves region, New South Wales, Australia

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Moderately to well-preserved radiolarians have been recovered from Jenolan Caves region, eastern NSW, Australia. Radiolarians were first reported from this area in the late 19^{th} Century by T.W. Edgeworth David (David, 1897) but were not figured. David & Pittman (1899) again mentioned the Jenolan occurrences but this paper concentrated on the now well-known Devonian radiolarians from Tamworth in the New England region. Nearly 120 years later we are able to present the first SEM images of these fossils together with microCT imagery of their internal structure.

The Jenolan Caves region holds great scenic value, with the best known and most magnificent limestone caves in Australia. Early Paleozoic rocks in this region form part of the Lachlan Fold Belt. Studies of the stratigraphic and structural relationships in the main limestone belt have revealed uncertainties in the age assignment of the surrounding units (Branagan et al., 2014). These uncertainties are caused by a lack of biostratigraphic studies and obscured stratigraphic and depositional relationships. The radiolarians reported in this paper include *Zadrappolus tenius* Furutani and *Zadrappolus yoshikiensis* Furutani. They were recovered from black siliceous siltstones of the Campbells Group, immediately west of Caves House. These rocks lie immediately west of the main Middle-Upper Silurian limestone belt. The exact nature of stratigraphic relationships and the age of the Campbells Group remain enigmatic (Branagan et al., 2014). However, the radiolarians present are consistent with those described from Upper Silurian strata in Japan (Furutani, 1990; Aitchison et al., 1996; Kurihara, 2007; Nuramkhaan et al., 2013) and typical of the Long-spined inaniguttid Zone 3 of Noble & Aitchison (2000).

References

Aitchison, J.C., Hada, S., Ireland, T. & Yoshikura, S., 1996. Ages of Silurian radiolarians from the Kurosegawa terrane, southwest Japan constrained by U/Pb shrimp data. Journal of Southeast Asian Earth Sciences 14, 53-70.

Branagan, D.F., Pickett J. & Percival I.G., 2014. Geology and geomorphology of Jenolan Caves and the surrounding region. Proceedings of the Linnean Society of New South Wales 136, 99-130.

David, T.W.E., 1897. The occurrence of Radiolaria in Palæozoic rocks in N.S. Wales. Proceedings of the Linnean Society of New South Wales 21, 553-570.

Furutani, H., 1990. Middle Paleozoic radiolarians from Fukuji Area, Gifu Prefecture, central Japan. Journal of Earth Sciences, Nagoya University 37, 1-56.

Kurihara, T., 2007. Uppermost Silurian to Lower Devonian radiolarians from the Hitoegane area of the Hida-gaien terrane, central Japan. Micropaleontology 53, 221-237.

Noble, P. & Aitchison, J., 2000. Early Paleozoic radiolarian biozonation. Geol. 28, 367-370.

Nuramkhaan, M., Horie, K. & Tsukada, K., 2013. SHRIMP U-Pb age of the radiolarian-bearing Yoshiki Formation in Japan. Bulletin of Geosciences 88, 223-240.

Key words: Radiolarians, Silurian, microCT, Jenolan Caves, the Lachlan Fold Belt, the Campbells Group.

New radiolarian records from pelagic red limestones in the eastern Black Sea Region (Giresun), NE Turkey

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Late Cretaceous period in the north zone of eastern Black Sea Region has special significance due to intensive volcanic activities. Intervals of volcanic indecision were deposited as thick volcano-sedimentary successions in the fore-arc region (Bektaş et al., 1995). Generally, these sedimentary deposits are dominated by turbidite containing widespread red biomicritic limestones.

The red colored biomicrite exposed in the Çanakçı-Akköy (Giresun) include a rich and well-preserved radiolarians assemblage consisting of *Acaeniotyle*, *Acanthocircus*, *Alievium*, *Amphipydax*, *Archaeospongoprunum*, *Crucella*, *Dictyomitra*, *Halesium*, *Holocryptocanium*, *Patellula*, *Pessagnobrachia*, *Praeconocaryomma*, *Pseudoaulophocus*, *Stichomitra*. These are the first Radiolaria assemblage described from red colored limestones at Çanakçı-Akköy (Giresun) region and these faunal assemblages are attributed to Coniacian-Santonian.

Reference

Bektaş, O., Yılmaz, C., Taslı, K., Akdağ, K. & Özgür, S., 1995. Cretaceous rifting of eastern Pontide carbonate platform, NE Turkey, the formation of carbonate breccias and turbidites as evidence of a drowned platform. G Geol 57, 233-244.

Key words: Eastern Black Sea Region, radiolarians, Coniacian-Santonian, red colored limestones.

Finding of planktonic foraminifera and radiolarians of Upper Cretaceous from the eastern Black Sea region (Trabzon, Turkey)

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Upper Cretaceous pelagic deposits outcropping in the Maçka (Trabzon) region include radiolarians and pelagic foraminifera. Two different sections (Çatak-1 and 2) are selected from clayey-sandy limestones and red colored limestones establishing the biostratigraphy of outcrops sedimentary units. ? *Archaeoglobigerina* sp., *Dicarinella algeriana* (Caron), *Dicarinella primitiva* (Dalbiez), *Hedbergella delrioensis* (Carsey), *H. simplex* (Morrow), *H. planispira* Tappan, *Helvetoglobotruncana helvetica* (Bolli), *Helvetoglobotruncana praehelvetica* (Trujill), *Marginotruncana marginata* Reuss, *M. sigali* (Reichel), *M. pseudolinneiana* Pessagno, *M. coronata* (Bolli), *M. coldreriensis* (Gandolfi), *Whiteinella archaeocretacea* Pessagno, *Whiteinella baltica* Douglas & Rankin *and Whiteinella paradubia* (Sigal) demonstrating early Turonian-Coniacian was obtained the Çatak-1 measured stratigraphic section. Early Turonian radiolarian fauna consisting of *Paronaella* spp., *Halesium sexangulum* Pessagno, *Crucella cachensis* Pessagno, *Crucella* spp., *Patelulla* sp., *Stichomitra* sp., *Stichomitra communis* Squinabol are also defined in the same section and the bottom of Çatak-1 section is as early Turonian in this way.

A radiolarian assemblage containing *Crucella, Halesium, Pessagnobrachia Patulibracchium, Alievium, Archaeospongoprunum, Dictyomitra*, *Stichomitra, Diacanthocapsa, Dactyliodiscus, Amphipyndax, Pseudoaulophocus*, *Acaeniotyle, Archaeodictyomitra*, *Actinomma*, *Xitus*, *Novixitus* and Neosciadocapsidae implying period from Cenomanian to Santonian have been recognized in the red-coloured pelagic limestones of the Çatak-2 succession. Also, planktonic foraminifera species of *Marginotruncana*, *Concavatotruncana, Hedbergella, Heterohelix*, *Globotruncana, Archaeoglobigerina, Contusotruncana* characterized Coniacian- Santonian is described in the thin section of same samples. The age of red-coloured limestones is assigned as Coniacian-early Santonian based on radiolarian and pelagic foraminifera fauna.

Consequently, radiolarians and pelagic foraminifera within sedimentary successions of the investigation area are distributed in two intervals that coincide with the early-middle Turonian-?Coniacian and Coniacian-early Santonian boundaries.

Key words: Planktonic foraminifera, radiolarians, early-middle Turonian-?Coniacian, Coniacian-early Santonian.

Session 2
Recent Advances in Radiolarian Biostratigraphy

Conveners
Rie S. HORI & Taniel DANELIAN

Revision of some Late Cretaceous multicyrtid Nassellaria: Biometrics and lineages

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Multicyrtid Nassellaria are commonly used in biostratigraphy of the Cretaceous. However, many species have holotypes that were defined by drawings from thin sections in classical works published at the turn of the 19th to the 20th century, or by transmitted light images in the second half of the 20th century. The comparison of the now most widely used SEM images with this earlier work is not easy. As a consequence, the "semantics" of many species has broadened by inclusion of a number of morphotypes that loosely compare to the original descriptions. However, the broader the species concept, the longer tends to be its range.

To obtain a better resolution for a global, low-latitude, Late Cretaceous radiolarian biochronology, we used the following strategies:

1. Obtain topotypic material from DSDP-ODP and land sites, where Late Cretaceous radiolarian taxa were described.
2. Compare SEM and transmitted light illustrations of topotypic material with original descriptions.
3. Use morphometrics to try to separate closely related forms in well-preserved material.
4. Construct evolutionary lineages for selected taxa.

So far we have been working on the following taxa:

- "*Dicyomitra" formosa* group, incuding "*D*". *torquata, "D." duodecimcostata*, "*D*". *koslovae* and other similar taxa.
- *Dictyomitra multicostata, D. densicostata*, and other similar taxa.
- "*Pseudodictyomira" pseudomacrocephala* group and related "*Pseudodictyomitra"* spp.

We define new genera and species.

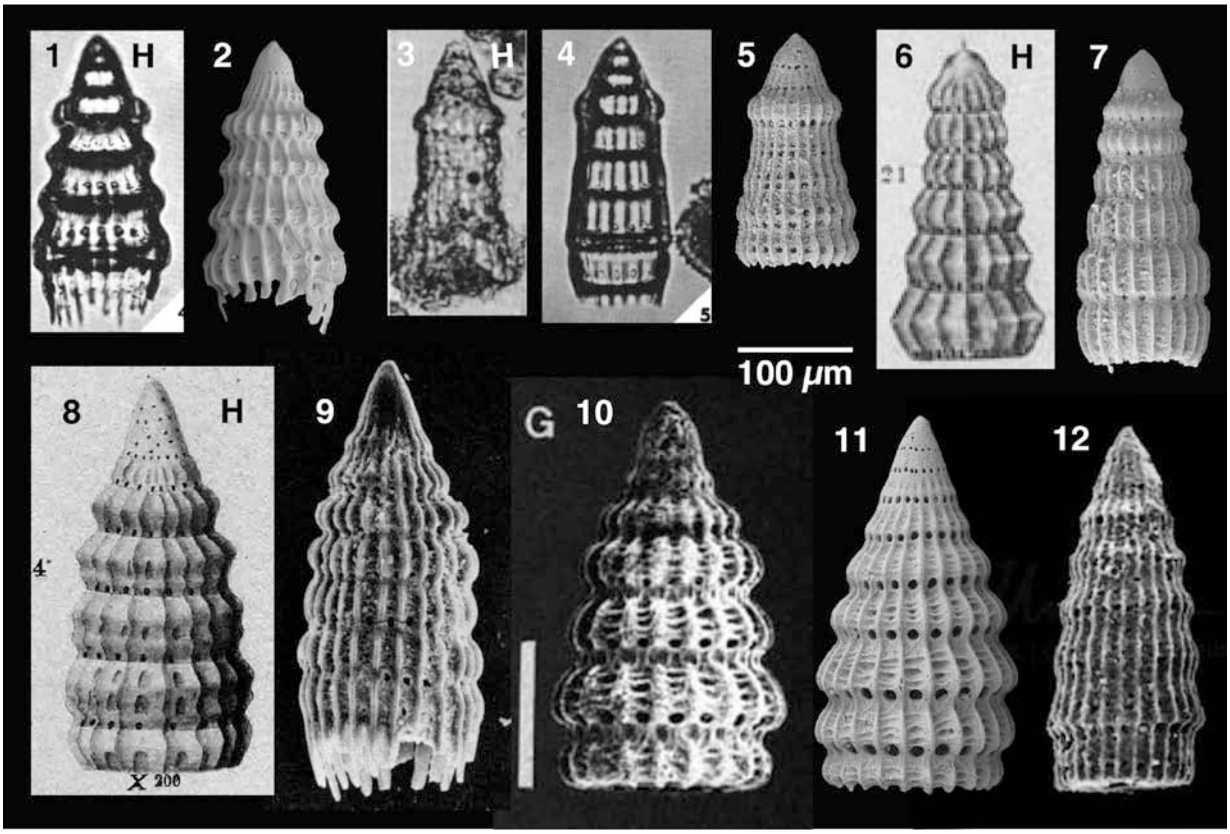

Figure 1. Comparison of some Late Cretaceous holotypes (H) and published specimens with topotypic material from DSDP sites. **1-2.** "*Dictyomitra*" *torquata* Foreman, 1971. 2: topotype from Site 061, 1 – 2, 7-10 cm. **3–5.** "*Dictyomitra*" *koslovae* Foreman, 1975. 3. Holotype, Site 310, 8, CC. 4. Site 61, 1, CC. 5. Site 061, 1 – 2, 7-10 cm. **6–7.** "*Dictyomitra*" *duodecimcostata* (Squinabol). 7. Site 061, 1 – 2, 7-10 cm. **8.** "*Dictyomitra*" *formosa* (Squinabol), holotype. **9.** "*D.*" *formosa* sensu Pessagno, 1976**. 10**. "*D.*" *formosa* sensu Okamoto et al., 1994. **11.** "*D.*"sp. aff. *formosa*, Site 061, 1 – 2, 7-10 cm. **12.** "*D.*" *formosa* sensu O'Dogherty, 1994 (late Cenomanian).

Key words**:** Nassellaria, Late Cretaceous DSDP-ODP samples, biochronology.

Late Oligocene to early Miocene radiolarian events recorded in the mid-latitude North Atlantic

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The recent Integrated Ocean Drilling Program (IODP) Expedition 342 (Paleogene Newfoundland Sediment Drifts) to the Newfoundland Ridge in the North Atlantic recovered continuous radiolarian-rich sediment archive with high mean deposition rates (~3cm/kyr) during the late Oligocene to early Miocene. We examined 20 pilot samples from ~70 to 110 m interval (CCSF, core composite depth below seafloor) of Site U1406 (40°21'N, 51°39' W). The preliminary result shows radiolarian assemblages comparable to tropical Pacific. The presence of zonal markers like *Theocyrtis annosa*, *Cyrtocapsella tetrapera*, *Eucyrtidium diaphanes*, and *Lychnocanoma elongata* helps to assign the examined interval from the top of Zone RP21 to the lower part of RN1. Combined with detailed magnetostratigraphic work conducted on the same sediment sequence at Site U1406, we recognize the first occurrence (FO) of *Cyrtocapsella tetrapera* in palaeomagnetic Chron C6Cn.1n, the FO of *E. diaphanes* within C6Cr, and the FO of *L. elongata* around the top of C7n.2n, which are generally consistent with the results from tropical radiolarian datum events (Sanfilippo & Nigrini, 1998; Nigrini et al., 2006; Kamikuri et al., 2012). However, the FO of *Calocycletta (Calocyclopsis) serrata* at Site U1406 is found in Chron C6Cr, much older than that reported from the tropical Pacific sites (Chron C6AAr) (Nigrini et al., 2006; Kamikuri et al., 2012).

References

Kamikuri, S., Moore, T.C., Ogane, K., Suzuki, N., Palike, H. & Nishi, H., 2012. Early Eocene to early Miocene radiolarian biostratigraphy for the low-latitude Pacific Ocean. Stratigraphy 9, 1, 77-108.

Nigrini, C., Sanfilippo, A. & Moore Jr, T.J., 2006. Cenozoic radiolarian biostratigraphy: a magnetobiostratigraphic chronology of Cenozoic sequences from ODP Sites 1218, 1219, and 1220, equatorial Pacific. In: Proceedings of the Ocean Drilling Program, Scientific Results (Wilson, P. A., Lyle, M. & Firth, J. V., Eds.), 199, 1–76.

Sanfilippo, A. & Nigrini, C., 1998. Code numbers for Cenozoic low latitude radiolarian biostratigraphic zones and GPTS conversion tables. Marine Micropaleontology 33, 1-2, 109-156.

***Key words*:** Cenozoic, North Atlantic, middle latitude.

Well-preserved Jurassic radiolarians from the Naga Hills ophiolite, Indo-Myanmar Range; constraints on intra-oceanic island arc development within eastern Tethys

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Red ribbon-bedded cherts associated with ophiolitic mélange that constitutes part of the Naga Hills ophiolite near Waziho, in eastern Nagaland, India, yield a well-preserved Middle Jurassic (Bathonian) radiolarian fauna. The fossil assemblage is slightly older than the Upper Jurassic (Kimmeridgian-Tithonian) one reported by Baxter et al. (2011) for localities around 20 km to the north. The Bathonian age for cherts that immediately overlie pillow basalts within the ophiolite is consistent with U/Pb SHRIMP ages for detrital zircons in ophiolite-derived sandstones of the overlying the Phokphur Formation (Roeder et al., 2014).

The Naga Hill ophiolite is one of many ophiolite occurrences of supra-subduction zone affinity that occur along the suture zone between India and Asia. Middle Jurassic ages are of particular interest as they are considerably older than mid Cretaceous ages reported for similar cherts associated with ophiolite occurrences in Tibet and Ladakh (Zyabrev et al., 2008). The age is, however, similar to that of radiolarians reported from ophiolitic elements of the Zedong terrane located along the Yarlung Tsangpo suture zone in eastern Tibet (Aitchison et al., 2007). These differences in fossil ages, amongst the few surviving fragments of the formerly extensive Neotethyan Ocean, suggest that this extensive basin was complex. Radiolarians continue to provide data essential to unraveling the tectonic history of lost oceans and are a vital element in any tectonocists toolbox.

References

Aitchison, J.C., McDermid, I.R.C., Ali, J.R., Davis, A.M. & Zyabrev, S.V., 2007. Shoshonites in southern Tibet record Late Jurassic rifting of a Tethyan intra-oceanic island arc. Journal of Geology 115, 197-213.

Baxter ,A.T., Aitchison, J.C., Zyabrev, S.V. & Ali, J.R., 2011. Upper Jurassic radiolarians from the Naga Ophiolite, Nagaland, northeast India. Gondwana Research 20, 638–644.

Roeder, T., Aitchison, J.C., Clarke, G.L., Ireland, T.R., Ao, A. & Bhowmik, S.K., 2014. Using zircon geochronology to unravel the history of the Naga Hills ophiolite. AGU 2014 Fall Meeting Abstract T21B-4603. AGU, San Francisco, USA.

Zyabrev, S.V., Kojima, S. & Ahmad, T., 2008. Radiolarian biostratigraphic constraints on the generation of the Nidar ophiolite and the onset of Dras arc volcanism: Tracing the evolution of the closing Tethys along the Indus – Yarlung-Tsangpo suture. Stratigraphy 5, 99-112.

***Key words*:** Radiolaria, Jurassic, Bathonian, the Indo-Myanmar Range, the Naga Hill ophiolite, Nagaland, the Phokphur Formation.

First radiolarian records in the Paleocene of the southern slope of the western Caucasus

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N.N. Borisenko (1958–1960) and V.A. Kraschenninikov (1960) were the first to study Ciscaucasian radiolarians and described more than 60 new species from the Paleocene and Eocene sequences of the western Caucasus. The species established by them were also found in other regions of the former Soviet Union and in oceanic sequences. However, unfortunately, their collections have been lost.

Subsequently, these studies were continued by R.Kh. Lipman (1984), who found several new species in the Abasin Formation on the Kuban River and recognized six stratigraphic units based on Paleocene radiolarians (Goryachii Klyuch and Abasin formations). In 1987, Lipman elaborated a biostratigraphic scheme of the Lower Paleogene based on radiolarians, including six zones. She paid particular attention to the section on the Kuban River, which is situated near the town of Cherkessk and is accepted as a parastratotype section for the southern former Soviet Union.

Lipman laid the foundations for the development of zonal stratigraphic schemes based on radiolarians. She has shown the great potential of radiolarians for biostratigraphy and, hence, stimulated similar studies in various regions of the Soviet Union.

The lithologic study previously performed by us revealed that siliceous rocks are widespread among the Paleocene strata of the western Caucasus (Agarkov, 1985; Agarkov et al., 1992). Thin sections of cherts have yielded remains of siliceous organisms of various taxonomic groups.

In the region considered, Paleocene deposits are represented by the Danian, Zelandian and Thanetian stages. The Zelandian part of the section, which covers the Tsitse Formation, is more siliceous.

The Tsitse Formation overlies with angular unconformity Maestrichtian and Danian rocks. The lower part of the formation is composed mainly of limestones, frequent layers of siliceous claystones (up to 0.7 thick), with rare lenticular sandstone interbeds and packages (up to 2 m thick) of fine interbedding gaize-like claystones, gaizes and flints. In addition to these rocks, 5–12 cm thick interbeds of clayey and pelitic limestones also occur. In some parts of the sequences, particularly its middle part, flints compose 44–70% of the volume. The maximum thickness of the strata described reaches 160 m (Pauk River).

The overlying beds begin with a horizon that is up to 1–130 m thick of the underwater landslide origin. Upwards, there are the strata of fine medium-rhythmic (8–30 cm thick) interbedding siliceous–calciferous claystones with rarer interbeds of calcic claystones and calcic clayey siltstones. Abundant lenticular flint interbeds (up to 0.2 m thick) are scattered throughout the section. The upper part of the stage ranges from 4 to 250 m of thickness (Pauk River).

The flint samples examined by us contain rich assemblages of well-preserved radiolarians. A total of over 40 species of the following genera have been identified: *Amphicarydiscus* Lipman, *Axoprounum* Haeckel, *Carposphaera* Haeckel, *Cenellipsis* Rust, *Cenodiscus* Haeckel, *Cenosphaera* Ehrenberg; *Ellipsostylus* Haeckel, *Paracenodiscus*

Kraschenninnikov, *Porodiscus* Haeckel, *Spongodiscus* Ehrenberg, *Stylodictya* Ehrenberg, *Theocampe* Haeckel, *Thecosphaerella* Haeckel, 1887; *Trochodiscus* Haeckel etc.

The assemblage described differs in species composition from the approximately contemporaneous assemblage from the northern slope of the western Caucasus. In this case the majority of taxa that are typical for the Boreal Zone are absent and a significant part of the assemblage is composed of Tethyan species. The assemblage is also characterized by the presence of up to 30% of endemic species, including new ones. This species composition is accounted for by the presence in the Paleocene of the Caucasus of two large islands with narrow straits restricting exchange. The combination of cold-water and warm-water taxa is promising for the development of a correlation scheme for the Boreal and Tethyan zones in the future.

References

Agarkov, Yu.V., Boiko, N.I. & Sedleckiy, V.I., 1992. Kremnistye porody Severnogo Kavkaza I perspektivy ih promyshlennogo ispolsovaniya. [Siliceous rocks of the Nothern Caucasus and prospects industrial use]. Rostov-na-Donu: Izd-vo RGU, 206.

Borisenko, N.N., 1958. Radiolarii paleocena zapadnoy Kubani [Paleocene Radiolaria of Western Kuban]. Trudy Vsesoyuznogo Neftegazovogo Nauchno-Issledovatelskogo Instituta, Krasnodarskiy Filial 17, 81–100 (In Russian).

Borisenko, N.N., 1960. Radiolarii nizhnego i srednego eocena zapadnoy Kubani [The radiolarians of the lower and middle Eocene of Western Kuban]. Trudy Vsesoyuznogo Neftegazovogo Nauchno-Issledovatelskogo Instituta, Krasnodarskiy Filial 4, 219–232 (In Russian).

Krasheninnikov, W.A., 1960. Nekotorye radiolarii nizhnego I srednego eocena zapadnogo predkawkazia. [Some radiolarians from the lover and middle Eocene Western Ciscaucasia]. Proceeding of the All Union Petroleum Scientific Research Institute for Geological Survey (VNIGRI) 16, 271–307 (In Russian).

Lipman, R.Kh., 1984. The correlation of zonal stratigraphical schemes of Paleocene and Eocene pre-Caucasus and Apscheronian Half Island by the radiolarians. In: Morphology, Ecology and Evolution of Radiolarians (Petrushevska, M.G. & Stepanjants, S.D., Eds.), Proceedings of the Fourth Eurorad Conference, Academy of Science, Leningrad, 211-220 (in Russian).

***Key words*:** Radiolarians, Paleogene, western Caucasus.

Upper Permian radiolarian biostratigraphy of deep-sea Panthalassic chert sections from the Mino Terrane, Japan

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We present Upper Permian radiolarian biostratigraphic results of bedded chert sequences from the Mino terrane, central Japan. The examined chert beds comprise the upper part of the Lower Permian to Lower Triassic deep-marine siliceous succession that accumulated on the lower flank of a seamount, situated in a pelagic realm of the Panthalassic Ocean. The stratigraphy and age of the Permian-Triassic boundary siliceous rocks have been already reported for the upper part of section NF 195 (Sano et al., 2012). Our preliminary work deals with the upper Middle Permian (upper Guadalupian) to upper Upper Permian (Changhsingian) ribbon-chert underlie the P-T boundary rocks of section NF 195 (Sano & Kuwahara, 2011).

We measured five subsections, NF 195G to NF 195 C in ascending order, of the upper Guadalupian to Wuchiapingian chert sequence. All beds of the five subsections were collected and examined in detail. Characteristics of the radiolarian fauna and assemblage zones of each subsection are summarized as follows;

Subsection NF 195G (ca. 3.5m thick): *Follicucullus scholasticus, Follicucullus charveti*, *Follicucullus* spp., *Foremanhelena triangula*, *Latentifistula texana*, *Latentifistula* spp., *Ishigaum trifustis* are detected. Latentifistularians are abundant. The section is correlated with the *Follicucullus charveti-Albaillella yamakitai* Zone (late Guadalupian).

Subsection NF195F (ca. 1.2 m thick): *Latentifistula texana, Latentifistula similicutis, Latentifistula* spp., *Ishigaum trifustis, Tormentum* sp. A occur. Albaillellarian species are rare. The studied sequence is correlated with the *Follicucullus charveti-Albaillella yamakitai* Zone.

Subsection NF195E (ca. 2.4 m thick): *Latentifistula texana*, *Latentifistula* sp. C, *Ishigaum trifustis* are found. Albaillellarian species are rare. *Albaillella yamakitai* probably marks the Guadalupian-Lopingian boundary. The studied sequence is correlated with the *Follicucullus charveti-Albaillella yamakitai* Zone.

Subsection NF195D (ca.1 m thick): *Latentifistula texana, Latentifistula* spp., *Albaillella protolevis, A. yamakitai* are present. The studied sequence is correlated with the *Follicucullus charveti-Albaillella yamakitai* and *Neoalbaillella ornithoformis* zones, the latter indicating the Wuchiapingian.

Subsection NF195C (ca. 5.1 m thick): *Albaillella protolevis, Foremanhelena triangula, Cauletella porosa, Triplanospongos musashiensis, Kashiwara magna* are identified. The studied sequence is correlated with the *Neoalbaillella ornithoformi*s Zone.

Results of our albaillellarian biostratigraphic examination show that the examined five subsections are correlated with the *Follicucullus charveti-Albaillella yamakitai* and *Neoalbaillella ornithoformi*s zones in ascending order. However the albaillellarian species are not abundant, except for the lower part of subsection NF 195G. Therefore, we suggest new assemblage zones based on Latentifistularia: *Foremanhelena triangula* Zone (NF 195G), *Tormentum* sp. A Zone (NF 195G and 195F), *Latentifistula* sp. C Zone (NF 195E and NF195D), *Albaillella protolevis* Zone (NF195D and NF195C), *Cauletella porosa* Zone (NF195C), *Triplanospongos musashiensis* Zone (NF195C) in ascending order. The base of *Neoalbaillella ornithoformis* Zone corresponds to the base of *Albaillella protolevis* Zone. Our results imply that Latentifistularian species are useful for the biostratigraphic zonation in the upper Guadalupian to Wuchiapingian albaillellarian-poor stratigraphic interval. Combined with the albaillellarians, the latentifistularians could play a significant role for the late Guadalupian to Wuchiapingian biostratigraphic zonation.

References

Sano, H. & Kuwahara, K., 2011. Upper Permian radiolarian biostratigraphy of the chert of Mino terrane in the Funabuseyama area, western Gifu. Abstract with Programs, 160^{th} Regular Meeting of Paleontological Society of Japan, 41.

Sano, H., Kuwahara, K., Yao, A. & Agematsu, S., 2012. Stratigraphy and age of the Permian-Triassic boundary siliceous rocks of the Mino terrane in the Mt. Funabuseyama area, central Japan. Paleontological Research 16, 124-145.

***Key words*: Permian biostratigraphy.**

The earliest radiolarians: The race is still open

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Radiolarians have been claimed to be present in the Lower Cambrian successions frequently, but have been described even from Late Precambrian rocks in the past. Usually, they are found in very few specimens, often single specimens have been used to argue for the presence of radiolarians in these strata. Unfortunately, a closer inspection may indicate that these records are untenable. The presence of lower Terreneuvian (Fortunian) Hetang and Kuanchuanpu formations of China (Braun et al., 2005, 2007) for example, has to be regarded as a contamination with younger material. The illustrated specimens indicate a late Palaeozoic, possibly Devonian age of the material.

The identification of spherical bodies as radiolarians (Braun & Chen, 2003; Braun et al., 2004) from the Early Cambrian black shales of the Fortunian *Anabarites trisulcatus-Protohertzina anabarica* assemblage zone of the Yangtze platform are thin-walled calcedony-filled bodies, apparently with an organic wall, and the identification as radiolarians was based solely on the shape of these. None of the spherical bodies shows and indications of the typical skeleton development of a radiolarian. They can alternately be identified as early diagenetic mineral fills of uncompacted sphaeromorph acritarch tests. Acritarchs of quite variable sizes, identified as *Lophosphaeridium* and *Leiosphaeridium* have been described from the locality (Zhang et al., 2014).

The main question remains: How should early radiolarian look like? - A question not easy to answer. However, earliest known true radiolarian faunas from the Middle Cambrian of Australia (Won & Below, 1999) provide a direction. If we trust the fossil record of Cambrian to Middle Ordovician radiolarians, we can safely say that early radiolarian are not the nice, perfectly spherical objects we know from younger taxa. The construction of early radiolarians, e.g. of the genera *Archeoentactinia*, *Spongomassa* and *Palaeospiculum* from the Middle Cambrian can be used as a basis for the interpretation. They invariably show a spicular development with some additional features. Their spicules remind of the spicules of hexactinellid sponges, even though a closer relationship of the Radiolaria to sponges cannot be established.

There is no record of Early Cambrian radiolarians so far. The age of presumed Terreneuvian (Fortunian) to Botomian radiolarians (Stage 3, Series 2) by Cao et al. (2014) needs verification. The material consists of two specimens of which one was identified as *Kalimnasphaera*, while the other, a spherical body with vaguely hexagonal meshes and without outer spines was undetermined due to poor preservation. Both specimens may indicate a contamination of younger material. Possibly genuine Botomian radiolarians are present in the Altai Mountains (Pouille et al., 2011), but the exact age needs verification. Korovnikov et al. (2013) indicated an upper Botomian (Cambrian Stage 4) age. Oldest diverse radiolarian faunas are presently documented from Stage 5 (Series 3) of the Cambrian System, leaving the biostratigraphical and evolutionary origin of radiolarians undecided.

References

Braun, A. & Chen, J.-J., 2003. Plankton from Early Cambrian black shale series on the Yangtze Platform, and its influences on lithologies. Progress in Natural Sciences 13, 10, 777-782.

Braun, A. & Chen, J.-J., Maas, A. & Waloszek, D., 2004. Plankton from Early Cambrian black shale series on the Yangtze Platform, and its influences on lithologies. In: Biological and Geological Processes of the Cambrian Explosion (Zhu, M. & Steiner, M., Eds.), Progress in Natural Sciences Special Issue, 7-12.

Braun, A., Chen J.-Y., Waloszek, D. & Maas, A., 2005. Micropalaeontological studies in Lower Cambrian rocks of the Yangtze Plate, China: methods and results. Studia Geologica Polonica 124, 11–20.

Braun, A., Chen J.-Y., Waloszek, D. & Maas, A., 2007. First Early Cambrian Radiolaria. Geological Society, London, Special Publications 286, 143-149.

Cao, W., Qinglai, F, Feng, F. & Ling, W. 2014. Radiolarian *Kalimnasphaera* from the Cambrian Shuijingtuo Formation in South China. Marine Micropaleontology 110, 3-7.

Korovnikov, I., Sennikov, N., Danelian, T., Obut, O. & Pouille, L., 2013. The biostratigraphic and paaleoenvironmental significance of Lower Cambrian (Botomian) trilobites from the Ak-Kaya section of the Altai Mountains (southern Siberia, Russia). Annales de Paléontologie 99, 79-89.

Pouille, L., Obut, O., Danelian, T. & Sennikov, N., 2011. Lower Cambrian (Botomian) polycystine Radiolaria from the Altai Mountains (southern Siberia, Russia). Comptes Rendus Palevol.

Won, M.Z. & Below, R., 1999. Cambrian radiolarians from the Georgina Basin, Queensland, Australia. Micropaleontology 45, 4, 325–363.

Zhang, L., Danelian, T., Feng, Q., Servais, T., Tribovillard, N. & Caridroit, M., 2013. On the Lower Cambrian biotic and geochemical record of the Hetang Formation (Yangtze Platform, south China): evidence for biogenic silica and possible presence of Radiolaria. Journal of Micropaleontology 32, 207-217.

***Key words*:** Radiolaria, Palaeozoic, evolution.

Carbon isotope correlation of Middle–Upper Jurassic radiolarian-bearing rocks across the Atlantic-western Tethys gateway

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In this contribution, we explore the potential of a well-calibrated $\delta^{13}C$ isotopic curve, recently established in low latitude areas, as a tool for stratigraphic correlation across deep-pelagic siliceous successions and to test the viability of using the carbon isotopes curve to resolve major biostratigraphic uncertainties of UAZones of Baumgartner et al. (1995), especially at the Middle–Upper Jurassic transition.

Twenty years ago we developed a precise radiolarian biochronology for the Jurassic to Middle Cretaceous interval (Baumgartner et al., 1995). This zonation has been widely used as a reference for biostratigraphic work with Middle Jurassic to Lower Cretaceous radiolarians worldwide. Despite some inconsistencies in the stratigraphic range of some characteristic species (see Suzuki & Gawlick, 2003; O'Dogherty et al., 2006; Beccaro, 2006; Chiari et al., 2007), the zonation provides itself a good relative timescale; actually no better alternative biostratigraphic schemes have been presented up to day. However, its correlation to the stages, via the co-occurrence of radiolarians and ammonites is still fragmentary. In particular, this correlation is quite imprecise for the time of most widespread radiolarite deposition (Bathonian–Oxfordian) because no other fossils coexist with radiolarians. An exception is found in the western basins (namely the Subbetic Realm) where nannofossils occur and the carbonate content of these siliceous facies is higher. We have conducted stable isotope stratigraphy (C, O) in the same sections that provide radiolarian and nannofossil stratigraphy to overcome the correlation problem.

This research presents a chemostratigraphic correlation between the carbon isotope curve of reference proposed for the Bajocian–Kimmeridgian (based on data from the pelagic Subbetic seamounts in Spain and the Subalpine Basin in France) and sixteen localities across the western Tethys where siliceous and radiolarian-bearing deposits are recorded. These are from west to east: Site 534A (central Atlantic), Jarropa, S. Harana, Ricote, Cuver (Subbetic Basin), Terminelleto (Umbria-Marche Apennines), Breggia, Tignale (Lombardian Basin, Southern Alps), Ceniga, Costton delle Vette (Trento Plateau, Southern Alps), Ardo (Belluno Basin, Southern Alps), Mangart (eastern Southern Alps) and the Krížna Unit (Tatra Mountains).

Another important topic, beside the biochronologic information, is the great potential for paleoenvironmental and paleoclimatic interpretation of these siliceous deposits. In that way, the evolution of the biosphere, lithologic, and preservational shifts, can directly be compared to parameters recording regional and/or global physico-chemical processes. The combination of several disciplines (biostratigraphy, stable isotope chemostratigraphy and geochemistry) may eventually help to overcome these fundamental problems in the future and lead to a more consistent model of the Middle-Late Jurassic paleoenvironmental/paleoclimatic evolution. At the same time the benefit of this contribution would be in a more coherent chronostratigraphic correlation of radiolarian biochronozones in the framework of the International Subcomission of Jurassic Stratigrahy.

References

Baumgartner, P. O., O'Dogherty, L., Goričan, Š., Urquhart, E., Pillevuit, A. & De Wever, P., 1995. Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology. Mémoires de Géologie (Lausanne) 23, 1–1172.

Beccaro, P., 2006. Radiolarian biostratigraphy of Middle-Upper Jurassic pelagic siliceous successions of western Sicily and the southern Alps (Italy). Mémoires de Géologie (Lausanne) 45, 1–114.

Chiari, M., Cobianchi, M. & Picotti, V., 2007. Integrated stratigraphy (radiolarians and calcareous nannofossils) of the Middle to Upper Jurassic Alpine radiolarites (Lombardian Basin, Italy): Constraints to their genetic interpretation. Palaeogeography, Palaeoclimatology, Palaeoecology 249, 233-270.

O'Dogherty, L., Bill, M., Goričan, Š., Dumitrica, P. & Masson, H., 2006. Bathonian radiolarians from an ophiolitic melange of the Alpine Tethys (Gets Nappe, Swiss-French Alps). Micropaleontology 51, 425–485.

Suzuki, H. & Gawlick, H.-J., 2003. Biostratigraphie und Taxonomie der Radiolarien aus den Kieselsedimenten der Blaa Alm und nödlich des Loser (Nördliche Kalkalpen, Callovium-Oxfordium). Mitteilungen der Gesellschaft der Geologie- und Bergbaustudenten in Österreich 46, 137–228.

***Key words*: C-Isotope, Jurassic, biostratigraphy.**

Reexaminaton of conodonts and radiolarians from type sections of the Upper Carboniferous–Lower Permian radiolarian biozones in Japan

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Upper Carboniferous–Permian radiolarian biozones in pelagic sediments such as cherts and siliceous mudstone have been established in the 1980’s (Ishiga, 1982, 1990; Ishiga et al., 1984). Their age assignment largely relied on a small number of conodonts found at the time. These age assignments have been followed by subsequent studies without re-examination, due to sever difficulties to extract sufficient numbers of age-diagnostic conodont elements from cherts, regardless of recent significant advances on conodont taxonomy and biostratigraphies. Recently a new proficient technique to extract conodonts from small fragments of cherts has been developed (Nishikane et al., 2011), which enables us to restudy the conodont biostratigraphy of the deep-water pelagic sediments in Japan.

We examined the same sections which were documented in Ishiga (1982) and Ishiga et al. (1984), with the help of Prof. Hiroaki Ishiga (Shimane University). The Maruyama section was composed of reddish brown bedded siliceous mudstones, where the Upper Carboniferous *Pseudoalbaillella nodosa* to *Ps. bulbosa* zones were established by Ishiga (1982); the Omori section of Ishiga et al. (1984) consists of reddish brown siliceous mudstone and chert in the lower part and thinly bedded cherts in the middle to upper part. The Omori section is the type section for the Lower Permian *Ps. u-forma* m. I to *Ps. lomentaria* zones. In the Maruyama section, nearly 2,500 conodont fragments were found in 81 out of 125 examined horizons. Although these conodonts were generally poorly preserved, age diagnostic conodonts were found in the Bashkirian (lower Pennsylvanian) to Sakmarian (Cisuralian) interval. The lower part (A subsection in Ishiga et al. 1984) of the Omori section, the type section for the radiolarian *Pseudoalbaillella u-forma* m. I zone, yields the Pennsylvanian-type *Gondolella* and many upper Pennsylvanian *Streptognathodus*.

Re-examination of radiolarians in these two sections reveals that diverse latentifistularids including *Latentifistula mushroomformis* occur throughout the sections. *Pseudoalbaillella bulbosa, Ps. simplex,* and *Ps. reflexa* are found from the Gzhelian, Asselian and Sakmarian, respectively. *Pseudoalbaillella u-forma u-forma* and *Ps. chilensis* were recovered from the uppermost part of the Ishiga’s subsection A. In opposition to the results of the studies by Ishiga (1982) and Ishiga et al. (1984), albaillellids occur discontinuously in the same sections. The integrated biostratigraphy between conodonts and radiolarians results to an entirely different correlation with the geologic time scale from what is known so far, although part of our results is in agreement with Nestell et al. (2012).

References

Ishiga, H., 1982. Late Carboniferous and Early Permian radiolarians from the Tamba Belt, southwest Japan. Earth Science 36, 333–339.

Ishiga, H., 1990. Paleozoic radiolarians. In: Pre-Cretaceous Terranes of Japan (Ichikawa, K., Mizutani, S., Hara, I., Hada, S. & Yao, A. Eds.), Publication of IGCP 224, Osaka City University, Osaka, 285–295.

Ishiga, H., Imoto, N., Yoshida, M. & Tanabe, T., 1984. Early Permian radiolarians from the Tamba Belt, southwest Japan. Earth Science 38, 44–52.

Nestell, G.P., Pope, J.P. & Nestell, M.K., 2012. Middle Pennsylvanian (Desmoinesian) Radiolaria from the Midcontinent of North America. Micropaleontology 58, 217–257.

Nishikane, Y., Kaiho, K., Takahashi, S., Henderson, C.M., Suzuki, N. & Kanno, M., 2011. The Guadalupian-Lopingian boundary (Permian) in a pelagic sequence from Phanthalassa recognized by integrated conodont and radiolarian biostratigraphy. Marine Micropaleontology 78, 84–95.

***Key words*:** Conodont, Carboniferous, Permian, type section.

Early Cretaceous Radiolaria from the Baergang section in southern Tibet and its significance

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The bilateral Sino-German joint field work related to the Cretaceous oceanic red beds (CORBs) in southern Tibet was taken by Chinese and German geologists in 2004. All of the red sedimentations (CORBs), including limestones, mudstones, pelagic marlstones, cherts, radiolarian cherts and so on, are assigned to the Chuangde Formation and considered as Santonian-Campanian in age by previous workers based on the foraminifera assemblages. Thirty one potentially radiolarian-bearing cherty samples, of which sixteen yielded moderately to well preserved radiolarians by using the standard method of extract radiolarian individuals from the cherts established by Dumitrica (1970) and Pessagno & Newport (1972) in the laboratory were sampled from the red chert beds of the Baergang section, Nagarze County, during that field trip.

Eighty four species, including one new species (*Archaeodictyomitra baergangensis* sp. nov.), within 32 genera were extracted from Beds 3, 4, 7, 13 and 16 of the Baergang Section. Of these radiolarian fossils, predominantly by Nassellarians, *Archaeodictyomitra* and *Pseudodictyomitra* with high diversity, *Pantanellium*, *Svinitzium*, *Tethysetta* etc. with relative low diversity and lacking *Mirifusus*. *Archaeodictyomitra apiarium*, *A. mitra*, *A. praegutta*, *A. vulgaris*, *Cryptamphorella conara*, *Holocryptocanium barbui*, *Pseudodictyomitra carpatica*, *P. conicostriata*, *P. nodocostata*, *Stichocapsa tuscanica*, *Thanarla brouweri* and *T. pulchra* are common. However, *Hiscocapsa asseni* is rare, it has relative short range and plays a key role to time the strata. This species only ranges from the base of Verbeeki subzone to the lower part of Romanus subzone of O'Dogherty (1994), and early Aptian-early Albian in age. *Pseudodictyomitra pseudomacrocephala* which ranges from the lower part of Romanus subzone of O'Dogherty (1994) can only be found in last sample, and the age of that sample may be early Albian.

Therefore, we conclude that the age of the red radiolarian-bearing cherts of the Baergang section is from early Aptian to early Albian rather than Santonian-Campanian as previously considered. Furthermore, the oceanic red beds of the Gaergang section may deposit as early as early Aptian, Early Cretaceous.

References

Dumitrica, P., 1970. Cryptocephalic and Cryptothoracic Nassellaria in some Mesozoic deposits of Romania. Revue Roumaine de Géologie, Géophysique et Géographie (série Géologie) 14, 1, 45-124.

O'Dogherty, L., 1994. Biochronology and Paleontology of mid-Cretaceous Radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). Mémoires de Géologie (Lausanne) 21, 1-415.

Pessagno, E. A. & Newport, R. L., 1972. A technique for extracting Radiolaria from radiolarian chert. Micropalaeontology 18, 2, 231-234.

Key words: Radiolaria, Cretaceous oceanic red beds, the Baergang section, early Aptian-early Albian, southern Tibet.

Mesozoic Radiolaria of Crimea

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Mesozoic radiolarians are wide spread within Crimea stratigraphic sequences (Vishnevskaya, 2001; Bragina, 2004; Vishnevskaya et al., 2006; Yudin et al., 2009). Cretaceous (Cenomanian-Turonian) radiolarians occur in intercalations of the limestone and marl beds (50–70 m) of the South Crimea and include *Alievium superbum* (Squinabol), *Crucella cachensis* Pessagno, *Xitus spicularius* (Aliev) and *Pseudodictyomitra pseudomacrocephala* (Squinabol), as well as the prevailing cryptocephalic *Holocryptocanium barbui* Dumitrica, *Diacanthocapsa antiqua* (Squinabol) with a hyperspherical abdomen, and others (Fig. 1: 1-17). Jurassic (Bajocian-Kimmeridgian) radiolarians occur in concretions in the clay aleurolite of the Petropavlovka quarry and belong to the Taurian Series. The marker taxon is *Levileugeo ordinarius* Yang & Wang (Fig. 1: 18-22).

Triassic (Carnian–early Norian) radiolarians occur in pebbles of green chert of Demerdgy Mountain (Yudin et al., 2009). The characteristic species are *Staurocontium*? *trispinosum* (Kozur & Mostler), *Spinotriassocampe*? *carnica* Kozur & Mostler and others (Fig. 1: 23-28).

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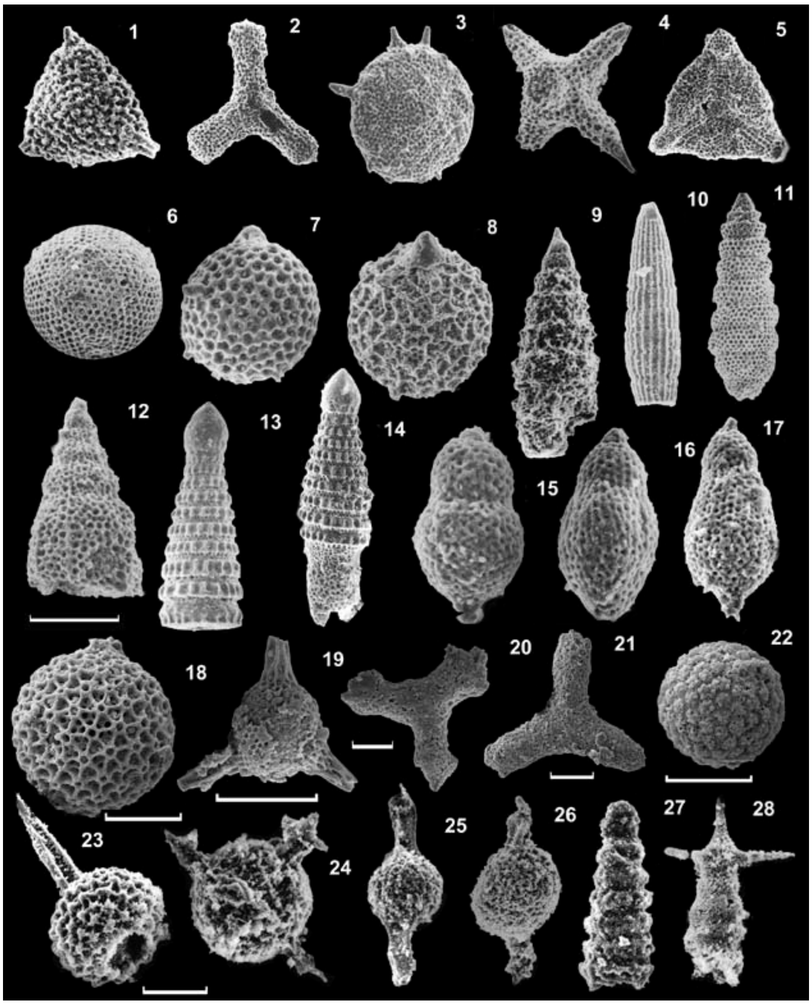

Figure 1. Mesozoic Radiolaria of Crimea. **1-17.** Cretaceous (Cenomanian–Turonian) of the Selbukhra Mountain: **1.** *Alievium superbum* (Squinabol), **2.** *Pessagnobrachia fabianii* (Squinabol), **3.** *Patellula helios* (Squinabol), **4.** *Crucella cachensis* Pessagno, **5.** *Pessagnobrachia rara* (Squinabol), **6.** *Holocryptocanium barbui* Dumitrica, **7.** *Trisyringium echitonicum* (Aliev), **8.** *T. capellinii* Vinassa, **9.** *Xitus spineus* Pessagno, **10.** *Dictyomitra montisserei* (Squinabol), 11. *Stichomitra communis* Squinabol, 12. *Dictyodedalus hesperis* O'Dogherty, **13, 14.** *Pseudodictyomitra pseudomacrocephala* (Squinabol), **15.** *Diacanthocapsa fossilis* (Squinabol), **16.** *D. antigua* (Squinabol), **17.** *D. euganea* Squinabol; 1-9 from sample 18A (Turonian); 1-17 from sample 136 (upper Cenomanian/lower Turonian boundary). **18-22**. Jurassic (Bajocian-Kimmeridgian) of Petropavlovka quarry: **18.** *Levileugeo ordinarius* Yang & Wang, **19.** *Triactoma jonesi* Pessagno, **20.** *Paronaella* ex gr. *mulleri* Pessagno, **21.** *P. kotura* Baumgartner, **22.** *Praeconocaryomma* sp. Sp. 3822. Triassic (Carnian–early Norian) of the Demerdgy Mountain: **23, 25**. *Pseudostylosphaera* ? sp., **24.** *Staurocontium* ? *trispinosum* (Kozur & Mostler), **26.** *Tubospongopallium* ? *tornatum* Tekin & Mostler, **27.** *Triassocampe* sp., **28.** *Spinotriassocampe* ? *carnica* Kozur & Mostler, Sp. 147-2-94. Scale bar equals 100 µm.

References

Bragina, L.G., 2004. Cenomanian–Turonian radiolarians of northern Turkey and Crimean Mountains. Paleontological Journal 38, 325–451.

Vishnevskaya, V.S., 2001. Radiolarian biostratigraphy of the Jurassic and Cretaceous in Russia. Moscow, GEOS, 1–273.

Vishnevskaya, V.S., Gorbachick, T.N., Kopaevich, L.F. & Bragina, L.G., 2006. Foraminifers and radiolarians across the Albian–Cenomanian and Cenomanian–Turonian boundaries (northern Peri–Tethys). Stratigraphy and Geological Correlation 14, 28–49.

Yudin, V.V., Vishnevskaya, V.S. & Kurilov, D.V., 2009. Ophiolitic radiolarites of the Crimea and their significance for geodynamics of Mesotethys. Doklady Earth Sciences 429, 8, 1278–1283.

Key words: Cretaceous, Jurassic, Triassic, taxonomy, methods, geologic settings.

Radiolarian biostratigraphy of the Cretaceous (Albian-Coniacian) deposits of the Kelevudag section (northeastern Azerbaijan)

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Cretaceous Radiolaria of Azerbaijan was studied in 60s of XX century by Khosrov Sh. Aliev who was a pioneer in Caucasus radiolarian investigations (Aliev, 1965, 1967, 1968). Many taxa described by Aliev are used for the biostratigraphy of Cretaceous. Due to these facts reexamination of Aliev's localities seems very important. We studied radiolarian-bearing Cretaceous deposits of the Kelevudag section located in the north-eastern slope of Greater Caucasus near village of Konahkend. This locality was studied by Aliev in details; he described Albian and Cenomanian radiolarians from this section. The Kelevudag section includes all Cretaceous and is represented mainly by limestones, marls and clastics. Here we give a short description of Albian–?Coniacian part of the section.

1. The Kyulyuli Formation (middle-upper Albian): Light yellowish-grey and greenish-grey thin-bedded cherty marls with interlayers of light-grey medium- to fine-grained sandstones, grey and yellowish-grey clays, grey cherty mudstones and black combustible shales (total thickness 60 m). Upper part of the formation is dated as upper Albian by *Neohibolites stylioides* Renng., *N. subtilis* Krimh. and bivalvs *Aucellina aptiensis* (d'Orb.), *A. pavlovi* Sok., *A. nassibianzi* Sok., A. *gryphaeoides* Sow., *A. renngarteni* Sok., *A. pompeckji* Pavl. Radiolarian assemblage with *Dorypyle ? anisa–Crolanium triangulare* was found here (Bragina & Bragin, 2015). The assemblage is characterized by common Tethyan taxa, typical for Albian and Cenomanian: *Acaeniotyle amplissima* (Foreman), *Dorypyle* ? *anisa* (Foreman), *Obeliscoites perspicuus* (Squinabol), *Pseudodictyomitra paronai* (Aliev), *Pseudoeucyrtis pulchra* (Squinabol), *Crolanium spineum* Pessagno, *Cr. triangulare* (Aliev), *Trisyringium echitonicum* (Aliev). Upper part of Kyulyuli Formation can be correlated with lower part of *Dorypyle ? anisa* Subzone (upper part of *Thanarla spoletoensis* Zone) of upper Albian–lower Cenomanian of Italy and Spain (O'Dogherty, 1994).

2. The Kemishdag Formation (Cenomanian);

Lower part: Flyshoid intercalation of grey fine-grained sandstones, greenish-grey clays, light yellowish-grey cherty marls, light-grey micritic limestones and black combustible shales (30 m). Lower part of unit yields belemnites *Neohibolites ultimus* (Orb.) and planktonic foraminifers *Thalmanninella appenninica* (Renz) (Geologiya SSSR…, 1972; Melovaya fauna…, 1988) and radiolarian assemblage with Patellula spica–Trisyringium echitonicum. Almost all taxa from assemblage with *Dorypyle* (?) *anisa–Crolanium triangulare* are present here, but representatives of *Crolanium* were found only in the lowermost part of this unit. *Trisyringium echitonicum* (Aliev) was described from middle Albian of Kelevudag section (Aliev, 1967) and it is present in lower Albian to lower Cenomanian of Italy and Spain (O'Dogherty, 1994 and in middle-upper Cenomanian of Turkey (Bragina, 2004). The age of assemblage with *Patellula spica–Trisyringium echitonicum* can be determined as Cenomanian because of presence of *Patellula spica* (not lower then lower Cenomanian) and *Trisyringium echitonicum* (not upper then upper Cenomanian). Lower part of Kemishdag Formation can be correlated with *Dactyliosphaera silviae* Zone of Cenomanian of Italy and Spain (O'Dogherty, 1994).

Upper part: Dark-grey clays with beds of yellowish-grey sandy limestones and grey calcareous gravelites (25 m). This part was assigned to upper Cenomanian (Geologiya SSSR…, 1972; Melovaya fauna…, 1988) due to the presence of foraminifers *Valvulineria* *lenticula* (Reuss), *Gyroidinoides nitidus* (Reuss), *Galevinella cenomanica* Brotz., *Hedbergella globigerinellinoides* (Subb.), *H. caspia* Vass., *Thalmanninella appenninica* (Renz), *Th. reicheli* (Morn).

3. The Kemchi Formation: Intercalation of light-grey, white, black and greenish-grey clayey cherts, yellowish-grey and light-grey cherty marls, grey fine- to medium-grained sandstones, light-grey cherty mudstones (15 m). This unit was previously assigned to Turonian due to the presence of foraminifers *Globotruncana linneiana* (d'Orb.), *Stensioina praeexsculpta* (Kell.) (Geologiya SSS, 1972; Melovaya fauna.., 1988). Lower part of unit is characterized by radiolarian assemblage with *Orbiculiforma quadrata–Pseudodictyomitra pseudomacrocephala*. This assemblage yield *Phaseliforma turovi* Bragina, important species typical for middle to upper Turonian of Crimea and unknown from older deposits (Bragina, 2014). The presence of *Orbiculiforma quadrata* (first appearance in the boundary strata of Turonian and Coniacian) and *Pseudodictyomitra pseudomacrocephala* (last appearance in the uppermost Turonian) radiolarian-bearing deposits can be assigned to upper Turonian–?lower Coniacian.

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References

Aliev, K. S., 1965. Radiolyarii nizhnemelovykh otlozhenii severo-vostochnogo Azerbaidzhana i ikh stratigraficheskoe znachenie. Izdatel'stvo Akademii Nauk, Azerbaidzhanskoi SSR, Baku, 125 (in Russian).

Aliev, K. S., 1967. Novye vidy radiolyarii valanzhinskogo i albskogo yarusov severo-vostochnogo Azerbaidzhana. In: Melovye Otlozheniya Vostochnogo Kavkaza i Prilegayushchikh Oblastei (Aliev, M. M., Ed.), Nauka, Moscow, 23-30 (in Russian).

Aliev, K. S., 1968. Novye vidy podsemeistva Lithocampinae iz albskikh i senomanskikh otlozhenii severo-vostochnogo Azerbaidzhana. Izvestiya Akademiya Nauk Azerbaidzhanskoi SSR, Seriya Nauk o Zemle 2, 26-32 (in Russian).

Bragina, L.G., 2004. Cenomanian-Turonian radiolarians of northern Turkey and the Crimean Mountains. Paleontological Journal 38, 4, 325-456.

Bragina, L.G., 2014. New Radiolarian Species from the Upper Cretaceous sections of the Crimean Mountains (Ukraine). Paleontological Journal 48, 1, 7-16.

Bragina, L.G. & Bragin, N.Yu., 2015. New data on Albian–Coniacian Radiolaria of the Kelevudag Section (North-Eastern Azerbajdzan). Stratigraphy and Geological Correlation 23, 1, 1–12.

Geologiya SSSR (Geology of the USSR). 1972. Vol. XLVII. Azerbajcan SSR. Geological description. Moscow: Nedra, 1-520 (in Russian).

Melovaya fauna Azerbaidzana (Cretaceous fauna of Azerbaijan). 1988. Baku: Elm, 1-648.

O'Dogherty, L., 1994. Biochronology and paleontology of mid-Cretaceous radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). Mém. Géol. Lausanne 21, 1-413.

Key words**:** Radiolaria, Cretaceous, Albian, Cenomanian, Turonian, Coniacian, Azerbaijan? Greater Caucasus.

Radiolarian and carbon-isotope stratigraphy dating the onset of siliceous deposits in pelagic seamounts of the Subbetic

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The External Zone of the Betic Cordillera (southern Iberian Margin) represents one of the best-preserved cross-sections of a Jurassic passive margin in the Mediterranean area, where the original relationships between different paleogeographic domains are still preserved. The Subbetic domain was located farthest from the continent, where pelagic facies began since the Intra-Pangean rifting phase. During the Jurassic, the paleotopography of the Subbetic was divided into submarine swells (Internal and External Subbetics) and a median through (Median Subbetic) which experienced a local, but intense volcanic extrusions. In this context, siliceous deposits, especially radiolarites became widespread as a unique facies in the Median Subbetic from the Bathonian to the late Oxfordian. However, the local topographic highs were characterized during most of this time by a condensed sedimentation of lime-poor nodular sediments often rich in ammonites.

Subsidence and the fault-controlled relief in each swell led to considerable variations in the progressive extension of the siliceous radiolarite deposition from the deepest part of the median through to the swell area. The onset of siliceous deposits in the bordering swells of the basin began only in the early Oxfordian. This siliceous sedimentation on the highs can be considered as a short and condensed radiolaritic episode, with maximum thickness of around two meters.

Three sections have been investigated in detail: the Martina section, the Cuber section (External Subbetic) and the Sierra Harana section (Internal Subbetic). The seamount radiolarites are generally red siliceous limestones with chert nodules and stringers interbedded with thin marls and clays in the Internal Subbetic, whereas siliceous marls and thin-bedded reddish radiolarites characterize the siliceous sedimentation in the External Subbetic. A cross correlation between the pelagic swells have been performed by means of carbon-isotope stratigraphy, radiolarians, ammonites and nannofossils.

In the Sierra Harana section, the δ^{13}C-stratigraphy recorded in red nodular limestone shows a progressive trend towards high values since the uppermost lower Oxfordian with a relative maximum (~3.2 ‰) in the middle Oxfordian (near the Plicatilis/Transversarium boundary). The radiolarian assemblages found in the siliceous limestones overlying these nodular limestones are assigned to UAZ 9. The carbon-isotope stratigraphy across these discrete levels shows values ranging between 2.8 to 2.4 ‰ that are similar to those found in coeval ammonitico rosso facies of the External Subbetic at the Bifurcatus–Bimammatum Ammonite Zones (upper Oxfordian).

In the sections located in the External domain, the siliceous sedimentation took place earlier at the Upper Plicatilis–Antecedens Ammonites Zones. In the Cuber Section the radiolarian UAZ 8 is recognized co-occurring with ammonites belonging to the Upper Plicatilis Zone. Carbon isotope data range between 3 ‰ and 3.5 ‰ and then values progressively decrease to a relative minimum of 2.4 ‰ in the Transversarium Ammonite Zone.

New biostratigraphic data from these sections allow us to discuss the range of some species belonging to UAZones 8 to 10 and to redefine the order of first occurrences of important stratigraphic taxa.

***Key words*: Upper Jurassic, Spain, integrated stratigraphy.**

Radiolarian biostratigraphy of the Suhaylah Formation (Upper Cretaceous) in the Oman ophiolite

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The Oman ophiolite crops out in the Oman Mountains and its outcrops are over 600 km long and up to 150 km wide. The ophiolite suite consists of mantle peridotites, gabbros, a sheeted dyke complex, and extrusive lavas overlain by pelagic sediments. The extrusive lavas have been subdivided into three volcanic units: the V1 lava with the N-MORB signature (Geotimes Unit), the V2 lava formed by intra-oceanic volcanism (the Alley unit), and the V3 lava (the Salahi unit) generated by intra-plate seamount magmatism (Ernewein et al., 1998). Pelagic sediments with metalliferous elements, called the Suhaylah Formation, commonly occur at the boundaries between these volcanic units. These sediments have been studied by Fleet & Robertson (1980) in terms of depositional environments. Tippit et al. (1981) conducted radiolarian biostratigraphic study for the sediments intercalated in the V2 lava, as well as sediments within and above the V1 lava. They concluded that radiolarian faunas range in age from early Cenomanian to Santonian; however detailed stratigraphic distributions of radiolarians were not shown in their study. In order to understand the history of pelagic sedimentation and volcanic activity, we have reinvestigated the lithology and radiolarian biostratigraphy of pelagic sediments of the Suhaylah Formation.

The radiolarian study has been conducted in the “Suhaylah” section, which is situated about 40 km west of Sohar. This section consists of the V1 lava and overlying metalliferous and pelagic sediments of which the maximum thickness reaches 18 m. The sediments are subdivided into three lithologies: metalliferous sediments interbedded with thin chert layers (3 to 8 meters thick), red mudstone with chert intercalations (3 to 6 meters thick), and micritic limestone (over 6 meters thick). The metalliferous sediments are dark purple to dark red in color, weakly stratified, and very fine grained with metallic luster. Thin laminations within the bed are frequently observable. The red mudstone is very fine grained. Several chert layers are intercalated with the upper part of the mudstone sequence. The micritic limestone is red in color in the lower part and greenish gray in the upper part. It contains numerous radiolarian tests.

Based on the species composition, we recognized two assemblages (Assemblage A and Assemblage B) from the study section. The Assemblage A, recovered from the lower part of the section (chert within metalliferous sediments and red mudstone), contains *Thanarla pulchra* (Squinabol), *Guttacapsa biacuta* (Squinabol), *Guttacapsa gutta* (Squinabol), *Rhopalosyringium mosquense* (Smirnova & Aliev), *Hemicryptocapsa tuberosa* (Dumitrica) and *Holocryptocanium tuberculatum* Dumitrica. The last occurrences of *T. pulchra* and *G. biacuta* are recognized in red mudstone and chert. According to O’Dogherty (1994), the last occurrences of these species are near the top of Cenomanian. Thus, Assemblage A is assignable to late Cenomanian. Assemblage B was obtained from red mudstone, chert, and micritic limestone. This assemblage is characterized by the abundant occurrence of *Rhopalosyringium scissum* O’Dogherty, *Dictyomitra formosa* Squinabol, *Dictyomitra multicostata* Zittel, *Hemicryptocapsa polyhedra* Dumitrica, *Pseudotheocampe urna* (Foreman) and *Pseudoaulophacus putahensis* Pessagno. The first occurrences of *R. scissum* and *H. polyhedra* are recognized near the base of Turonian (O’Dogherty, 1994). This indicates that Assemblage B is assignable to Turonian. Based on the occurrences of these radiolarians, the boundary between Cenomanian and Turonian is thought to be present in the red mudstone above the V1 lava. Time scale given by this result has potential usefulness to give age constraint for the eruption age of the V1 lava.

References

Ernewin, M., Pflumio, C. & Whitechurch, H., 1988. The death of an accretion zone as evidenced by the magmatic history of the Sumail ophiolite (Oman). Tectonophysics 151, 247–274.

Fleet, A.J. & Robertson, A.H.F., 1980. Ocean-ridge metalliferous and pelagic sediments of the Semail Nappe, Oman. Journal of the Geological Society, London 137, 403–422.

O'Dogherty, L., 1994. Biochronology and paleontology of mid-Cretaceous radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). Mémories de Géologie (Lausanne) 21, 1–415.

Tippit, P.R., Pessagno, E.A. Jr. & Smewing, J.D., 1981. The biostratigraphy of sediments in the volcanic unit of the Semail ophiolite. Journal of Geophysical Research 86, 2756–2762.

***Key words*: Late Cretaceous radiolarians, the Oman ophiolite, Cenomanian, Turonian.

Mesozoic radiolarian biostratigraphy in pelagic sediments in the Kermanshah area, west Iran

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The ophiolite belts in Iran are important regions to elucidate paleoenvironmental reconstruction of the entire Neo-Tethys. Pelagic sequences associated with ophiolitic rocks are well exposed in the Kermanshah area, west Iran. In our field survey in 2011, we worked at several localities of the pelagic sequences. Radiolarian analysis revealed that the pelagic sequences are categorized into two groups: Upper Triassic sequence represented by the Gohareh section and Middle Jurassic-Lower Cretaceous sequence represented by the Bisetun section.

The Gohareh section is composed mainly of red bedded cherts with alternating beds of chert and limestone. Some micritic limestone beds contain nodular cherts. Several samples of red chert yield moderately preserved Late Triassic radiolarians including *Tritortis* (?) sp. and *Capnucosphaera* sp. The Bisetun section consists of red and green chert. Limestone-dominated intervals are also recognized in the section. Middle Jurassic to Early Cretaceous radiolarians were obtained from red and green chert samples. Identified radiolarian zones include the *Striatojaponocapsa conexa* Zone (JR5) (middle Bathonian-late Callovian), *Kilinora spiralis* Zone (JR6) (Oxfordian), *Hsuum maxwelli* Zone (JR7) (Kimmeridgian), and *Pseudodictyomitra carpatica* Zone (KR1) (Tithonian-early Valanginian) of Matsuoka (1995).

Gharib & De Wever (2010) reported Mesozoic radiolarians ranging in age from early Pliensbachian to Turonian in the Kermanshah area for the first time. Our research adds the occurrences of Late Triassic radiolarians from pelagic sequences together with Middle Jurassic-Early Cretaceous radiolarians. The pelagic sequences in the study area were accumulated at different depositional sites of the Neo-Tethys. Our research clarified that the depositional history of the ophiolitic belts in west Iran, part of the Neo-Tethys, can be traceable to the Late Triassic.

References

Gharib, F. & De Wever, P., 2010. Radiolaires mesozoiques de la formation de Kermanshah (Iran). Comptes Rendus Palevol 9, 209-219.

Matsuoka, A., 1995. Jurassic and Lower Cretaceous radiolarian zonation in Japan and in the western Pacific. Island Arc 4, 140-153.

***Key words*:** Mesozoic, biostratigraphy, Kermanshah, west Iran.

Callovian–Oxfordian Carbon isotope stratigraphy of Site 534A DSDP, Leg 76: facies evolution and revision of radiolarian occurrences

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We present new data on Middle–Upper Jurassic siliceous deposits from the central proto-Atlantic Ocean (DSDP Site 534A, Blake Bahama Basin) and a correlation with the basins located in the western Tethys seaway (the Subbetic). These areas are important because they unravel the early history of the Atlantic opening and its deep-water sedimentation. These deep-sea regions record thick radiolarian-rich deposits with organic-rich claystones and calcareous claystones. This is a characteristic feature distinguishing these sediments from coeval Alpine-Mediterranean radiolarites.

In this study we present a chemostratigraphic correlation between a reference Carbon isotope curve established for the Callovian–Oxfordian interval in low latitude areas and the carbon isotope curve of DSDP at Site 534A. The carbon isotope curve data together with a thorough revision of the radiolarians at Site 534A allows us to re-evaluate the age of the radiolarian bearing deposits at the Black Bahama Basin and to reconsider the onset of the oceanization.

The $\delta^{13}C$ curve in the lower part of the Site (core interval 126–123) exhibits a progressive increase from very low values (between 0,28 and -0,11 ‰) to reach values around 2,1–2,4 ‰ at top of core 123. This trend, starting from very low $\delta^{13}C$, is in agreement with values recorded in well-dated lower–middle Callovian sequences in the Subbetic Basin (Spain), the Subalpine Basin (France) and the Polish Jura Chain (Poland). This increase from very low values up to 2.5 ‰ in $\delta^{13}C$ is recognized between the Gracilis to Coronatum Zones in the Subbetic Basin and in the Subalpine Basin. Just below the relative minimum of the Lower Callovian the FAD of *Stephanolithion bigotii* is recognized in sample 126-4, 70 and defines the base of the NJ12b nannofossil zone (upper Lower Callovian) at Site 534A. The lower part of the NJ13 nannofossil zone at Site 534A is recognized by the LAD of *Stephanolithiom hexum* (sample 123-3, 131) and *Ansulosphaera helvetica* (sample 123-4, 82). This bioevent is found in other Tethyan areas at the lowermost upper Callovian.

A rapid excursion to low values is recorded at the core interval 122–119. This isotopic event has been recognized at the Atleta–Lamberti Ammonite Zones in Spain and France. Following this episode, the middle part of the Site (core interval 118–106) displays relatively constant $\delta^{13}C$ values (3,5–4 ‰) similar to those found in the lower Oxfordian in the Subbetic Basin.

The middle Oxfordian to lower Kimmeridgian is recorded at the upper part of the Site (core 113–106) displaying $\delta^{13}C$ values between 2,5–3 ‰; a similar trend has been detected through the Transversarium–Platynota Zones in the Subbetic Basin. The FAD of *Vagalapilla* *stradneri* in sample 113-1, 47 marks the base of the middle Oxfordian (Plicatilis Ammonite Zone).

The revisions of some important taxa allow us to reassign the age of some critical samples of the Site. As most important, we have detected two erroneous identifications that modify the boundaries for the Jurassic UA Zones (Baumgartner et al., 1995) at this Site. UAZ 6 was identified in sample 127-1-13-15 by the presence of *Ares cylindricus flexuosus,* the single occurrence of this species suggested the middle Bathonian as the oldest radiolarian age recognized at this site. This species was unfortunately mistaken for *Hilarisirex quadrangularis* and hence the correct zonal assignment for this sample would be UAZ 7. The late Kimmeridgian–early Tithonian age (UAZ 11) assigned for sample 106-1-029 was based on the presence of *Parvicingula* sp. aff. *P. elegans*. The revision of all photographed species for this sample reveals that this species was wrongly introduced in the database for the calculation of the UAZones. Actually, the taxon recognized in the revised collection of negatives must be regarded as *Parvicingula mashitaensis.*

The radiolarian revision is based on a complete set of illustrations of all species recordered through the Site 534A, including 20 species that were previously not used in the zonation of Baumgartner et al. (1995). This revised dataset can improve our knowledge on Bathonian–Callovian radiolarian stratigraphy.

Reference

Baumgartner, P.O., Bartolini, A., Carter, E.S., Conti, M., Cortese, G., Danelian, T., De Wever, P., Dumitrica, P., Dumitrica–Jud, R., Goričan, Š., Guex, J., Hull, D.M., Kito, N., Marcucci, M., Matsuoka, A., Murchey, B., O'Dogherty, L., Savary, J., Vishnevskaya,V., Widz, D. & Yao, A., 1995. Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. In: Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology (Baumgartner, P.O., O'Dogherty, L., Goričan, Š., Urquhart, E., Pillevuit, A. & De Wever, P., Eds). Mémoires de Géologie (Lausanne) 23, 1013–1048.

Key words**:** Jurassic, C-isotope, biostratigraphy.

Session 3
Radiolarians in Geodynamics

Conveners
Peter O. BAUMGARTNER & Marco CHIARI

Discovery of Late Cretaceous Radiolaria in the Loma Chumico Formation stratotype (Nicoya Peninsula, Costa Rica). New constraints on the tectonostratigraphic evolution of terranes in the Nicoya Peninsula

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Outcrops of the Nicoya Peninsula and Gulf area represent a collage of Mesozoic oceanic terranes that became assembled during the latest Cretaceous along the western edge of the Caribbean Plate, at the boundary between the Caribbean Large Igneous Province s.s. (CLIP s.s.) to the south and the Mesquito Composite Oceanic Terrane (MCOT) to the north. In previous studies the subdivision of terranes was 3-fold (Flores, 2006; Bandini et al., 2008): (1) the Nicoya Complex s.s., a highly deformed mélange of pre-Campanian plateau-like igneous rocks that extruded and intruded into Middle Jurassic to Santonian ribbon radiolarites; (2) the Matambú Terrane, a pre-Albian oceanic basement covered by Upper Cretaceous hemipelagic/turbiditic sediments and characterized by the occurrence of the "Albian" Loma Chumico Formation, (3) the Manzanillo Terrane, a pre-Turonian oceanic basement intruded by the Turonian Tortugal picritic suite. The Manzanillo Terrane is regarded as the westernmost outcrop of the CLIP s.s. and is covered by the Coniacian-late Campanian (Bandini et al., 2008) arc-derived Berrugate Formation cropping out in the southeastern and eastern Nicoya Peninsula and in the Nicoya Gulf area.

Our radiolarian biostratigraphic study focused on hemipelagic, tuffitic siliceous mudstones and cherts exposed in the southeastern and central Nicoya Peninsula. We found green, often organic-rich cherts, shales and tuffacous siliceous mudstones to volcanic sandstones in outcrops mapped as the "Albian" Loma Chumico Formation (Denyer et al., 2014). However, lithostratigraphy, microfacies and geochemistry indicate that these rocks are distal equivalents of the Berrugate Formation defined in the Nicoya Gulf area in somewhat more proximal facies including volcaniclastic turbidites and debris flows (Flores et al., 2003). The tuffitic lithologies contain well-preserved radiolarians with Turonian – Santonian assemblages very similar to those described by Bandini et al. (2008) (see figure). In S-Nicoya the Berrugate Formation grades during the late Campanian into the overlying Piedras Blancas Formation, a pelagic, weakly tuffaceous limestone.

More recently, we sampled the type area of the Loma Chumico Formation, where, allegedly, ammonite fragments of late Albian age were found (*Neokentroceras* sp., Azéma et al., 1979). To our surprise, we found very similar Turonian – Santonian radiolarian assemblages in this locality (see figure).

As a consequence, the Loma Chumico organic-rich shales are a facies that is coeval with the Berrugate Formation and should be considered as a facies variation, also found in S-Nicoya (e.g, Punta Pochote). The roughly coeval the Sabana Grande and the Nambí formations are lateral facies variations probably formed more distally with respect to the arc activity recorded in Berrugate.

We conclude that the former Matambú and Manzanillo Terranes could represent one paleogeographic fore-arc domain with a CLIP-like basement overlain since the Coniacian by siliceous arc-derived or siliceous/calcareous hemipelagic formations depending on the proximity and activity of an intermediate volcanic arc. By late Campanian times the arc became temporarily extinguished, which gave rise to a late Campanian-Maastrichtian pelagic limestone sequence (the Piedras Blancas Formation). The CLIP-like basement became accreted in latest Turonian-earliest Coniacian time, shortly after the Tortugal picritic intrusion

(89 Ma, Alvarado et al., 1997). The Nicoya Complex s.s. is clearly exotic with respect to the above domain, since it contains Middle Jurassic to Santonian ribbon bedded radiolarites of open oceanic origin, devoid of any arc influence. The youngest plateau-like intrusions are dated as 83 Ma (earliest Campanian, Sinton et al., 1997). We conclude that the Nicoya Complex s.s. became accreted in the late Campanian, when arc activity temporarily ceased in the area. Tectonic uplift and emersion is indeed documented by boulder conglomerates and the unconformably overlying shallow-water El Viejo Formation.

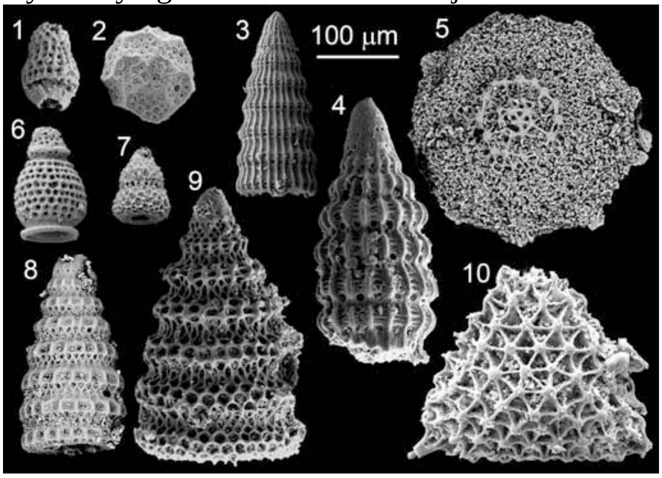

Figure 1. Turonian-Santonian radiolarians from the southern Nicoya Peninsula (Costa Rica) from outcrops of the Berrugate Formation (so far mapped as the Albian Loma Chumico Formation). 1. *Dictyoprora* sp. cf. *P. ascalia* (Foreman) (sample OTE18). 2. *Hemicryptocapsa polyedr*a Dumitrica (sample LCH0). 3. *Dictyomitra formosa* Squinabol sensu O'Dogherty (sample CRPC 03). 4. *Dictyomitra* sp. aff. *D. formosa* Squinabol (sample CRPC03). 5. *Patellula* sp. (sample 1PCH7). 6. *Dictyopora* sp. aff. *D. urna* (Foreman) (sample OTE18). 7. *Dictyopora* sp. aff *D. apicata* (Foreman) (sample OTE18). 8. *Pseudodictyomitra nakasekoi* Taketani (sample 1PCH7). 9. *Eostichomitra* sp. aff. *E. perapedhia* (Bragina) (sample CRPC03). 10. *Alievum gallowayi* Pessagno (sample CRPC03). These species have also been found at the type locality of the Loma Chumico Formation.

References

Alvarado, G., Denyer, P. & Sinton, C.W., 1997. The 89 Ma Tortugal komatiitic suite, Costa Rica: Implications for a common geological origin of the Caribbean and Eastern Pacific region from a mantle plume. Geology-25, 5, 439-442.

Azéma, J., Tournon, J. & Sornay, J., 1979. Presencia de amonites del Albiano Superior en las formaciones del Complejo de Nicoya. El yacimiento de Loma Chumico, provincia de Guanacaste, Costa Rica. Inf. Sem. I.G.N. 1978 2, 71-76.

Bandini, A. N., Flores, K., Baumgartner, P. O., Jackett, S.-J. & Denyer, P. 2008. Late Cretaceous and Paleogene Radiolaria from the Nicoya Peninsula, Costa Rica: a tectonostratigraphic application. Stratigraphy 5, 3-21.

Denyer, P., Aguilar, T. & Montero, W., 2014. Cartografia geologica de la Peninsula de Nicoya, Costa Rica: Mapas geologicos, 1 :50’000. Ed. Universidad de Costa Rica.

Flores, K., 2006. Jurassic – Late Cretaceous oceanic crustal terranes and arc-derived sediments south Chortis Block (NE Nicaragua to NW Costa Rica). Preliminary results of two key areas: Nicoya Peninsula and Siuna District. Unpublished DEA Thesis, Univ. of Lausanne, 107p.

Flores, K., Denyer, P. & Aguilar, T., 2003. Nueva propuesta estratigráfica: Geología de las hojas Matambú y Talolinga, Guanacaste, Costa Rica. Rev. Geol. de Am. Cent. 28, 131-138.

Sinton, C.W., Duncan, R.A. & Denyer, P., 1997. Nicoya Peninsula, Costa Rica: A single suite of Caribbean oceanic plateau magmas. Journ. of Geophy Res.-Solid Earth 102, 15507-15520.

***Key words**:* Radiolarians, Late Cretaceous, terranes, Nicoya Peninsula, Costa Rica.

New discovery of the Triassic radiolarians from Yarlung Zangbo Suture Zone in the Jinlu area, Zetang, southern Tibet

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Abundant, very diverse, and well-preserved radiolarian faunas have been extracted from eleven bedded chert samples collected near Jinlu Village, Zetang, Southern Tibet. These bedded silicic rocks belong to the Mélange blocks of the Yarlung Zangbo Suture Zone which contains a lot of fragmented remains of the lost Neotethyan Ocean. More than 19 genera were identified preliminary in the studied samples. They include *Baumgartneria yehae, Capnuchosphaera theloides, Celluronta donax, Dictyomitra pessagnoi, Muelleritortis cochleata, Tritortis kretaensis, Xiphothecaella karpenissionensis, Turospongus trispinosus* and so on. Compared with the radiolarian faunas of Japan and Europe, these radiolarian assemblages approximately indicate Middle to Late Triassic age (Neviani, 1900; De Wever et al., 1979; Nakaseko & Nishimura, 1979; Dumitrica, 1982; Kozur & Krahl, 1984; Kozur & Mostler, 1994, 1996a, 1996b; Sugiyama, 1997; O'Dogherty et al., 2010). Moreover, the discovery of *Celluronta donax, Celluronta jovi* and *Pseudotriassocampe hungarica* which occurred only in Anisian may offer new evidence for the age of the chert block. A more detailed study of these radiolarian assemblages will give an exact age control for the chert block and that is very significant for the origin of the Tethys Ocean in southern Tibet. This study is supported by the "Strategic Priority Research Program (B) of the Chinese Academy of Sciences, Grant No. XDB03010102.

References

De Wever, P., Sanfilippo, A., Riedel, W. R. & Gruber, B., 1979. Triassic Radiolaria from Greece, Sicily and Turkey. Micropaleontology 25, 1, 75-110.

Dumitrica, P., 1982. Triassic Oertlisponginae (Radiolaria) from eastern Carpathians and Southern Alps), Dari de Seama ale Sedintelor, Institutul de Geologie si Geofizica, Bucharest 67, 3, 57-74.

Kozur, H. & Krahl, J., 1984. Erster Nachweis triassischer Radiolaria in der Phyllit-Gruppe auf der Insel Kreta. Neues Jahrbuch für Geologie und Paläontologie-Monatshefte 7, 400-404.

Kozur, H. & Mostler, H., 1994. Anisian to middle Carnian Radiolarian zonation and description of some stratigraphically important radiolarians. Geologisch-Paläontologische Mitteilungen Innsbruck 3, 39-255.

Kozur, H. & Mostler, H., 1996a. Longobardian (late Ladinian) Muelleritortidae (Radiolaria) from the Republic of Bosnia-Hercegovina. Geologisch-Paläontologische Mitteilungen Inns. 4, 83-103.

Kozur, H. & Mostler, H., 1996b. Longobardian (late Ladinian), Oertlispongidae (Radiolaria) from the Republic of Bosnia-Hercegovina and the Stratigraphic value of advanced Oertlispongidae. Geologisch-Paläontologische Mitteilungen Innsbruck 4, 105-193.

Nakaseko, K. & Nishimura, A., 1979. Upper Triassic Radiolaria from southwest Japan. Scientific Report, College of General Education, Osaka University 28, 2, 61-109.

Neviani, A., 1900. Supplemento alla fauna a radiolari delle rocce Mesozoiche del Bolognese. Bulletino Societa Geologico Italiana 19, 645-671.

O'Dogherty, L., Carter, E.S., Gorican, Š. & Dumitrica, P., 2010. Triassic radiolarian biostratigraphy. Geological Society, London, Special Publications 334, 163-200.

Sugiyama, K., 1997. Triassic and Lower Jurassic Radiolarian biostratigraphy in the siliceous claystone and bedded chert units of the southeastern Mino Terrane, central Japan. Bulletin of the Mizunami Fossil Museum 24, 79-193.

***Key words*:** Triassic, southern Tibet.

Radiolarian biostratigraphy and geochemistry of the ophiolites in the northern Albania

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The Dinaric-Hellenic Chain, a portion of the Alpine collisional belt, extends from Slovenia to the southern Greece. This belt is derived from the collision between the Adria and the Eurasian Plates that resulted by the closure, due to an eastward subduction (present-day coordinates), of the Maliac-Vardar Ocean.The ophiolites cropping out in Albania (also known as the Mirdita Ophiolitic Nappe) represent remnants of the lithosphere of this ocean. They constitute nowadays a nappe system which overlies the units of the deformed Adria margin and includes, from the bottom upwards (Bortolotti et al., 2013), a Sub-ophiolite mélange (Rubik Complex), the Triassic ocean-floor ophiolites (Porava Unit) and two ophiolitic units (Western and Eastern Belts). The Mirdita Ophiolitic Nappe is overlain by the Simoni Mélange and the Firza Flysch. It is worth nothing that the Triassic ocean floor ophiolites unit is known with different names in the Dinaric-Hellenic belt e.g. Fourka Unit in Koziakas and Othris regions.

The Western Belt ophiolitic unit includes rocks generated in both mid-ocean ridge (MOR) setting and supra-subduction zone (SSZ) setting. In fact, medium-Ti basalts (MTB) generated in a nascent forearc setting are interlayered within typical MOR volcanic sequences. These sequence, are also crosscut by boninitic dykes and southward, in the Pindos Massif, they are topped by boninitic lavas. By contrast, the Eastern Belt ophiolitic unit includes typical SSZ crustal sequences such as island arc tholeiitic (IAT) and boninitic series. The Sub-ophiolite mélange incorporates a number of different volcanic rocks, which include: Triassic normal-MOR (N-MORB) and enriched MOR basalts, undated calc-alkaline basalts, Jurassic N-MORBs, MTBs and boninites.

By consequence, the ophiolitic unit of the Western Belt (Jurassic fore-arc ophiolite unit of Bortolotti et al., 2013) represents an oceanic lithosphere generated at a MOR and nascent forearc settings; whereas the Eastern Belt ophiolitic unit (Jurassic intra-oceanic-arc ophiolite of Bortolotti et al., 2013), represents an oceanic basin developed in an intra-oceaic arc setting above a subduction zone. The Eastern Belt overthrusts westwards the Western Belt. The Sub-ophiolite Mélange with the overlying Porava Unit was previously called “volcano-sedimentary formation” and, successively “Rubik Complex”.

This paper concerns the study of the radiolarian cherts associated to the basalts of six sections in the Mirdita area: Gurthi, Gurth 2, Gurth 4 that belong to the Eastern Belt while Gomsiqe, Karma and Koman pertain to the Sub-ophiolite mélange. The radiolarian cherts gave the following ages:

a) The *Gurthi section*, latest Bajocian-early Bathonian to middle Bathonian (UAZ 5-6) on the basis of the occurrence of *Eucyrtidiellum semifactum* Nagai & Mizutani and *Japonocapsa* sp. aff. *J. fusiformis* (Yao).

b) *The Gurth 2 section*, middle Bathonian to late Bathonian-early Callovian (UAZ 6-7) on the basis of the co-occurrence of *Eucyrtidiellum unumanese dentatum* Baumgartner with

Theocapsomella cucurbiformis (Baumgartner) and *Theocapsomella medvednicensis* (Goričan).

c) *The Gurth 4 section*, latest Bajocian-early Bathonian (UAZ 5) on the basis of the occurrence of *Eucyrtidiellum semifactum* Nagai & Mizutani and *Unuma latusicostatus* (Aita).

Gomsiqe section, late Bajocian to latest Bajocian-early Bathonian (UAZ 4-5) on the basis of the co-occurrence of *Archaeodictyomitra* (?) *amabilis* (Aita), *Unuma gordus* Hull and *Unuma latusicostatus* (Aita).

d) *The Karma section*, middle Bathonian (UAZ 6) on the basis of the presence of *Striatojaponocapsa synconexa* O'Dogherty, Goričan & Dumitrica and *Kilinora* (?) *oblongula* (Kocher).

e) The Koman section, late Bajocian to middle Bathonian (UAZ 4-6) on the basis of the occurrence of *Unuma gordus* Hull and *Striatojaponocapsa synconexa* O'Dogherty, Goričan & Dumitrica.

Our data show that the Jurassic ages of the radiolarian cherts from the Eastern Belt are comparable with those of the cherts from the Sub-ophiolitic mélange. Given that the Jurassic components of the Sub-ophiolitic mélange (namely, N-MORB, MTB and boninite; Saccani et al., 2011) were entirely derived from the Western Belt unit, it is possible to postulate that there was the coexistence of MOR and SSZ magmatisms in the Maliac-Vardar Ocean during the Middle Jurassic.

References

Bortolotti, V., Chiari, M., Marroni, M., Pandolfi, L., Principi, G. & Saccani, E., 2013. Geodynamic evolution of the ophiolites from Albania and Greece, (Dinaric-Hellenic Belt): one, two or more oceanic basins? International Journal of Earth Sciences (Geol. Rundsch.) 102, 783-811.

Chiari, M., Baumgartner, P.O., Bernoulli, D., Bortolotti, V., Marcucci, M., Photiades, A. & Principi, G., 2013. Late Triassic, Early and Middle Jurassic Radiolaria from ferromanganese-chert 'nodules' (Angelokastron, Argolis, Greece): evidence for prolonged radiolarite sedimentation in the Maliac-Vardar Ocean. Facies 59, 391-424.

Saccani, E., Beccaluva, L., Photiades, A. & Zeda, O., 2011. Petrogenesis and tectono-magmatic significance of basalts and mantle peridotites from the Albanian–Greek ophiolites and sub-ophiolitic mélanges. New constraints for the Triassic–Jurassic evolution of the Neo-Tethys in the Dinaride sector. Lithos 124, 227-242.

***Key words*:** The Dinaric-Hellenic Chain, Albania, ophiolites, radiolarians, Middle Jurassic.

Jurassic – Early Cretaceous radiolarian stratigraphy of the Danubian nappes (eastern Serbia)

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The Danubian nappes of eastern Serbia belong to a much larger Dacia Mega-Unit. The Dacia Mega-Unit actually comprises different allochthonous smaller units in East and South Carpathians. These units are considered to be parts of the European continent that were detached from it during Jurassic rifting in the domain of the Alpine Tethys (Schmid et al., 2008). Some of these units were separated from Europe by oceanic lithosphere of the Ceahlau-Severin oceanic domain, while other units, including the Danubian nappes were just later scraped off the European margin due to strong coupling of the orogenic wedge and the foreland (Ziegler et al., 1995). According to Schmid et al. (2008), the Danubian nappes were detached from the Moesian foreland. Together with more internal units located underneath the Transilvanian Basin and outcropping in the North Apuseni Mountains (Tisza Mega-Unit; Haas & Pero, 2004), they invaded the Carpathian embayment in Cenozoic times (i.e. Royden, 1988; Csontos & Vörös, 2004; Horváth et al., 2006) and finally docked with the European foreland during the Miocene.

In eastern Serbia, the Mesozoic successions of the Danubian nappes are exposed along the valley of the Danube River. Our knowledge on Mesozoic microfauna from the Danubian nappes is still insufficient. Particularly scarce are published data on Jurassic – Early Cretaceous microfauna on which this study concentrates. Data on radiolarian assemblages are available for locality Svinița in Romania (Dumitrica, 1995), which is located in the vicinity of our sections in Serbia.

The information on Jurassic – Early Cretaceous Radiolaria from eastern Serbia presented here comes from a few sections which crop out along the road Dobra – Boljetinsko brdo. In the studied area, Jurassic sedimentation began with clastic deposits that transgressively overlie Permian rocks. Two considerably different successions were studied above the Lower Jurassic quartz sandstone and conglomerate. The first succession, exposed between tunnels no 17 and 21 (22°00.1'E, 44°36.1'N), is over 150m thick and typical of a deep-water basin. The following units occur in stratigraphic order: red shale with intercalations of thin beds of nodular limestone; white marly limestone that transits upwards into well-bedded limestone with subordinate marly interlayers; thin-bedded green and upsection red calcareous radiolarite; indistinctly bedded grey marly limestone; well-bedded reddish limestone with chert nodules and interlayers of dark red shale. Several breccia and calcarenite beds are interstratified in the last unit.

The second succession (exposed at tunnel no 10; 22°01.0'E, 44°34.1'N) indicates deposition on a pelagic plateau. This section is much more condensed, not exceeding 20m in total thickness. The predominant facies is red nodular limestone of Rosso Ammonitico type. Rare chert nodules and layers exist only in the middle part of the section. Slumped beds and intraformational conglomerates occur in the upper half. Both sections continue with a thick succession of light grey micrite with chert nodules that closely resembles the Maiolica limestone of the Southern Alps. Up to several meters thick slumped levels are common in this Lower Cretaceous limestone.

In addition to these two sections, several short sections in the upper part of the Maiolica limestone and in the overlying Barremian marls and marly limestones were sampled for radiolarians and stable carbon isotope analyses. The interest of precise stratigraphic studies is based on the fact that, according to the recent geotectonic interpretations (e.g., Schmid et al., 2008), the study area actually represents the easternmost part of the Alpine Tethys. Radiolarian dating has been undertaken primarily to elucidate the rifting history in this domain. Post-rift sedimentary successions of a deep basin and a pelagic plateau have been distinguished. These successions indicate a typical horst-and-graben topography, well known from other domains of the Alpine Tethys. The topographic difference was apparently diminished by the Early Cretaceous, when Maiolica type limestone became ubiquitous as is now confirmed also with radiolarians.

References

Csontos, L. & Vörös, A., 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. Paleogeography, Paleoclimatology, Paleoecology 210, 1–56.

Dumitrica, P., 1995. Upper Jurassic and Lower Cretaceous Radiolarians at Svinița (Romania). In: Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology (Baumgartner, P. O., O'Dogherty, L., Goričan, Š., Urquhart, E., Pillevuit, A. & De Wever, P., Eds.), Mém. Géol. Lausanne 23, 897-905.

Haas, J. & Pero, S., 2004. Mesozoic evolution of the Tisza Mega-unit. International Journal of Earth Sciences 93, 297–313.

Horvath, F., Bada, G., Szafian, P., Tari, G., Adam, A. & Cloetingh, S., 2006. Modes of basin (de) formation, lithospheric strength and vertical motions in the Pannonian-Carpathian system: inferences from thermomechanical modeling. In: European Lithosphere Dynamics (Gee, D.G. & Stephenson, R.A., Eds.), Geological Society of London Memoirs 32, 191–206.

Royden, L.H., 1988. Late Cenozoic Tectonics of the Pannonian Basin System. In: The Pannonian Basin, a Study in Basin Evolution (Royden, L.H. & Horvath, F., Eds.), American Association of Petroleum Geologists Memoir 45, 27–48.

Schmid, M.S., Bernoulli, D., Fügenschuh, B., Matenco, L., Schefer, S., Schuster, R., Tischler, M. & Ustaszewski, K., 2008. The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. Swiss Journal of Geosciences 101, 1, 139-183.

Ziegler, P.A., Cloetingh, S. & van Wees, J.D., 1995. Dynamics of intra-plate compressional deformation: the Alpine Foreland and other examples. Tectonophysics 252, 7–59.

***Key words*:** Radiolaria, Jurassic, Early Cretaceous, the Danubian Nappes, eastern Serbia.

Opening, evolution and closure of the Neotethyan Oceanic Branches in Anatolia as inferred by radiolarian research

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Eastern Mediterranean area is characterized all along its geological past by the amalgamation of number of terranes of continental as well as oceanic origin. Their identification is mainly based upon the presence of suture belts represented by belts with ophiolites or ophiolitic mélanges. Despite disagreements on the numbers and locations of these belts, those with Triassic to Late Cretaceous oceanic assemblages are ascribed to the multi-branched Neotethys. In the last twenty years we performed detailed studies on the radiolarian-based ages and geochemistry of the oceanic volcanic rocks along the three main suture belts representing the Intra-Pontide, Izmir-Ankara-Erzincan and southern oceanic branches of Neotethys (Fig. 1). The results of this multi-disciplinary approach mainly comprise the data obtained from volcanic rocks and radiolarian-bearing sediments in depositional relation with them.

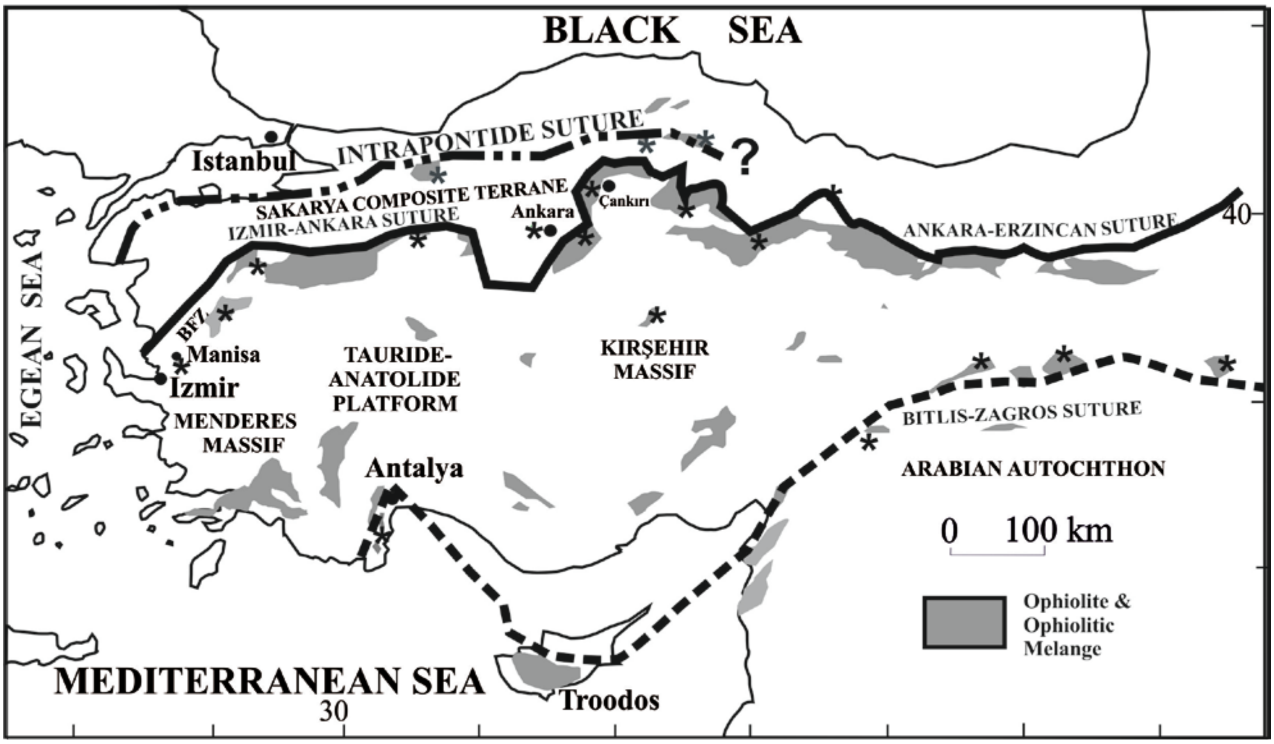

Figure 1 Distribution of the Neotethyan ophiolites, ophiolitic mélanges and suture belts in Anatolia. (*) stands for outcrops with dated radiolarians.

A-The Intra-Pontide Oceanic Branch (IPO): The suture of the IPO stretches from the Aegean coast to northern Central Anatolia, where it probably joins the suture of the IPO. Radiolarians obtained from mélange blocks correspond to very probably only a limited life-span of this oceanic branch (Fig. 2). Even though not yet clearly dated, HP/LT as well as LP/LT metabasic rocks of supra-subduction-type dominate over other tectono-magmatic settings. The IPO may stand for the eastern extension of the Vardar Ocean, where successive intra-oceanic subduction-accretion events were realized during the Mesozoic.

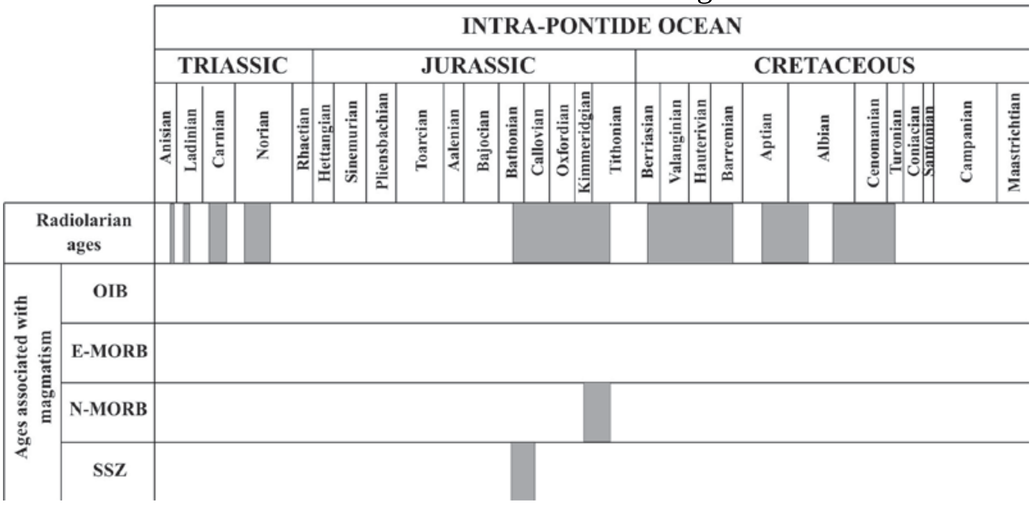

Figure 2 Radiolarian ages obtained from mélange blocks and from basalts with well-defined tectono-magmatic settings within the Intra-Pontide suture belt.

B-The Izmir-Ankara-Erzincan Oceanic (IAEO) Branch: Geographically it consists of the Izmir-Ankara and Ankara- Erzincan branches and separates the Sakarya Composite Terrane and the Tauride-Anatolide Block (Fig. 1). IAEO has the most complete record of radiolarian-rich oceanic deposition between the Middle Triassic and mid Late Cretaceous. Geochemical data from various types of basalts indicate that already during the early Late Cretaceous (or even during the Middle Jurassic, as deduced from radiometric age data from metamorphic soles) it started to close by intra-oceanic subduction. MORB basalts of Early Cretaceous age, on the other hand is indicative for ongoing spreading in another segment of the IAEO.

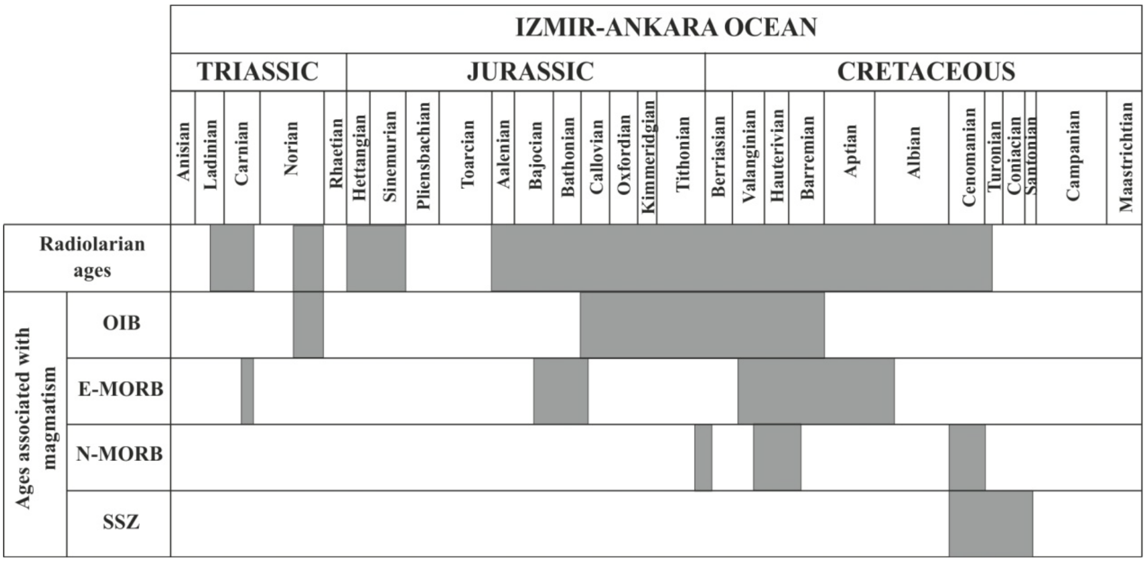

Figure 3 Radiolarian ages obtained from mélange blocks and from basalts with well-defined tectono-magmatic settings within the Izmir-Ankara-Erzincan suture belt.

C-The Southern Branch of Neotethys: The remnants of this main Neotethyan oceanic branch are distributed from Oman in the east to N Zagros-SE Anatolia-Troodos-Antalya and the Hellenic trench in the west (Fig.1). Yet, there is no consensus whether the ophiolitic bodies and the remnants of the subduction accretion prism represent a single or a multi-branched oceanic system. The radiolarian data from the SE Anatolian ophiolitic assemblages indicates a long-lasting oceanic deposition whereas the limited geochemical data suggests Late Triassic oceanic crust generation and Late Cretaceous subduction. The radiolarian data from the Antalya area stands for a more continuous oceanic deposition from Middle Triassic to Late Cretaceous with very limited geochemical data corresponding to the presence of an oceanic crust during the Carnian.

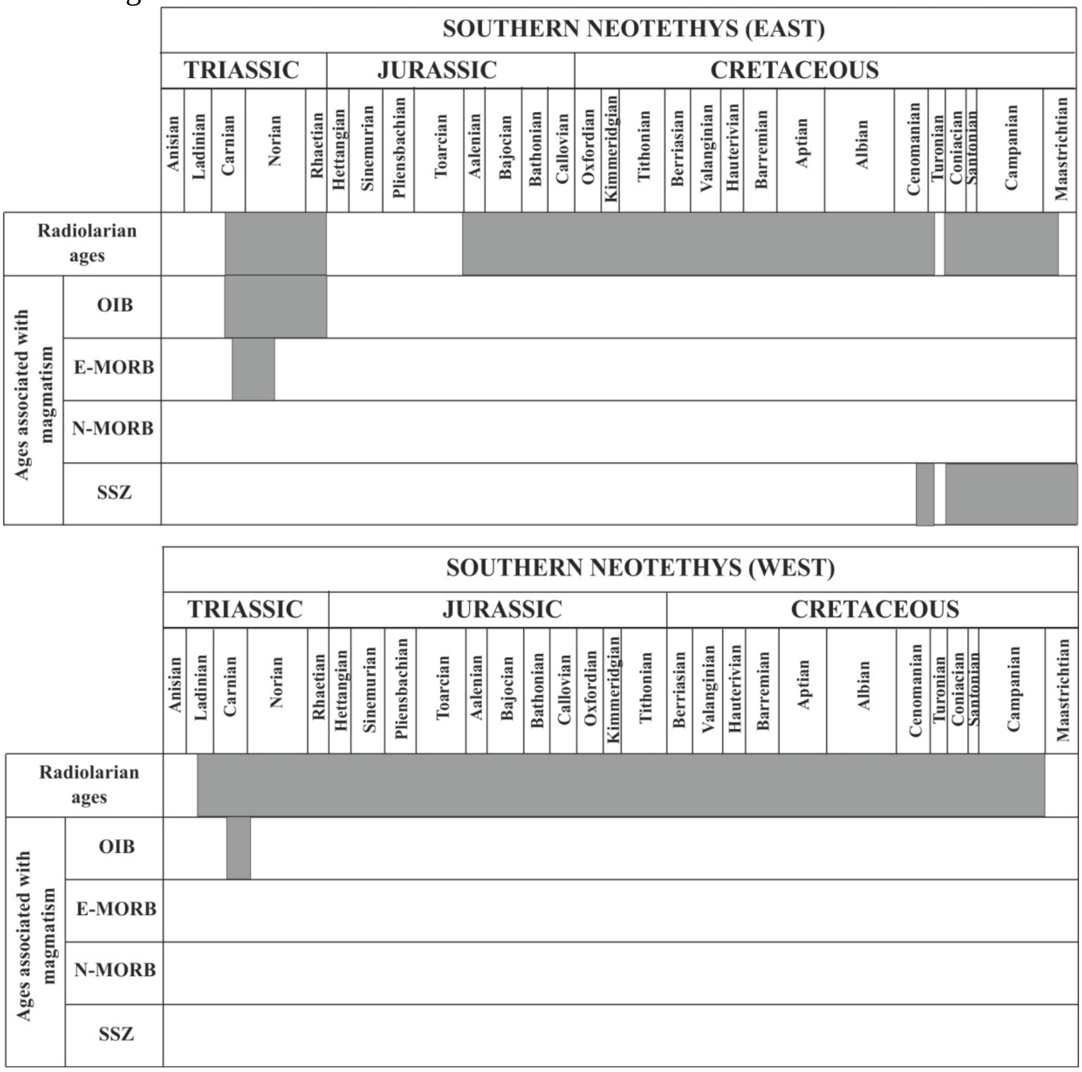

Figure 4 Radiolarian ages obtained from mélange blocks and from basalts with well-defined tectono-magmatic settings within the Southern branch/branches of Neotethys.

No combined data from basalt-radiolarian chert associations were reported yet from the allochthonous oceanic rocks that are assumed to represent some possible sutures (e.g. Inner Tauride Ocean).

Radiolarian assemblages from the continental shelf sediments of the Middle Jurassic Kaizara Formation and the Late Jurassic Ikenoue Formation in Japan

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Radiolarian assemblages from the continental shelf sediments during Jurassic and Cretaceous in Japan have been examined; the Middle Jurassic Kaizara Formation of the Tetori Group in Hokuriku Region and Late Jurassic Ikenoue Formation in the western Kii Peninsula. These strata are mainly composed of thick muddy deposits with some intercalations of fine- to coarse-grained sandstone beds. Also radiolarian-bearing calcareous nodules are concentrated at a few horizons within the mudstone facies.

Radiolarians were first observed under a scanning electron microscope for assigning radiolarian ages. The Kaizara Formation has been dated to the UAZone 7 (late Bathonian to early Callovian) for the co-occurrence of *Amphipyndax tsunoensis*, *Pantanellium riedeli* and *Podobursa helvetica*. This radiolarian age is concordant with the ammonoid age already reported by Sato and Westermann (1991) and Handa et al. (2014). The Ikenoue Formation is assigned to the UAZ. 9-10 (middle Oxfordian to early Kimmeridgian) by co-occurrence of *Emiluvia ordinaria*, *Paronaella mulleri* and *Podobursa spinellifera*. This radiolarian age is not inconsistent with that reported by Kashiwagi & Yao (1993, 1999).

Radiolarians were subsequently observed under an optical microscope for counting radiolarian specimens. Totally 1427 specimens from the Kaizara Formation and 1193 specimens from the Ikenoue Formation were examined. Spumellarians were divided into 8 morphological groups: 1) discoid form including *Orbiculiforma*, *Teichertus*, etc., 2) elliptical form including *Phaseliforma*, etc., 3) spherical test with 2 polar spines including *Archaeospongoprunum* and *Pantanellium*, 4) spherical test with 3 spines including *Triactoma*, *Tripocyclia*, etc., 5) three arms in same plane including *Paronaella*, *Tritrabs*, etc., 6) four arms in same plane including *Crucella*, *Emiluvia*, *Higumastra*, etc., 7) quadrangular test with four spines at each corner in same plane including *Emiluvia*, etc. and 8) spherical test including *Cenosphaera*, *Leugeo*, *Praeconocaryomma*, *Praeconosphaera*, etc.; nassellarians are also subdivided into 3 forms.

The Kaizara and Ikenoue formations show spumellarian-dominated radiolarian assemblages, respectively; the former consists of 1324 spumellarians and 103 nassellarians in number; the latter includes 880 spumellarians and 313 nassellarians in number. Among spumellarians except for the spherical test, the discoid form is the most dominant (334 specimens out of 1324 specimens in the Kaizara Formation and 78 specimens out of 880 specimens in the Ikenoue Formation). Also the spherical test with 2 polar spines is only 23 specimens in the Kaizara Formation, while they are absent in the Ikenoue Formation.

After Casey (1993), spumellarian radiolarians dominate in shelf waters. The mudstone facies of the Kaizara and Ikenoue formations indicate the shelf environments. Therefore the spumellarian-dominated radiolarian assemblages of the Kaizara and Ikenoue formations are a typical shelf assemblage. Common orbiculiformids including *Orbiculiforma* is one of the characteristics for the Northern Boreal Province sensu Kiessling 1999 in the Tithonian time. Sano et al. (2010) reported the Boreal belemnite from the Kaizara Formation, and concluded that a cooler current possibly from the Arctic reached to the mid-latitudes of the Northwest

Pacific in the earliest Callovian time. Common orbiculiformids as the characteristics for the Northern Boreal Province could be tentatively assigned to the Middle Jurassic time for the abundant occurrence of the discoid form including *Orbiculiforma*, *Teichertus*, etc. in the Middle Jurassic Kaizara Formation. After Pessagno－Blome's radiolarian paleogeographic model for the Jurassic, high pantanelliid (including *Pantanellium*) abundance shows the Tethyan Realm (e.g., Pessagno et al., 2009). The spherical tests with 2 polar spines including *Archaeospongoprunum* and *Pantanellium* are very rare from the Kaizara Formation, and absent from the Ikenoue Formation. Therefore both strata almost lack Tethyan radiolarian elements. We conclude that the radiolarian assemblages from the Middle Jurassic Kaizara Formation and the Late Jurassic Ikenoue Formation show typical shelf assemblage, and are characterized by abundant Boreal elements and very rare Tethyan elements.

References

Casey, R.E., 1993. Radiolaria. In: Fossil Prokaryotes and Protists (Lipps, J.H., Ed.), Blackwell Scientific Publications, 249-284.

Handa, N., Nakada, K., Anso, J. & Matsuoka, A., 2014. Bathonian/Callovian (Middle Jurassic) ammonite biostratigraphy of the Kaizara Formation of the Tetori Group in central Japan. Newsletters on Stratigraphy 473, 283-297.

Kashiwagi, K. & Yao, A., 1993. Jurassic to Early Cretaceous radiolarians from the Yuasa area in western Kii Peninsula, Southwest Japan and its significance. News of Osaka Micropaleontologists, Special Volume 9, 177-189 (in Japanese with English abstract).

Kashiwagi, K. & Yao, A., 1999. Upper Jurassic to Lower Cretaceous Ikenoue Formation around the Kurosegawa Terrane in the western Kii Peninsula, southwest Japan. The Journal of the Geological Society of Japan 105, 8, 523-534 (in Japanese with English abstract).

Kiessling, W., 1999. Late Jurassic radiolarians from the Antarctic Peninsula. Micropaleontology 45, supplement 1, 1-96.

Pessagno, E.A.Jr., Cantu-Chapa, A., Mattinson, J.M., Meng, X. & Kariminia, S.M., 2009. The Jurassic-Cretaceous boundsary: new data from North America and the Caribbean. Stratigraphy 6, 3, 185-262.

Sano, S., Goto, M., Dzyuba, O.S. & Iba, Y., 2010. A late Middle Jurassic Boreal belemnite *Cylindroteuthis* from central Japan and its paleobiogeographic implications. Memoir of the Fukui Prefectural Dinosaur Museum 9, 1-7.

Sato, T. & Westermann, G.E.G., 1991. Japan and South-East Asia. In: Jurassic taxa ranges and correlation charts for the Circum Pacific (Westermann, G.E.G. & Riccardi, A.C., Eds.), Newsletters on Stratigraphy 24, 81–108.

***Key words*: Radiolaria, Spumellaria, discoid form, *Orbiculiforma*.

Jurassic–Early Cretaceous pelagic succession of the eastern Southern Alps (NW Slovenia) and its correlation with the central Dinarides (Bosnia and Herzegovina, Montenegro)

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The eastern Southern Alps, including the Julian Alps in NW Slovenia, are a structurally complex area where the South Alpine and the Dinaric structures overlap. The Julian Alps preserve remnants of several paleotopographic units (basins and swells), of which the Bled Basin (Cousin, 1981) had the most distal position on the Adriatic continental margin facing the Neotethys. This paleogeographic location is assumed because the flysch-type sedimentation in the Bled Basin started in the Early Cretaceous, significantly earlier than the Campanian to Maastrichtian start in more proximal basins of the Julian Alps. Continental-margin successions of comparable stratigraphy/paleogeography occur in the Central Dinarides. These successions are structurally sandwiched between the External Dinarides and the Western Vardar ophiolites that were obducted onto the Adriatic margin during the Late Jurassic.

The latest Triassic to Early Cretaceous stratigraphic evolution of the Bled Basin was restored from several partial sections in vicinity of Bohinj in the Julian Alps. Three additional sections were studied in the central Dinarides: Kalinovik in Bosnia and Herzegovina, and Kaludarska Rijeka and Čehotina in Montenegro. These sections were previously investigated by Cadet (1978) and Rampnoux (1974), respectively. Our stratigraphic research is primarily based on radiolarian dating.

During the Late Triassic and early Early Jurassic the Bled Basin was characterized by deposition of relatively thick-bedded limestones with chert of the Zatrnik formation. In the uppermost part of the formation calcarenites with abundant resedimented echinoderm fragments prevail. Pelagic limestones with chert were deposited during this period in the Central Dinarides as well and are well exposed in all three sections studied. At Kaludarska Rijeka section these limestones contain resedimented ooids in addition to echinoderms.

In the Pliensbachian the coarse-grained Ribnica Breccia was deposited above the Zatrnik formation in the Bled Basin as a result of tectonic activity that affected the continental margin in this period. A similar breccia is also found above pelagic limestone at Čehotina in Montenegro.

A subsidence pulse in the Bajocian was responsible for a stratigraphic gap in the Bled Basin. This gap is documented with uppermost Bajocian-lower Bathonian (UAZ 5 of Baumgartner et al., 1995) radiolarian cherts, which directly overlie the Ribnica Breccia. At Kaludarska Rijeka the oldest radiolarian sample yielded late Aalenian age (UAZ 2) within a shale/chert interval. Higher in the Kaludarska Rijeka section, radiolarian cherts were also dated as latest Bajocian-early Bathonian (UAZ 5). Siliceous sedimentation prevailed in all sections from then onward. The uppermost part of the chert succession was dated only in the Bled Basin as early Tithonian.

Deposition of the pelagic Biancone limestone started in the Bled Basin in the late Tithonian (UAZ 13) and was followed by carbonate gravity-flow deposits. These Berriasian gravity-flow deposits, named the Bohinj Formation (Kukoč et al., 2012), contain clasts of shallow-water origin as well as clasts of basalt. They prove the existence of a carbonate platform, named the Bohinj Carbonate Platform (Kukoč et al., 2012), which formed on top of an ophiolite nappe stack following the obduction on the continental margin. This platform is not preserved today. Regional correlations suggest that the Bohinj Carbonate Platform may have existed from the early Kimmeridgian to the late Berriasian. Similar gravity-flow deposits, previously dated as Berriasian (Cadet, 1978) and containing clasts of shallow-water carbonates and basalt were found at Kalinovik in Bosnia and Herzegovina directly above radiolarites. At Kaludarska Rijeka, only pelagic limestone comparable to the Biancone limestone is exposed.

The Bohinj Formation is overlain by mixed carbonate-siliciclastic turbidites in which the proportion of siliciclastic component progressively increases higher in the succession. The Studor Formation in the uppermost part of the Bled Basin succession is composed predominantly of sandstones, whose composition indicates ophiolitic origin, but carbonate clasts are also common. The lower part of the formation is dated as late Berriasian-early Valanginian (UAZ 13-16). The Studor Formation correlates to the similar Lower Cretaceous formations containing ophiolitic debris in the Northern Calcareous Alps and Dinarides (the Rossfeld Formation and the Vranduk Formation, respectively). Sandstones with clasts of mafic and metamorphic rocks were found at the topmost part of the Kaludarska Rijeka section. Mixed carbonate-siliciclastic turbidites with progressively increasing proportion of siliciclastics are a time-transgressive unit of the entire orogen. Berriasian turbidites at the top of the Kalinovik and the Kaludarska Rijeka sections in the Central Dinarides are also assignable to this unit. For detailed reconstruction of the Early Cretaceous foreland basin(s) a more systematic biostratigraphic research of this unit is needed.

The newly obtained data are in accordance with previously proposed geodynamic scenario, which included opening and an extensional phase within the Neotethys in the Triassic and possibly Early Jurassic, intraoceanic subduction in the Middle Jurassic and progressive closure from the Late Jurassic through the Early Cretaceous. The data from the Bohinj area confirm that the Bled Basin, whose remnants are now preserved in the eastern Southern Alps, evolved in the Early Cretaceous as part of the Dinaric orogen.

References

Baumgartner, P.O., Bartolini, A., Carter, E.S., Conti, M., Cortese, G., Danelian, T., De Wever, P., Dumitrica, P., Dumitrica–Jud, R., Goričan, Š., Guex, J., Hull, D.M., Kito, N., Marcucci, M., Matsuoka, A., Murchey, B., O’Dogherty, L., Savary, J., Vishnevskaya, V., Widz, D. & Yao, A., 1995. Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. In: Baumgartner, P.O., O’Dogherty, L., Goričan, Š., Urquhart, E., Pillevuit, A., De Wever, P. (Eds.), Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology. Mémoires de Géologie (Lausanne) 23, 1013-1048.

Cadet, J.-P., 1978. Essai sur l’évolution Alpine d’une paléomarge continentale: les confins de la Bosnie-Herzégovine et du Monténégro (Yougoslavie). Mémoires de la Société Géologique de France (Nouvelle série) 133, 83p.

Cousin, M., 1981. Les rapports Alpes-Dinarides. Les confins de l’Italie et de la Yougoslavie. Société géologique du Nord, Publication n^{o} 5, Vol. I: 1-521, Vol. II Annexe: 1-521, Villeneuve d'Ascq.

Kukoč, D., Goričan, Š. & Košir, A., 2012. Lower Cretaceous carbonate gravity-flow deposits from the Bohinj area (NW Slovenia): evidence of a lost carbonate platform in the Internal Dinarides. Bulletin de la Société Géologique de France 183, 4, 383-392.

Rampnoux, J.-P., 1974. Contribution a l'étude géologique des Dinarides: un secteur de la Serbie méridionale et du Monténégro oriental (Yougoslavie). Mémoires de la Société Géologique de France (Nouvelle série) 119, 99p.

***Key words*:** Southern Alps, Dinarides, Jurassic, Cretaceous.

Huğlu-Pindos remnants in the Kopría (Rhodes, Greece) and in the Mersin (southern Turkey) mélanges: evidence from exceptionally preserved lower Tuvalian (upper Carnian) radiolarian fauna

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The deep-see sedimentary units in the Hellenides-Taurides belt provide important clues to the geodynamic evolution of Paleotethyan and Neotethyan series in the eastern Mediterranean region. The most external parts of the Hellenides-Taurides system present striking similarities. In particular, the platform development of the Beydağları parautochthonous sequence in Turkey correlates well with the pre-Apulian units of the Paxos-Zanthe-Kastellórizo zone in Greece (Moix et al., 2013). In addition to that, the classical Pindos-type series in Greece and the Huğlu-Pindos-type sequences in Turkey (the Köycegiz and Haticeana Dag series in the Lycian Nappes, part of the Antalya Nappes, the Beyşehir-Hoyran Nappes, broken-formations in the Mersin mélange, and the Köseyahya Nappe in Elbistan) show striking similarities. Both types of series are related to the latest extensional events leading to back-arc openings in the Variscan cordillera during the Late Triassic. These events are marked by widespread Triassic volcanism (e.g., Huğlu tuffitic series in Turkey) and by condensed Ammonitico Rosso horizons during the Liassic, leading to the onset of a passive margin setting that lasted until the Late Cretaceous obduction of supra-subduction type ophiolites (Moix et al., 2011). All these nappes represent segments of the northern Mesozoic passive margin of the Anatolian and Sitia-Pindos GDUs (e.g., Huğlu-Pindos back-arc basin margins), including its flexure during the Late Cretaceous (from Cenomanian to Senonian) and the thrusting by ophiolitic nappes during the Maastrichtian. The ophiolitic nappes correspond to a Late Cretaceous obduction from an intra-oceanic subduction zone onto a passive margin-type sequence (Oman-style). This nappes pile was then displaced again during the Tertiary. Similar Pindos-type units are also found in Crete and in several islands of the Dodecanese.

Rhodes is composed of several thrust sheets characterized by continental-margin to oceanic series. The Profitis Ilias unit is composed of Upper Triassic flyschoid deposits with *Aulacoceras* sp., marls and *Halobia*-bearing pelagic limestones, followed by a pelagic Mesozoic sequence preceding a lower to middle Maastrichtian flysch. The Kopría Mélange, located between the lower Oligocene Katavia flysch and the Carnian to Cretaceous slope to-basin series of the Profitis Ilias Group, represents locally dismembered units of the latter. A pelagic limestone block embedded in the Kopría Mélange and associated with volcaniclastics, tuffs and lavas yielded well-preserved radiolarians indicating the lower Tuvalian *Spongotortilispinus moixi* radiolarian zone. This zone was previously defined in the Mersin mélanges (southern Turkey), from limestones intercalated in tuffs (the Tavusçayırı Block) belonging to the Huğlu-type series. A very well-preserved and unique Tuvalian radiolarian fauna has been described from the *S. moixi* Zone (Mersin Mélange, SE Turkey) in a series of papers by Moix et al. (2007) and Kozur et al. (2007a-c, 2009). Moix et al. (2008) reported comparable (practically equal) radiolarian fauna from the Kopría Mélange (Rhodes, Greece). Not only the species content is similar, but also the preservation degree of the specimens and the lithology of the samples, proving doubtlessly that both faunas come from the same paleogeographic area. These faunas have many elements in common with the middle Carnian (*Tetraporobrachia riedeli* Zone) fauna from the Köseyahya Nappe in Elbistan (Tekin & Bedi, 2007a-b; Dumitrica et al., 2010, 2013a, b), also partly studied until now. The differences between them are a just a consequence of the extinction of some genera and species during the time interval between the two zones and the appearance of new taxa during the same interval.

References

Dumitrica, P., Tekin, U. K. & Bedi, Y. 2010. Eptingiacea and Saturnaliacea (Radiolaria) from the middle Carnian of Turkey and some late Ladinian to early Norian samples from Oman and Alaska. Paläontologische Zeitschrift 84, 259–292.

Dumitrica, P., Tekin, U. K. & Bedi, Y. 2013a. Taxonomic study of the tetrahedral, pentagonal and hexagonal spongy spumellarian Radiolaria from the middle Carnian (Late Triassic) of the Köseyahya nappe (Elbistan, SE Turkey) and other Triassic localities. Pal. Zeit. 87, 311–344.

Dumitrica, P., Tekin, U. K. & Bedi, Y. 2013b. Taxonomic study of spongy spumellarian Radiolaria with three and four coplanar spines or arms from the middle Carnian (Late Triassic) of the Köseyahya nappe (Elbistan, SE Turkey) and other Triassic localities. Paläontologische Zeitschrift 87, 345–396.

Kozur, H.W., Moix, P. & Ozsvárt, P., 2007a. Stratigraphically important Spumellaria and Entactinaria from the lower Tuvalian (Upper Triassic) of the Huğlu Unit in the Mersin Mélange, south-eastern Turkey. Bull. Soc. Vaud. Sc. nat. 90, 3, 151–173.

Kozur, H.W., Moix, P. & Ozsvárt, P., 2007b. Stratigraphically important Spumellaria and Entactinaria from the lower Tuvalian (Upper Triassic) of the Huğlu Unit in the Mersin Mélange, south-eastern Turkey. Bull. Soc. Vaud. Sc. nat. 90, 3, 175–195.

Kozur, H.W., Moix, P. & Ozsvárt, P., 2007c. Further new Nassellaria of the lower Tuvalian (Upper Triassic) *Spongotortilispinus moixi* Zone of the Huğlu Unit in the Mersin Mélange. Bull. Soc. Vaud. Sc. nat. 90, 3, 197–215.

Kozur, H.W., Moix, P. & Ozsvárt, P., 2009. New Spumellaria (Radiolaria) from the Early Tuvalian *Spongotortilispinus moixi* Zone of Southeastern Turkey, with some remarks on the age of this fauna. Jahrbuch der Geologischen Bundesanstalt 149, 1, 25–59.

Moix, P., Kozur, H.W., Stampfli, G.M. & Mostler, H., 2007. New palaeontological, biostratigraphical and palaeogeographical results from the Triassic of the Mersin Mélange, SE Turkey. In: The Global Triassic (Lucas, S.G. & Spielmann, J.A., Eds.), New Mexico Museum Nat. Hist. Sci. Bull. 41, 282–311.

Moix, P., Beccaletto, L., Masset, O., Kozur, H.W., Dumitrica, P., Vachard, D., Martini, R. & Stampfli, G.M., 2011. Geology and Correlation of the Mersin Mélanges, Southern Turkey. Turkish Journal of Earth Sciences 20, 57–98.

Moix, P., Hungerbühler, A., Guex, J. & Stampfli, G.M. 2008. First evidence of Tuvalian (upper Carnian) radiolarians from the Kopría Mélange in Rhodos (Greece). 33IGC, Oslo

Moix, P., Vachard, D., Allibon, J., Martini, R., Wernli, R., Kozur., H. & Stampfli, G. M., 2013. Paleotethyan, Neotethyan and Huğlu-Pindos series in the Lycian nappes (SW Turkey): geodynamical implications. In: The Triassic system (Tanner, L.H., Spielmann, J. A. & Lucas, S.G, Eds.), New Mexico Museum of Natural History and Science, Bulletin 61, 401–444.

Tekin, U.K. & Bedi, Y., 2007a. Ruesticyrtiidae (Radiolaria) from the middle Carnian (Late Triassic) of Köseyahya Nappe (Elbistan, eastern Turkey). Geologica Carpathica 58, 2, 153–167.

Tekin, U.K. & Bedi, Y., 2007b. Middle Carnian (Late Triassic) Nassellaria (Radiolaria) of Köseyahya nappe from eastern Taurides, eastern Turkey. Rivista Italiana di Paleontologia e Stratigrafia 113, 2, 167–190.

Key words: Carnian radiolarians, the Huğlu-Pindos unit, the Kopría (Rhodes) mélange, the Mersin mélange.

Radiolarian biostratigraphy of the Southern Kronotskii paleoarc (eastern Kamchatka)

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The eastern peninsulas of Kamchatka are mostly composed of tectonostratigraphic complexes, which were formed within the Late Cretaceous-Eocene Kronotskii-Kamchatka arc. The accretion of this paleoarc to the Kamchatka margin of northeastern Asia in the terminal Cenozoic represented the last collisional event in the formation of the present-day structure of Kamchatka. We present new data on the age, composition, and structure of the tectonostratigraphic complexes consisting of the southern segment of the Kronotskii-Kamchatka paleoarc. It is shown that the oldest rocks of these complexes are the Campanian in age and represented by volcano-sedimentary rocks that were formed in different geodynamic environments. The investigated igneous rocks are attributed to two types: (1) the tholeiite series of a mid-oceanic ridge (MOR) (Vetlovaya Complex); (2) tholeiite and calc-alkaline series of island arcs (Shipunskii Sequence of the Kronotskii Group) (Tsukanov et al., 2014).

The representative radiolarian assemblages were extracted from the Shipynskii Sequence and Vetlovaya Complex. The analysis of these assemblages provides grounds for dating the host rocks to the Campanian. Both assemblages are dominated by prunobrachiid representatives, which indicate cold-water depositional environments. The assemblages include wide-spread *Prunobrachium articulatum* (Lipman), *Amphibrachium spongiosum* Lipman, *Phaseliforma carinata* Pessagno, *P.meganosensis* Pessagno, *Amphipyndax stocki* (Campbell & Clark).

The igneous rocks from the southern segment of the Kronotskii paleoarc belong to the tholeiite and calc-alkaline series of island arcs and started forming in the Campanian.

The Vetlovaya complex of the Vakhil uplift represents a fragment of the accretionary wedge, the formation of which commenced in the Campanian. It is established that, in addition to the Paleocene-Eocene siliceous-carbonate oceanic rocks, its structure includes the Campanian and Campanian-Maastrichtian volcanogenic-siliceous complexes and tuffaceous-sedimentary deposits with olistostromes containg Late Cretaceous (Campanian) olistoliths.

The composition of the rocks from the southern segment of the Kronotskii paleoarc and the Vetlovaya Complex of the Vakhil uplift makes it possible to reconstruct the island arc system (island arc and back-arc basin). Volcanic activity in the arc was in progress at least since the Campanian until the middle Eocene. The oceanic basin existed also since the Campanian until the middle Eocene. The similar taxonomic composition of the radiolarian assemblages from different fragments of the Vetlovaya Complex and Shipynskii sequence implies their formation in the same sedimentation basin.

References

Tsukanov N.V., Palechek T.N, Soloviev A.V. & Savelyev D.P., 2014. Tectonostratigraphic complexes of the Southern Kronotskii Paleoarc (eastern Kamchatka): Structure, age and composition. Russian Journal of Pacific Geology 8, 4, 233-246.

Key words**:** Radiolaria, tectonostratigraphic complexes, Upper Cretaceous, volcanic arc, Kamchatka.

New paleontological insights for the Siquisique Ophiolite (northern Venezuela) using radiolarians

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The Siquisique ophiolite complex is located in northern Venezuela, in the border between Lara and Falcón states. At Los Algodones, the type locality, the ophiolite is composed of cumulate gabbros, a sheeted dyke complex, basalts, and stratigraphically overlying black cherts. Mafic complexes similar to Siquisique have been identified in three other places in north Venezuela: Yurí-Chorrerones, Llanaditas and Limon, the former being the most extended locality and the latters, small outcrops (Fig. 1A).

Bajocian–Bathonian ammonites in interpillow sediment were reported by (Bartok et al., 1985) from basalt blocks in Las Petacas Creek (Fig. 1C). The ammonite locality was associated with the Siquisique ophiolite, hence considered as a remnant of the Jurassic proto-Caribbean. However, recent detailed geological mapping (e.g., Reategui & Urbani, 2012) have found that the ammonite locality is associated with basaltic blocks of unknown origin embedded in a Paleogene tectonic mélange. Hence, they cannot be considered as part of the Siquisique ophiolite.

In the Guaparo creek (Macuere area, fig. 1D) we recovered poorly preserved radiolarian assemblages from green to black laminated ribbon bedded chert, apparently in stratigraphic contact with basaltic breccias. An assemblage includes *Stichomitra communis* (Squinabol), *Stichomitra japonica* (Nakaseko & Nishimura), *Dictyomitra montisserei* (Squinabol), *Dictyomitra undata* (Squinabol). Using maximum ranges of the taxa published in several regional zonations, we determined a Middle Cretaceous age for this outcrop. This datum is in agreement with previously published ^{40}Ar-^{39}Ar ages, of approximately 95 to 90 Ma (Neill et al., 2014) for the underlying volcanic rocks.. The geochemistry of these rocks suggests that they were derived rather from a deep mantle plume than from a mid-ocean ridge. It is unclear if these basalts represent a fragment of the original proto-Caribbean ocean floor (Kerr et al., 2011; Neill et al., 2014), therefore the source of the Middle-Late Cretaceous fragments present in the proto-Caribbean remains equally uncertain.

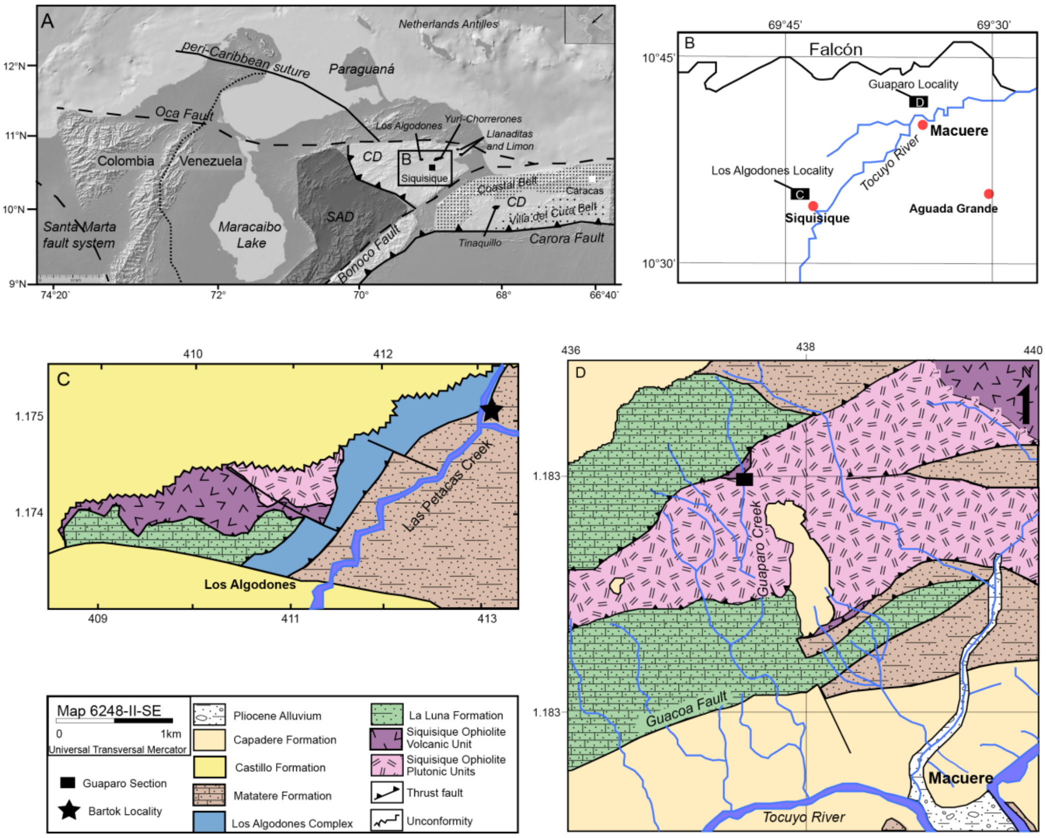

Figure 1. A) Regional location showing the principal geological structures in northern Venezuela. **B)** Location of the Siquisique complex in the studied area (Guaparo locality) and Los Algodones type locality. **C)** Geological map of the Los Algodones Locality **D)** Geological map of the studied area.

References

Bartok, P., Renz, O. & Westermann, G.E.G., 1985. The Siquisique ophiolites, northern Lara State, Venezuela: a discussion on their Middle Jurassic ammonites and tectonic implications. GSA Bull. 96, 1050–1055.

Kerr, A., Neill, I., Urbani, F., Spikings, R., Barry, T. & Tarney, J. 2011. The Siquisique basalts and gabbros, Los Algodones, Venezuela: late Cretaceous oceanic plateau formed within the proto-Caribbean plate? Volcanic and Magmatic Studies Group Annual Meeting. Queens´College Cambridge, 5-7 Enero 2011. Abstracts, A49.

Neill, I., Kerr, A., Chamberlain, K., Schmitt, K, Urbani, F., Hastie, A., Pindell, J, Barry, T. & Millar, I., 2014. Vestiges of the proto-Caribbean seaway: Origin of the San Souci Volcanic Group, Trinidad. Tectonophysics 626,170–185.

Reategui, W. & Urbani, F., 2012. Reconocimiento geológico de la región comprendida entre Guacamo y Puente Limón, municipios Urdaneta y Federacion, estados Lara y Falcón. Geos 42. IV Simposio Venezolano de geociencias de las Rocas Ígneas y Metamórficas, 90–93.

Key words: Radiolaria, Middle Cretaceous, Venezuela, the Siquisique Ophiolite, proto-Caribbean.

Silurian radiolarians from the Indochina Terrane

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Late Silurian radiolarian cherts have been found for the first time along the western margin of the Indochina terrane in Lao PDR which indicate the existence of a deep marine environment which along with widespread andesitic volcanism suggests proximity to a Late Silurian-Early Devonian subduction complex. The chert samples were collected from a large abandoned pit and a small quarry in the Sepon mining district including the Huai Yang Pit and the 'chert quarry' sections.

Cherts from the Huai Yang Pit section are maroon in color and contain *Futobari morishitai* Furutani, *Zadrappolus* sp., *Secuicollacta* sp. and others. *Futobari morishitai* was first described from the Yoshiki Formation, Fukuji area by Furutani in the *Zadrappolus yoshikiensis* Assemblage. The genus *Futobari* has its first appearance in the latest Silurian and its acme in the Early Devonian on the basis of radiolarian biostratigraphy in the Kurosegawa Belt (Umeda, 1997). Most of the species belonging to *Secuicollacta* have been reported from the Silurian with only a few species of this genus known in Devonian rocks (Nazarov & Ormiston, 1986). Based on the occurrence of *Futobari morishitai* with *Zadrappolus* sp. and *Secuicollacta* sp., the age of the chert sequence is probably Ludlow to Pridoli (Late Silurian).

The chert from a small nearby 'chert quarry' section is light brown and includes *Zadrappolus yoshikiensis* Furutani, *Zadrappolus tenuis* Furutani and others. These are the most characteristic species of the *Zadrappolus yoshikiensis* Assemblage from the Fukuji area, Gifu prefecture, central Japan (Furutani, 1990) and indicate a latest Silurian to earliest Devonian age. However, Noble (1994) assigned the *Zadrappolus yoshikiensis* Assemblage of Furutani (1990) to the Ludlow to Pridoli in the Silurian radiolarian biostratigraphy of the Caballos Novaculite, West Texas. Kurihara & Sashida (2000) also assigned this assemblage to the Ludlow to Pridoli in the Kazuryu lake district of the Hida Gaien Belt, Fukui Prefecture, central Japan.

Differences in chert lithology between these localities such as color and bedding characteristics might reflect a different in depositional environment and a complicated interchange among the open marine basin and a deeper part of the continental margin. Further study on the geochemical composition of these well dated chert samples is required in order to test this scenario.

Lithostratigraphical and palaeontological transition during the Silurian-Devonian interval plus an unconformity underlying the Early Devonian sequences reported both in Lao PDR and Vietnam supports a subduction and collision event. Late Silurian graptolites *Neodiversograptus nilssoni*, *Monograptus* sp., and *Pristiograptus* sp. observed from black argillaceous shale with interbedded sandstone and gritstone from the upper part of the Long Dai Formation in central Vietnam supports deep marine lateral facies variations (e.g., Tong-Dzuy Thanh & Vu Khuc, 2006).

References

Furutani, H., 1990. Middle Paleozoic Radiolarians from Fukuji Area, Gifu Prefecture, Central Japan. Journal of Earth Sciences, Nagoya University 37, 1–56.

Kurihara, T. & Sashida, K., 2000. Early Silurian (Llandoverian) radiolarians from the Ise area of the Hida "Gaien" Belt, central Japan. Paleontological Research 4, 147—162.

Nazarov, B. B. & Ormiston, A. R., 1986. Trends in the Development of Palaeozoic radiolaria. Marine Micropaleontology 11, 3-32.

Noble, P., 1994. Silurian Radiolarian zonation for the Caballos Novaculite, Marathon Uplift, West Texas. Bulletin of American Paleontology 106, 55p.

Tong-Dzuy Thanh & Vu Khuc, 2006. Stratigraphic Units of Vietnam. Vietnam National University Publishing House, Hanoi, 526p.

Umeda, M., 1997. Late Silurian and Early Devonian radiolarians from the Konomori area in the Kurosegawa Terrane, Southwest Japan. Earth Science 51, 413–432.

***Key words*: Silurian, Radiolaria, the Indochina Terrane, Lao PDR.**

Paleocene radiolarians from the Sangdanlin Section, southern Tibet

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As a key tectonic boundary in the Tibet Plateau, the Yarlung Tsangpo Suture Zone represents the position of Neo-Tethys oceanic crust subducted and closed. Paleogene radiolarian-bearing sediments are widespread in this zone and they can provide very important evidence for interpreting the evolution of the Neo-Tethys (Liang et al., 2012). To date only a few Paleocene radiolarian discoveries have been reported in Tibet (Liu & Aitchison, 2002; Ding, 2003; Chan Sik-Lap, 2006; Liang et al., 2012), and these articles lack detailed systematic taxa descriptions. Recently, a rich assemblage of Paleocene radiolarians was extracted from silicalites and siliceous mudrocks in Sangdanlin Section, Gyirong County of the southern Tibet. Abecedarian identified radiolarians include *Amphisphaera macrosphaera*, *Amphisphaera goruna*, *Bekoma campechensis*, *Buryella tetradica*, *Buryella pentadica*, *Bathopyramis sanjoaquinensis* s.l., *Clathrocycloma parcum*, *Dorcadospyris platyacantha*, *Hexacontium palaeocenicum*, *Lamptonium* sp., *Lychnocanoma babylonis*, *Lychnocanoma coastata*, *Orbula comitata*, *Phormocyrtis striata exquisita*, *Spongurus*(?) *regularis*, *Spongodiscus quartus bosoculus* and *Spongotrochus* sp. etc.

The aims of this study are to give proper systematic taxa descriptions and to establish relatively precise zones of Paleocene radiolarians in southern Tibet. In contrast with the previous data (Foreman, 1973; Riedel & Sanfilippo, 1978; Nishimura, 1987, 1992; Hollis, 1997, 2002), the above identified radiolarian faunas correspond to the *Bekoma campechensis* Zone, and the age is considered to be a preliminary late Paleocene, which suggests that there still existed remnant oceanic sediments in the Saga-Gyirong area during late Paleocene.

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References

Chan Sik-Lap, J., 2006. Paleocene deep-marine sediments in southern central Tibet: indication of an arc-continent collision. Master Thesis, University of Hong Kong.

Ding, L., 2003. Paleocene deep-water sediments and radiolarian faunas: Implications for evolution of Yarlung-Zangbo foreland basin, southern Tibet. Science in China, Series D: Earth Sciences 46, 1, 84-96.

Foreman, H.P., 1973. Radiolaria of Leg 10 with systematics and ranges for the families Amphipyndacidae, Artostrobiidae and Theoperidae. In: Initial Reports of the Deep Sea Drilling Project (Worzel, L. & Bryant, W., Eds.), U.S. Government Printing Office, Washington, D.C. 10, 407-474.

Hollis, C.J., 1997. Cretaceous-Paleocene Radiolaria from eastern Marlborough, New Zealand. Institute of Geological and Nuclear Sciences, Monograph 17, 1-152.

Hollis, C.J., 2002. Biostratigraphy and paleoceanographic significance of Paleocene radiolarians from offshore eastern New Zealand. Marine Micropaleontology 46, 3-4, 265-316.

Liang, Y.P., Zhang, K.X., Xu, Y.D., He, W.H., An, X.Y. & Yang, Y.F., 2012. Late Paleocene radiolarian fauna from Tibet and its geological implications. Canadian Journal of Earth Sciences 49, 11, 1364-1371.

Liu, J. & Aitchison, J.C., 2002. Upper Paleocene radiolarians from the Yamdrok Melange, South Xizang (Tibet), China. Micropaleontology 48, 145-154.

Nishimura, A., 1987. Cenozoic Radiolaria in the western North Atlantic, Site 603, Leg 93 of the Deep Sea Drilling Project. In: Initial Reports of the Deep Sea Drilling Project (Van Hinte, J.E., Wise, S.W.J. et al., Eds.), U.S. Government Printing Office, Washington, D.C., 713-737.

Nishimura, A., 1992. Paleocene radiolarian biostratigraphy in the northwest Atlantic at Site 384, Leg 43, of the Deep Sea Drilling Project. Micropaleontology 38, 4, 317-362.

Riedel, W.R. & Sanfilippo, A., 1978. Stratigraphy and evolution of tropical Cenozoic radiolarians. Micropaleontology 24, 1, 61-96.

***Key words*:** Paleocene, southern Tibet, Neo-Tethys.

Microfacies and biogenic sedimentation processes by using high-resolution SEM revealed in the Middle Triassic bedded chert from Motutapu Island, New Zealand

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The bedded chert section of the Waipapa terrane from Administration Bay on Motutapu Island (Hauraki Gulf, near Auckland) is comprised of black laminated chert/ black siliceous shale (ca. 3m thick) and red chert (ca. 10m thick). Based on conodont biostratigraphy, the black chert is Spathian (Induan) and the red chert is early to middle Anisian in age.

In order to unravel the sedimentary facies and microstructure of the bedded chert, high-resolution SEM observations (10240 x 7680 pixels) by using a DigiCapture Device (Sanyu Electron, SUP-7707) were carried out on HF acid-etched chert slabs that were collected from the section bed by bed.

Three microfacies have been recognized: ordinary pelagic chert facies (G2), pelagic siliceous clay facies (E1/E2) and biogenic siliceous constituent facies (G1-1) comprising abundant sponge spicules and radiolarian shells. Facies G2 has a chert matrix with a high biosiliceous component (10-30%) which appears as mostly dissolved and/or poorly preserved microfossils. Facies G2 is subdivided into G2-1 (no structures) and G2-2 (with structure; lamination and/or grading). Facies E1/E2 has a siliceous clay matrix with a low content (1-10%) of biosiliceous shells and spicules. E1 shows no structures whereas E2 has grading and/or laminations. Facies G1-1 is (a few mm-scale) characterized by densely packed, non-cemented sponge spicules and spherical radiolarian shells (Fig.1).

The state of microfossil preservation within Facies G1-1 is exceptionally well-preserved compared with those of Facies G2 and E1/E2. Facies G1-1 can change stratigraphically in proportion of silica within a single chert bed ranging from <10% to 100%. Our interpretation of these rapid facies changes in bedded chert is that Facies G1-1 represents abrupt, high sedimentation events intercalated within the more ‘normal’ or background slow sedimentation Facies G2 and Facies E1/E2.

In the lower section (0-1.3m), background sedimentation Facies E2 and G2-1 bare dominated and then the ratio of E2 is rising upward and Facies G1-1 changes from 18% to 46% with episodic increasing events. In the mid to upper section (1.5-2.3m), Facies G2-2 enhanced in the middle, and followed by increase of Facies E2. Facies G1-1 indicates its ratio from 7% to 61%.

An exceptional enhanced biogenic silica sedimentation history has been recorded within a single chert bed and we can reconstruct the continuous record of history on biogenic constituents of the bedded chert sequences of Middle Triassic in New Zealand. The bedded chert sequence from Administration Bay on Motutapu Island provides significant new information about biological, sedimentary and oceanographic processes in the Panthalassa Ocean.

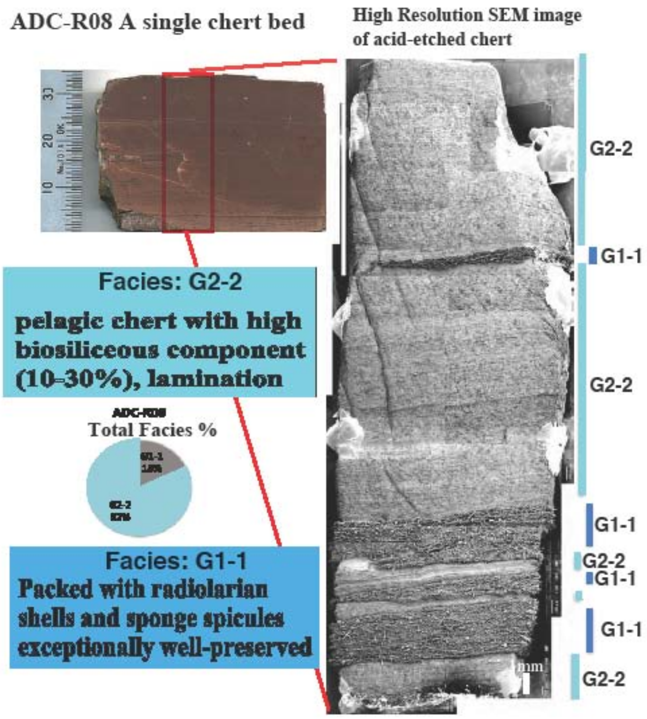

Fig. 1. High-resolution SEM image on the acid-etched chert bed and sedimentary microfacies.

Key words: Facies, sedimentation process, bedded chert, Middle Triassic, high-resolution SEM.

Middle Triassic Radiolaria from the manganese carbonate lens from the Motutapu Island, North Island, New Zealand

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The pelagic to hemipelagic succession of the Waipapa terrane from Administration Bay on Motutapu Island (Hauraki Gulf, near Auckland) is comprised of black laminated chert/ black siliceous shale (3m thick), red chert (10m thick), reddish purple/green shale (7.5m thick), purple shale with manganese carbonate lens and green siliceous shale (16m thick). Based on conodont biostratigraphy, the black chert is Spathian (Induan) and the red chert is early to middle Anisian in age. The section is covered by thick massive sandstone. The detrital zircons U-Pb age from the sandstone at the Administration Bay was reported as 213±2 Ma (Norian, Late Triassic) by Adams et al. (2013).

The well-preserved radiolarian assemblage is recovered from the manganese carbonate lens (Ad-8) within purple shale. The fauna is characterized by abundant occurrence of the genera *Glomeropyle, Hozmadia, Parentactinia*, and other thick-walled multicyrtoid Nassellarians. The species belonging to the genus *Glomeropyle* with a bipolar nature include *G. bispinosa*, *G. calavatum*, *G.* aff. *grantmackiei* and other three undescribed forms. Other distinctive forms including Genus et sp. indet. A and *Pararuesticyrtium* sp. A are present and these forms were recorded from the fauna (MAH-1.4) from the Unit 2 of the Mahinepua Section, Whangaroa area, Northland (Aita & Bragin, 1999). The present fauna includes *Parentactinia pugnax, Poulpus curvispinus, Eptingium nakasekoi, Foremanelina aranea, Silicamiger costatus costatus, Tiborella* cf. *anisica, Planispinocyrtis kotelnyensis, Pylostephanidium clavator, Sarla compressa and Triassospongocyrtis yaoi*. The age of the fauna is late Anisian.

The abundant forms of thick-walled multicyrtoid Nassellarians were also reported from Bull Creek, south of Dunedin, South Island, New Zealand. These forms might indicate an endemic fauna in southern high-latitude area during the Middle Triassic.

References

Adams, C. J., Mortimer, N., Campbell, H.J. & Griffins, W.L., 2013. Detrital zircon geochronology and sandstone provenance of basement Waipapa Terrane (Triassic - Cretaceous) and Cretaceous cover rocks (Northland Allochthon and Houhora Complex) in northern North Island, New Zealand. Geological Magazine 50, 1, 89-109.

Aita, Y. & Bragin, N.J., 1999. Non-Tethyan Triassic Radiolaria from New Zealand and Northeastern Siberia. Geodiversitas 21, 4, 503-526.

Key words: Middle Triassic, manganese carbonate, Motutapu Island, New Zealand.

δ_{age} dating: combining new and traditional techniques to inform 4D models for understanding ancient ocean basin evolution

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Nearly five decades since development of the plate tectonics paradigm we know the location of numerous ancient convergent plate margins and associated accretionary complexes that developed above subduction zones. We also have a basic understanding of the configuration of supercontinents through time. What continues to elude us is a comprehensive understanding of now consumed ancient basins.

The utility of powerful plate tectonic modeling software such as the elegant GPlates paleo-GIS system is constrained by the types of data that are useful for reconstructions (Boyden et al., 2011). In the case of Cenozoic models marine magnetic anomaly data from oceanic crust existing in modern basins allows highly accurate reconstructions to rapidly be generated. However, older oceanic crust has been subducted with only fragments of it preserved in accretionary complexes associated with ancient convergent margins. We thus seek new methodologies to inform accurate reconstructions for Mesozoic and Paleozoic time.

Significant advances in the technology associated with analytical geochemistry have made previously expensive and time-consuming radiometric dating techniques relatively commonplace. Development of LA-ICP-MS allows large quantities of detrital zircons extracted from clastic sediments to be rapidly dated using the U-Pb technique. Data thus generated provide constraints on the ages of the sources of this detrital material. Already areas such as the Central Asian Orogenic Belt (CAOB) are awash with volumes of such data (e.g. Song et al., 2013; Tian et al., 2014). In the case of accretionary complex material that accumulated in subduction zone trenches this is commonly unfossiliferous and no other technique for dating exists. The youngest ages of detrital zircons in such sediment are widely regarded as representative of the age of deposition (Dickinson & Gehrels, 2009).

More traditional techniques applied to investigations of accretionary complexes in the 1980’s and 90’s used radiolarian biostratigraphy to constrain the ages of cherts overlying mid ocean ridge basalt (MORB) accreted as tectonic slices into these complexes. Such investigations revolutionised understanding of the tectonic evolution of areas such as the Japanese isles (for summary see Isozaki et al., 2010). This cost effective technique was aided by the development of Cenozoic, Mesozoic and Paleozoic radiolarian biostratigraphies, which have since been considerably further refined to significantly improve the stratigraphic resolution available today.

Early on it was realised that within individual tectonic slices within accretionary complexes the ages of siliceous sediments typically decrease up-section towards the clastic trench-deposited sediment and the now famous Ocean Plate Stratigraphy (OPS) of Matsuda & Isozaki (1991) was recognised. In some rare cases, where reversal of this pattern were observed, this was used to demonstrate possible ridge subduction events based on the basic plate tectonic concept that oceanic crust becomes progressively older either side of spreading ridges (Isozaki et al., 2010). The acme of this radiolarian research was reached late last century and although large quantities of data exist the cherts within many accretionary complexes await detailed investigation.

By combining the two techniques outlined above we present a powerful new cross-disciplinary tool that provides the potential to significantly advance understanding and provide the data necessary to inform models for ancient ocean basin evolution. Using the New England region of NSW Australia as an example we will illustrate the power of this methodological combination. The Late Paleozoic of the New England orogen is dominated by rocks associated with convergent plate margin activity along the continental margin of eastern Gondwana. Widespread granites and volcanic rocks preserve the magmatic record of this convergence whilst the regionally extensive Anaiwan terrane represents an associated accretionary complex. Radiolarian faunas were first reported from cherts in this terrane in the late 1980s (Aitchison, 1988). Since then numerous additional localities have been reported. In recent years the trend has been for detrital zircon studies of unfossiliferous trench-fill turbidite sediments that succeed the cherts (Korsch et al., 2009).

References

Aitchison, J.C., 1988. Late Paleozoic radiolarian ages from the Gwydir terrane, New England orogen, eastern Australia. Geology 16, 793-795.

Boyden, J.A., Müller, R.D., Gurnis, M., Torsvik, T.H., Clark, J.A., Turner, M., Ivey-Law, H., Watson, R.J. & Cannon, J.S., 2011. Next-generation plate-tectonic reconstructions using GPlates. Geoinformatics: Cyberinfrastructure for the Solid Earth Sciences 95-114.

Choulet, F., Faure, M., Cluzel, D., Chen, Y., Lin, W., Wang, B. & Jahn, B.-M., 2012. Architecture and evolution of accretionary orogens in the Altaids collage: The early Paleozoic West Junggar (NW China). American Journal of Science 312, 1098-1145.

Dickinson, W.R. & Gehrels, G.E., 2009. Use of U–Pb ages of detrital zircons to infer maximum depositional ages of strata: A test against a Colorado Plateau Mesozoic database. Earth and Planetary Science Letters 288, 115-125.

Isozaki, Y., Aoki, K., Nakama, T. & Yanai, S., 2010. New insight into a subduction-related orogen: A reappraisal of the geotectonic framework and evolution of the Japanese Islands. Gondwana Research 18, 82-105.

Korsch, R.J., Adams, C.J., Black, L.P., Foster, D.A., Fraser, G.L., Murray, C.G., Foudoulis, C. & Griffin, W.L., 2009. Geochronology and provenance of the Late Paleozoic accretionary wedge and Gympie Terrane, New England Orogen, eastern Australia. Australian Journal of Earth Sciences 56, 655-685.

Matsuda, T. & Isozaki, Y., 1991. Well-documented travel history of Mesozoic pelagic cherts in Japan: from remote ocean to subduction zone. Tectonics 10, 475-499.

Tian, Z., Xiao, W., Windley, B.F., Lin, L.N., Han, C., Zhang, J.E., Wan, B., Ao, S., Song, D. & Feng, J., 2014. Structure, age, and tectonic development of the Huoshishan–Niujuanzi ophiolitic mélange, Beishan, southernmost Altaids. Gondwana Research 25, 820-841.

Key words**:** Subduction, ocean basin evolution, radiolarians, detrital zircons.

Preliminary results of the radiolarian biochronological study of the basal sediments at IODP Site U1438 (Amami Sankaku Basin, Northern Philippine Sea)

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One of the major objectives of IODP Expedition 351 (Izu-Bonin Marian Arc origins) is to understand the mechanism of subduction inception and evolution of Izu-Bonin-Mariana Arc. To that end, the age of the oldest sediments is critical for reconstructions of the arc initiation. The basal sedimentary sequence at Site U1438 (the Amani Sankaku Basin, Northern Philippine Sea) yielded rare and poorly preserved microfossils, which provided poorly constrained biochronological ages. Another site in this area (Site 1201 of Leg 195), has a similar basal sedimentary section to Site U1438. The age constraints on the basal 47 m of sediments at Site 1201 are also poor (> 35 Ma, based on nannofossils) and the radiolarians, which have been reported from the basal unit, have never been studied.

We are in the process of further investigating the biostratigraphy of samples from the basal units of Sites 1201 and U1438 to better constrain the earliest deposition history associated with the arc inception. The preliminary results will be presented at the conference.

Diachronous Middle-Late Jurassic ophiolite obduction and exposure along the eastern Pelagonian Margin (Hellenides, Greece)

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This paper intends to clarify, based on radiolarian biochronology, the extent of diachronism in the obduction history of ophiolites in Eastern Greece, in response to an article by Scherreiks et al. (2014). These authors conclude on Berriasian-Valanginian arrival of the ophiolite nappe stack in northern Evvoia, partly based on an early radiolarian age published by Baumgartner & Bernoulli (1976), who suggested a Neocomian age for a radiolarite sample immediately beneath detrital sediments with ophiolitic clasts. However, this age was stated in absence of any Late Jurassic radiolarian zonation at that time. We have since revised this age assignment in 3 successive publications: Baumgartner (1984), Baumgartner et al. (1993, 1995). The sample contains *Eucyrtidiellum ptyctum* Riedel & Sanfilippo, *Homoeoparonalella argolidensis* Baumgartner, *Hemicryptocapsa carpathica* Dumitrica, *Transhsuum brevicostatum* (Ozvoldova), *Archaeodictyomitra apiarium* Ruest, *Pseudodictyomitra primitiva* Matsuoka & Yao, *Wrangellium okamurai* Mizutani, *Solenotryma ichikawai* Matsuoka & Yao, *Cinguloturris* sp and *Saitoum* sp. This assemblage can be dated as UAZ 8-11 (middle Callovian/early Oxfordian to late Kimmeridgian/early Tithonian). A Late Kimmeridigian/Early Tithonian age would be in agreement with the presence of *Cladocoropsis mirabilis* and *Zergabriella embergeri* (Scherreiks et al., 2014) found in turbidites interbedded with radiolarian cherts, a few m down-section from the radiolarian sample discussed here. De Bono (1998) also decribed radiolarian assemblages from samples directly below ophiolitic detritus, of UAZ 11 (late Kimmeridgian/early Tithonian) age from the Olympus Chert of Central Evvoia. Hence, the late Kimmeridgian/early Tithonian is the latest time for the arrival of ophiolite nappes in central and N-Evvoia.

However, in the Argolis Peninsula (revision of the data of Baumgartner 1985 in Baumgartner et al., 1995) the first ophiolite detritus (chrome spinels) is recorded in the Koliaki Chert of the Asklipion Unit, which represents the Maliac margin of the Pelagonian, in UAZ 8 (middle Callovian – early Oxfordian). On the Pelagonian Platform (Basal sequence of the Didhimi-Trapezona Composite Unit) the first ophiolite detritus occurs in UAZ 9 (middle-late Oxfordian), whereas in the more external (western) Adhami Basal Sequence, ophiolite detritus arrives first in UAZ 10 (latest Oxfordian/early Kimmeridgian). These age differences not only show the westward advancement of the ophiolite nappes from the Maliac margin onto the Pelagonian platform, but also demonstrate the important telescoping of units during the latest Jurassic and during the Early Tertiary orogenic phases.

The so far oldest ophiolite detritus on the Pelagonian margin occurs in Middle Jurassic siliceous mudstones in the north of the island of Hydra (Attika, S of the Argolis Peninsula). It is dated as UAZ 4-7 (late Bajocian – early Callovian (Baumgartner et al., 1993). This age in is accordance with the age of ophiolite-derived bauxites on Evvoia, now dated as post late Bathonian – pre Early Oxfordian (Scherreiks et al., 2014).

If the age of the first arrival of ophiolite-derived materials on the Pelagonian platform is taken as a criterion for the internal vs. external palaeogeographic position of units with respect to the ophiolite obduction, then the N-Hydra unit, as well as the bauxite-bearing platform sequences of Evvoia are the most internal units of the Pelagonian, whereas the Late Jurassic carbonates and overlying radiolarites of Central and N–Evvoia, with ophiolite detritus as young as Tithonian, must belong to more external units.

Scherreiks et al. (2014) argue for a Late Bathonian first obduction on the Pelagonian platform in the Sporades (Aegean Sea) and believe that ophiolite material would have been transported over 200 km on land to form the bauxites of N-Evvia, an area which was finally reached by the ophiolite nappe itself in Berriasian-Valanginian times (here revised as late Kimmeridgian/early Tithonian). We suggest that the juxtaposition of internal and external Pelagonian units in Evvoia is the result of either latest Jurassic or Early Tertiary telescoping of the Pelagonian. In fact, on the geologic maps of Scherreiks et al. (2014) bauxite-bearing and Late Jurassic radiolarite-bearing sequences are always separated by faults. Many of these faults are young normal faults that reactivated older nappe contacts during the Neogene Aegean extension.

In conclusion, an important diachronism of the first ophiolite detritus, ranging at least from early Callovian to early Tithonian can be observed in the Pelagonian of Eastern Greece. In Evvoia, more internal, “Callovian” bauxite-bearing units could have been thrust over more external Pelagonian units that received the first signs of ophiolite erosion as late as the Tithonian.

References

Baumgartner, P. O., 1984. A Middle Jurassic-Early Cretaceous low-latitude radiolarian zonation based on Unitary Associations and age of Tethyan radiolarites. Eclogae Geologicae Helvetiae 77/3, 729-837.

Baumgartner, P. O., 1985. Jurassic sedimentary evolution and nappe emplacement in the Argolis Peninsula (Peloponnesus, Greece). Denkschr. Schweiz. Nat. Ges., 99, 1-111.

Baumgartner, P.O. & Bernoulli, D., 1976. Stratigraphy and radiolarian fauna in a Late Jurassic-Early Cretaceous section near Achladi (Evvoia, eastern Greece). Eclogae Geologicae Helvetiae 69/3, 601-626.

Baumgartner, P.O., Danelian, T., Dumitrica, P., Gorican, S., Jud, R., Dogherty, L.O., Carter, B., Conti, M., De Wever, P., Kito, N., Marcucci, M., Matsuoka, A., Murchey, B. & Urquart, E., 1993. Middle Jurassic-Early Cretaceous radiolarian biochronology of Tethys: implications for the age of radiolarites in the Hellenides. Bulletin of the Geological Society of Greece XXVIII/3, 13-23.

Baumgartner, P.O., O’Dogherty, L., Gorican, S., Urquhart, E., Pillevuit, A. & De Wever, P. (Eds.), 1995. Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurences, Systematics, Biochronology. In: Mémoires de Géologie (Lausanne) 23, 1013-1048.

De Bono, A., 1998. Pelagonian margins in Central Evia Island (Greece). Stratigraphy and geodynamic evolution. Ph D. Thesis, Univerity of Lausanne. http://www.unil.ch/files/live//sites/iste/files/shared/X.Library/PhD%20theses/De%20Bono%20Andrea%20%281998%29.pdf

Scherreiks, R., Meléndeu, G., BouDagher-Fadel, M., Fermeli, G., & Bosence, D., 2014. Stratigraphy and tectonics of a time-transgressive ophiolite obduction onto the eastern margin of the Pelagonian platform from Late Bathonian until Valanginian time, exemplified in northern Evvoia, Greece. Inernational Journal of Earth Sciences (Geol Rundsch) 103, 2191–2216.

Key words**:** Pelagonian, Middle – Late Jurassic, radiolarian biochronology, ophiolite detritus, obduction, telescoping of units, Hellenides.

Radiolarian biostratigraphy and geochemistry of the ophiolitic complexes of the Izmir-Ankara Mélange (Turkey)

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In this work, we present the age data of the radiolarian cherts laying on the top of basalts incorporated in the Eastern Ankara Mélange (part of the Izmir-Ankara Mélange). Petrological studies on basalts were carried out in order to constrain the tectonic setting of formation of the basalt-chert sequences. Nine sections were sampled to the East of Ankara and fifty one samples were collected for biostratigraphic and geochemical analyses.

The oldest radiolarian cherts, documented in this work, are late Norian in age (Section 6) for the presence of *Betraccium deweveri* Pessagno & Blome and *Tetraporobrachia* sp. A sensu Carter (1993); these cherts are associated with basaltic rocks with OIB (Ocean Island Basalt) character.

OIB type volcanic rocks are also found in the Section 1 and Section 3 and are associated with radiolarian cherts of middle-late Oxfordian to late Kimmeridgian-early Tithonian age (Section 3), for the occurrence of *Podocapsa amphitreptera* Foreman with *Fultacapsa sphaerica* (Ozvoldova), and late Valanginian to late Hauterivian age (Section 1), for the presence of *Aurisaturnalis variabilis variabilis* (Squinabol) with *Hemicryptocapsa capita* Tan.

E-MORB (Enriched Mid-Ocean Ridge Basalt) type rocks are associated with radiolarian cherts of middle late Barremian-early early Aptian age (Section 4), for the occurrence of *Aurisaturnalis carinatus perforatus* Dumitrica & Dumitrica Jud, and Valanginian to middle Aptian-early Albian age (Section 7), for the occurence of *Cryptamphorella clivosa* (Aliev) with *Praeconosphaera sphaeroconus* (Rüst).

The oldest N-MORBs (Normal Mid-Ocean Ridge Basalt) were found in the Section 5, and are associated with radiolarian cherts of early-early late Tithonian age, for the occurrence of *Cinguloturris cylindra* Kemkin & Rudenko, *Eucyrtidiellum pyramis* (Aita), *Ristola cretacea* (Baumgartner) with *Loopus primitivus* (Matsuoka & Yao). Other N-MORBs are associated with radiolarian cherts of late Valanginian-early Barremian age (Section 8), for the occurrence of *Cecrops septemporatus* (Parona).

At last P-MORBs (Plume type Mid-Ocean Ridge Basalt) type rocks were found in the Section 2 and the radiolarian cherts show an early-middle Bajocian to late Bathonian-early Callovian age, for the presence of *Stichomitra* (?) *takanoensis* Aita.

Summarizing, we document the occurrence of OIB-type rocks of Late Triassic, as well as of rocks showing different geochemical affinities (N-, E-, P-MORBs and OIB) belonging to the Middle-Late Jurassic-Early Cretaceous time span. N-MORBs are compatible with composition of melts generated by partial melting of a depleted MORB mantle source. In contrast, OIBs are compatible with partial melting of enriched-type mantle source. E-MORBs may have derived from mantle source slightly enriched with respect to DMM (Depleted MORB Mantle) source, whereas P-MORBs are compatible with melts generated from a mantle source significantly enriched, compared to DMM. The chemical differences shown by these basalts can be related either to differences in source composition or different tectonic settings of formation, which may have existed during the Late Jurassic-Early Cretaceous time span.

Reference

Carter, E.S., 1993. Biochronology and paleontology of uppermost Triassic (Rhaetian) radiolarians, Queen Charlotte Island, British Columbia, Canada. Mém. Géol. (Lausanne) 11, 1-175.

Key words: Ophiolites, basalts, geochemistry, radiolarians, Triassic, Jurassic, Early Cretaceous, the Izmir-Ankara Mélange, Turkey.

Lower and Middle Jurassic Radiolaria from cherts of the Kiselevka-Manoma accretionary complex (lower flow of Amur River, eastern Russia)

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The Kiselevka-Manoma Complex is represented by Jurassic – Early Cretaceous cherts, basic volcanics and limestones. It is the youngest accretionary complex of Sikhote-Alyn accretionary system. It forms long, narrow and discontinuous band along lower flow of Amur River, and it is located directly east from Amur Terrane composed of Lower Cretaceous clastics (Khanchuk et al., 1994; Zyabrev, 1994, 1996; Zyabrev et al., 2005). Kiselevka-Manoma Complex was repeatedly studied during long time interval. Units of this complex exposed in type locality near Kiselevka Village were dated by ammonoids and bivalvs from limestones as Lower Jurassic (most possibly Hettangian to Sinemurian) (Zhamoida, 1972), and as Upper Triassic – Lower Jurassic by radiolarians studied from cherts in thin sections (Zhamoida, 1972). Later studies substantionally changed and detalized the stratigraphy of the Kiselevka-Manoma Complex. According to Zyabrev (1996) and Zyabrev & Anoikin (2013), this complex consists of:

1. Basic volcanics and Liassic limestones in tectonic contact.
2. Cherts, mostly red, sometimes interbedded with cherty mudstones, with radiolarian assemblages ranging from Lower Jurassic to Lower Cretaceous (Hauterivian).
3. Olive-grey cherty mudstones, replaced upsection by dark-grey mudstones, with radiolarians of Lower Cretaceous (Barremian – middle Aptian)
4. Clastic turbidites.

Cretaceous Radiolaria were illustrated by Zyabrev, but Jurassic ones still remained not illustrated and even not studied, so that we have no exact knowledge of their age/composition as well as of detailed stratigraphy of Jurassic part of the Kiselevka-Manoma Complex. The aim of this work is to give first results on the Lower to Middle (Toarcian – Bajocian) Jurassic radiolarians. We studied the chert units on the left bank of Amur River west from Izvestkovyi Bay. Cherts exposed here are deformed into large synform complicated by thrusts and shear zones. Cherts are characterized by abundant radiolarians that allow to reconstruct the part of stratigraphic section starting from lower part:

Unit 1. Red to brownish-red clayey cherts intercalated with brownish-red cherty mudstones with Pliensbachian to lower Toarcian Radiolaria: *Canoptum* sp. cf. *C. anulatum* Pessagno & Poisson, *Crucella* sp., *Hsuum* sp. cf. *H. exiguum* Yeh & Cheng, *Katroma clara* Yeh, *Katroma* sp. cf. *K. ninstintsi* Carter, *Lantus* sp. cf. *L. obesus* (Yeh), *Parahsuum ovale* Hori & Yao, *Paronaella* sp. cf. *P. corpulenta* De Wever, *Paronaella* sp. cf. *P. curticrassa* Carter & Dumitrica, *Pleesus* sp. cf. *P. aptus* Yeh. Upper part of unit is characterized by *Bistarkum* sp. cf. *B. rigidium* Yeh, *Citriduma* sp. cf. *C. hexaptera* (Conti & Marcucci) and *Parahsuum* sp. aff. *P. edenshawi* (Carter). Thickness is 20-25 m.

2. Red ribbon cherts with rare intercalations of grey cherts and red cherty mudstones with the following radiolarian assemblages:

Middle Toarcian to lower Aalenian with *Crucella* sp. cf. *C. angulosa* (s.l.) Carter, *Hsuum exiguum* Yeh & Cheng, *Hsuum* sp. aff. *H. exiguum* Yeh & Cheng, *Hsuum* sp. cf. *H. lucidum* Yeh, *Parasaturnalis* sp. cf. *P. yehae* Dumitrica & Hori and *Paronaella grahamensis* Carter;

Lower Aalenian to lower-middle Bajocian with *Hsuum matsuokai* Isozaki & Matsuda, *Linaresia* sp., *Parahsuum* ? sp. cf. *P. hiconocosta* Baumgartner & De Wever, *Parahsuum* ? *grande* Hori & Yao, *Parahsuum* sp. cf. *P. longiconicum* Sashida and *Parasaturnalis diplocyclis* (Yao);

Upper Aalenian to upper Bajocian with *Hexasaturnalis hexagonus* (Yao), *Parahsuum* ? *hiconocosta* Baumgartner & De Wever, *P.* ? sp. cf. *P. natorense* (El Kadiri), *P.* ? sp. cf. P. magnum Takemura and *Tetraditryma* sp. cf. *T. praeplena* Baumgartner;

Lower to middle Bajocian with *Dictyomitrella* (?) sp. aff. *D. kamoensis* Mizutani & Kido, *Emiluvia splendida* Carter, *Sella benilderkoulensis* (El Kadiri), *Sella chrafatensis* (El Kadiri), *Mirifusus proavus* Tonielli, *Palinandromeda* sp. cf. *P. sognoensis* Baumgartner, *Parahsuum* sp. aff. *P. izeense* (Pessagno & Whalen), *P.* sp. cf. *P. izeense* (Pessagno & Whalen), *Transhsuum maxwelli* (Pessagno), *T. hisuikyoense* (Isozaki & Matsuda) and *Tritrabs simplex* Kito & De Wever. Thickness is 40-50 m.

These chert units are in tectonical contact with clastic turbidites in the west and are limited by shear zone in the east, furthermore chert blocks in this shear zone have Early Cretaceous age. Therefore we examined only fragment of Jurassic section and we still don't know the oldest age of the section as well as the composition of Upper Jurassic radiolarian assemblages. At last the examined Lower and Middle Jurassic assemblages display clear Tethyan affinity and they were analyzed utilizing the biozonations of Baumgartner et al. (1995) and Carter et al. (2010).

References

Baumgartner, P.O., Bartolini A., Carter E.S. & others, 1995. Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on unitary associations. Mem. Geol. Lausanne. 23, 1013-1048.

Carter, E.S., Goričan, Š., Guex J. & others, 2010. Global radiolarian zonation for the Pliensbachian, Toarcian and Aalenian. Palaeogeography, Palaeoclimatology, Palaeoecology 297, 401-419.

Khanchuk, A.I., Ognyanov, N.V., Popova, I.M. & Filippov, A.N., 1994. New data on the Early Cretaceous deposits of the Lower Amur region. Dokl. Ross. Akad. Nauk 338**,** 5, 666–671.

Zhamoida, A.I., 1972. Biostratigraphy of the Mesozoic chert units of the East of USSR (on the base of radiolarian study). Ministry of geology USSR. Trans. All Union Geological Scientific Research Institute (VSEGEI), N.S. 183, 1-238.

Zyabrev, S.V., 1994. Early Cretaceous cherts of the Kiselevka–Manoma terrane—the youngest oceanic deposits in the structure of southern continental part of Russian Far East // Tikhookeanskaya Geologiya 6, 74–82.

Zyabrev, S.V., 1996. Cretaceous radiolarian fauna from the Kiselyovsky subterrane, the youngest accretionary complex of the Russian continental far east: Paleotectonic and paleogeographic implications. The Island Arc 5, 140-155.

Zyabrev, S.V. & Anoikin V.I., 2013. New age data on the deposits of the Kiselevka–Manoma accretionary complex based on radiolarian fossils. Russian Journal of Pacific Geology 7 3, 217–225.

Zyabrev, S.V., Martynyuk, M.V. & Shevelev, E.K., 2005. Southwestern fragment of the Kiselevka–Manoma accretionary complex, Sikhote-Alin: stratigraphy, subduction accretion, and post-accretionary displacements. Tikhookeanskaya Geologiya 24 1, 45–58.

Key words: Radiolaria, Lower Jurassic, Middle Jurassic, accretionary complex, eastern Russia.

Late Cretaceous and early Eocene radiolarian faunas from the internal Makran Accretionary Wedge (southeast Iran)

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The Makran accretionary wedge is active since at least the Late Cretaceous. It developed as a thrust-and-fold belt with forward propagation of thrusting, sediment underplating at the front and subsequent thickening and uplift of the accretionary complex. In the hinterland, the highest thrust unit is North Makran, which comprises 1) remnants of a continental sliver; 2) a succession of non-metamorphic ophiolites overlain by Cretaceous deep-water sediments and 3) an imbricate zone including non-metamorphic and anchimetamorphic to blueschist-facies marine sediments and volcanics (Burg et al., 2013).

Sample Mak-07-159 comes from an olistholith in a late Miocene giant olisthostrome covering much of the outer fold-and-thrust belt and postdating the thrusting of North Makran onto the outer wedge (Burg et al., 2008). The co-occurrence of *Pseudotheocampe urna* (Foreman) and *Stichomitra mediocris* (Tan) dates the sample to the Coniacian to Santonian, most probably the Coniacian (ranges after Popova-Goll et al., 2005; Robin et al., 2010) and testifies to the former presence of non-metamorphic radiolarites of Cretaceous age in North Makran wherefrom the olisthostrome is derived.

Sample Mak-09-128 comes from a non-metamorphic succession of radiolarites, shales and volcanics in a tectonic window below low-grade metamorphic rocks in North Makran. The age of the radiolarites is early Eocene, based on the co-occurrence of *Podocyrtis acalles* Sanfilippo & Riedel and *Theocotylissa ficus* (Ehrenberg) (ranges after Hollis, 2006; Jacket et al., 2008). This fauna is particularly important because it shows that 1) these radiolarites are age-equivalent with Eocene pelagic deposits underlying the Tertiary terrigenous turbidites in the accretionary wedge beneath North Makran; 2) non-metamorphic Tertiary sediments occur in a tectonic window below the North Makran units; 3) North Makran is a collage of metamorphic and non-metamorphic units thrust as a composite unit after the early Eocene onto the modern accretionary wedge.

References

Burg, J.-P., Bernoulli, D., Smit, J., Dolati, A. & Bahroudi, A., 2008. A giant catastrophic mud-and-debris flow in the Miocene Makran. Terra Nova 20, 188-193.

Burg, J.-P., Dolati, A., Bernoulli, D. & Smit, J., 2013. Structural style of the Makran Tertiary accretionary complex. In: Lithosphere Dynamics and Sedimentary Basins: The Arabian Plate and Analogues (Al Hosani, K., Roure, F., Ellison, R. & Stephen, L., Eds.), Frontiers in Earth Sciences, Springer-Verlag, Heidelberg, 239-259.

Hollis, C.J., 2006. Radiolarian faunal turnover through the Paleocene-Eocene transition, Mead Stream, New Zealand. Eclogae geol. Helv. 99, Supplement 1, S79–S99.

Jackett, S.J., Baumgartner, P.O. & Bandini, A.N., 2008. A new low-latitude late Paleocene-early Eocene radiolarian biozonation based on unitary associations: applications for accreted terranes. Stratigraphy 54, 1, 39-62.

Popova-Goll, I., Vishnevskaya, V. & Baumgartner, P.O., 2005. Upper Cretaceous (Santonian-Campanian) radiolarians from Voronesh Anticline, southwestern Russia. Micropaleontology 51, 1, 1-38.

Robin, C., Goričan, Š., Guillocheau, F., Razin, P., Dromart, G. & Mosaffa, H., 2010. Mesozoic deep-water carbonate deposits from the southern Tethyan passive margin in Iran (Pichakun nappes, Neyriz area): biostratigraphy, facies sedimentology and sequence stratigraphy. In: Tectonic and Stratigraphic Evolution of Zagros and Makran during the Mesozoic-Cenozoic (Leturmy, P. & Robin, C., Eds.), Geological Society of London Special Publication 330, 179-210.

Key words: Radiolarite, Late Cretaceous, early Eocene, the Makran Accretionary Wedge, Iran.

Deciphering geodynamic clues from radiolarian biochronology in the Lesser Caucasus and NW Iran

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The ophiolites that crop out in the Lesser Caucasus (Armenia, Karabagh) are part of an over 2,000 Km-long suture zone, which runs through the northern part of Turkey towards Iran. The dating of the siliceous sedimentary cover of these ophiolites is important for understanding the geodynamic evolution of the greater area between Eurasia and the South-Armenian Block, a Gondwana-derived microcontinent.

The examined radiolarian assemblages establish that radiolarian cherts, overlying or intercalated with lavas flows, accumulated during the Bajocian to Cenomanian interval. The Bajocian is now widely established for both the Sevan-Hakari and Vedi ophiolites. An early-middle Bajocian radiolarian assemblage characterized by the co-occurrence of *Parasaturnalis diplocyclis* (Yao) and *Archicapsa* (?) *pachyderma* (Tan) (U.A.Z. 3) was recently extracted from a chert that is in stratigraphic contact with variolitic lavas in a block included in the Cretaceous mélange unit of the Erakh anticline (south of Yerevan, Armenia) and related with the Vedi ophiolite.

New radiolarian ages, obtained recently on numerous tuffites intercalated in siliceous sequences along the Amasia-Sevan ophiolite zone (Amasia, Sarinar, Old Sodk pass sections) suggest that subaerial volcanic activity was underway for most of the Middle Jurassic to Lower Cretaceous interval (Bajocian/Bathonian to Albian).

The Bajocian appears to be a key time interval for the onset of a new geodynamic regime in the Tethyan domain of the Lesser Caucasus, with the initiation of a Mariana-type subduction below the Eurasian margin and probably with the opening of a marginal back-arc basin situated behind an intra-oceanic subduction zone.

The Cenomanian is another time interval of major geodynamic changes in this area, involving both the late stages of submarine oceanic magmatic activity (as established in the Amasia region) and the obduction of ophiolites onto the South-Armenian Block (established in the Vedi region).

Finally, recent biostratigraphic results from the Khoy ophiolite in NW Iran provide evidence for the presence of subaerial volcanic activity for most of the Middle Jurassic to Lower Cretaceous interval and more specifically between the latest Bajocian/early Bathonian (U.A.Z. 5) and the latest Tithonian/earliest Berriasian to early Valanginian (U.A.Z. 13-16).

Key words: Radiolaria, Jurassic, Armenia, Lesser Caucasus, Iran.

Denudation history of mid-Mesozoic accretionary complexes in East Asia: compilation of microfossil-bearing clasts within the Upper Mesozoic strata

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Upper Mesozoic neritic–terrestrial strata in East Asia interbed conglomerates including microfossil-bearing clasts (e.g. Ishida et al., 2003; Ito et al., 2012). Some clasts were assumedly derived from mid-Mesozoic accretionary complexes (ACs) in East Asia (inc. the Tamba-Mino-Ashio, Chichibu composite, Samarka, Khabarovsk, Taukha and other terranes). Previous researches have discussed the initiation of the denudation of the mid-Mesozoic ACs (Takeuchi et al., 1991; Kamata et al., 2000), whereas few studies have highlighted staged denudation of the mid-Mesozoic ACs. This study compiles previous reports of microfossil-bearing clasts within the Upper Mesozoic in the Inner Zone of Southwest Japan and in the southeastern Korean Peninsula, in addition to our previous data (Ito et al., 2012, 2014, in press). As a result, three denudation stages (Stages A, B and C) are recognized.

A pre-stage (–Kimmeridgian) is characterized by no-denudation. Microfossil-bearing clasts occurred in some pre-Kimmeridgian strata in the Inner Zone of southwest Japan, but these clasts yielded only Permian radiolarians probably originated from pre-Mesozoic units (e.g. the Akiyoshi and the Maizuru terranes).

Stage A (Tithonian–Hauterivian) is characterized by initial and narrow denudation. There are a few reports of mid-Mesozoic-AC-derived clasts in previous studies in this stage, suggesting a denudation narrow in extent.

Stage B (Barremian–early Albian) is characterized by wide denudation and supply of Jurassic clasts. Microfossil-bearing clasts, presumed to be originated from the mid-Mesozoic ACs, have occurred in many geologic units corresponding partially to the Barremian–early Albian (e.g., the Mizukamidani and the Itsuki formations). Additionally, Middle Jurassic radiolarians occurred in chert clasts within the Itsuki Formation (Ito et al., in press) and in a siliceous mudstone clast within the Mizukamidani Formation (Ito et al., 2014). Based on the general features of the mid-Mesozoic ACs, the former clast was derived from Middle or early Late Jurassic ACs and the latter clasts were derived from the late Middle Jurassic or younger ACs.

Stage C (late Albian–) is characterized by denudation of all-age of the mid-Mesozoic accretionary complexes. Clasts within the Kisadong Formation of the Hayang Group yielded Tithonian radiolarians (Kamata et al., 2000), although the radiolarian origins are uncertain. Tithonian radiolarians occurred in the Early Cretaceous ACs (e.g. Matsuoka et al., 1998), which are nearly the youngest in the mid-Mesozoic ACs. Consequently, if the Tithonian radiolarians were not derived from a matrix but from a clast, Tithonian microfossil-bearing clasts started to be supplied by the depositional time of the Kisadong Formation in the provenance of the Hayang Group. Here, the Kisadong Formation corresponds tentatively to the Albian based on geochemical dating (e.g., Lee et al., 2010).

These denudational changes seem to be consistent with some events in East Asia, such as the uplift of the Tetori Group in the late Hauterivian–early Barremian (e.g., Matsukawa and Fukui, 2009) and the initiation of the granitic activity in the middle Albian (e.g., Isozaki et al., 2010). These events might be related to the denudational changes.

References

Ishida, K., Kozai, T., Park, S.O. & Mitsugi, T., 2003. Gravel bearing radiolarian as tracers for erosional events: a review of the status of recent research in SW Japan and Korea. Journal of Asian Earth Science 21, 909–920.

Isozaki, Y., Aoki, K., Nakama, T. & Yanai, S., 2010. New insight into a subduction-related orogen: A reappraisal of the geotectonic framework and evolution of the Japanese Islands. Gondwana Research 18, 82–105.

Ito, T., Sakai, Y., Feng, Q.L. & Matsuoka, A., in press. Middle Jurassic radiolarians from chert clasts within conglomerates of the Itsuki Formation of the Itoshiro Subgroup (Tetori Group) in the Taniyamadani Valley, Fukui Prefecture, central Japan. Science Reports of Niigata University (Geology) 30.

Ito, T., Sakai, Y., Ibaraki, Y. & Matsuoka, A., 2014. Middle Jurassic radiolarians from siliceous mudstone clast within the Tetori Group in the Itoigawa area, Niigata Prefecture, central Japan. Science Reports of Niigata University (Geology) 29, 1–11.

Ito, T., Sakai, Y., Ibaraki, Y., Yoshino, K., Ishida, N., Umetsu, T., Nakada, K., Matsumoto, A., Hinohara, T., Matsumoto, K. & Matsuoka, A., 2012. Radiolarian fossils from siliceous rock pebbles within conglomerates in the Mizukamidani Formation of the Tetori Group in the Itoigawa area, Niigata Prefecture, central Japan. Bulletin of the Itoigawa City Museums 3, 13–25 (in Japanese with English abstract).

Kamata, Y., Hisada, K. & Lee, Y.I., 2000. Late Jurassic radiolarians from pebbles of Lower Cretaceous conglomerates of the Hayang Group, southeastern Korea. Geosciences Journal 4, 165–174.

Lee, Y.I., Choi, T.J., Kim, H.S. & Orihashi, Y., 2010. Detrital zircon geochronology of the Cretaceous Sindong Group, southeast Korea: Implications for depositional age and Early Cretaceous igneous activity. Island Arc 19, 647–658.

Matsukawa, M. & Fukui, M., 2009. Hauterivian–Barremian marine molluscan fauna from the Tetori Group in Japan and late Mesozoic marine transgressions in East Asia. Cretaceous Research 30, 615–631.

Matsuoka, A., Yamakita, S., Sakakibara, M. & Hisada, K., 1998. Unit division for the Chichibu Composite Belt from a view point of accretionary tectonics and geology of western Shikoku Japan. Journal of the Geological Society of Japan 104, 634–653 (in Japanese with English abstract).

Takeuchi, M., Saito, M. & Takizawa, F., 1991. Radiolarian fossils obtained from conglomerate of the Tetori Group in the upper reaches of the Kurobegawa River, and its geologic significance. Journal of the Geological Society of Japan 97, 345–359 (in Japanese with English abstract).

Key words**:** Accretionary complex, conglomerate, denudation, East Asia, Upper Mesozoic, provenance.

Lithology and geochemistry of chert-argillaceous rock sequences in the Inthanon Zone, northern Thailand: implications for accretionary ages in the Paleo-Tethys subduction zone

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Two chert-argillaceous rock sequences in the Inthanon Zone (Ueno & Charoentitirat, 2011), of northern Thailand, were examined, based on lithology, radiolarian biostratigraphy, and geochemistry. Lithological changes from well-bedded radiolarian chert to argillaceous rocks are gradual, and indicate that the depositional site of these sequences had migrated from a pelagic area of the Paleo-Tethys to near a trench where was influenced by the terrigenous influx near an active continental margin. The migration towards the trench indicated by the lithological change implies that the formation of the accretionary complex is related to the subduction of the Paleo-Tethys oceanic plate. In the two studied sections, radiolarian biostratigraphy has allowed to date lithological changes from well-bedded radiolarian chert to argillaceous rocks as Early Permian (Asselian) and Middle Permian (Capitanian), respectively. Microscopic observation showed that well-bedded radiolarian chert consists primarily of radiolarian tests with microcrystalline quartz matrix and absence of the terrestrial grains such as detrital quartz grains. Whereas overlying argillaceous rocks contain detrital quartz grains which increase in abundance upsection. X-ray diffractometer patterns of the sections show an upward increasing clay mineral content. The concentration profile of terrestrial-derived elements such as Al_2O_3, Rb, and Zr (e,g., Tada & Iijima, 1992; Jones & Manning, 1994; Murray, 1994; Hori et al., 2007) also have a tendency to increase with upsection, confirming the lithologic change from the lower chert to the upper argillaceous rocks. These increasing tendencies showing in the lithological and geochemical data indicate that the sequences are equivalent of a part of Ocean Plate Stratigraphy (OPS) that is a representative succession of an accretionary complex (e.g., Isozaki et al., 1990; Matsuda & Isozaki, 1991; Wakita & Metcalfe, 2005). The presented two sections are particularly equivalent to the chert-siliceous shale (pelagic to hemipelagic facies) transitional part of the OPS based on the mentioned above features. The migration of the sedimentary sites shown in this study suggests formation of an accretionary complex at the trench where the Paleo-Tethys oceanic plate subducted under Indochina (including the Sukhothai arc).

References

Hori, R.S., Higuchi, Y., Fujiki, T., Maeda, T. & Ikehara, M., 2007. Geochemistry of the Oruatemanu Formation, Arrow Rocks, Northland, New Zealand. In: The Oceanic Permian/Triassic Boundary Sequence at Arrow Rocks (Oruatemanu), Northland, New Zealand (Spoerli, K.B., Takemura, A., Hori, R.S., Eds.), GNS Sci. Monograph, 24. GNS Sci., Lower Hutt, 123–156.

Imai, N., Terashima, S., Itoh, S. & Ando, A., 1996. 1996 compilation of analytical data on nine GSJ geochemical reference samples, “Sedimentary Rock Series”. Geostand. Newsletter 20, 165–216.

Isozaki, Y., Maruyama, S. & Furuoka, F., 1990. Accreted oceanic materials in Japan. Tectonophysics 181, 179–205.

Jones & Manning, D.A.C., 1994. Comparison of geochemical indices used for the interpretation of paleoredox conditions in ancient mudstones. Chem. Geol. 111, 111–129.

Matsuda, T. & Isozaki, Y., 1990. Well-documented travel history of Mesozoic pelagic chert in Japan: from remote ocean to subduction zone. Tectonics 10, 475–499.

Murray, R.W., 1994. Chemical criteria to identify the depositional environment of chert: general principles and applications. Sed. Geol. 90, 213–232.

Tada & Iijima A., 1992. Lithostratigraphy and compositional variation of Neogene hemipelagic sediments in the Japan Sea. Proc. ODP Sci. Res. 127/128, 1229–1260.

Ueno, K. & Charoentitirat, T., 2011. Carboniferous and Permian. In: The Geology of Thailand (Ridd, M.F., Barber, A.J. & Crow, M.J., Eds.), The Geological Society of London, 71-136.

Wakita, K. & Metcalfe I., 2005. Ocean Plate Stratigraphy in East and Southeast Asia. Journal of Asian Earth Sciences 24, 679–702.

***Key words*:** Paleo-Tethys, accretionary complex, chert, the Inthanon zone, Thailand.

Cretaceous radiolarians from chert-clastic rock sequence of the Matoya Group (Northern Shimanto belt), Kii Peninsula, southwest Japan

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The Shimanto belt, located in the Pacific side of the Japanese Islands, presented the Cretaceous (northern part) to Paleogene (southern part) convergent margin between the subducting Kula plate (paleo-Pacific plate) and the overlying continental plate. The Matoya Group (Upper Cretaceous accretionary complexes in the Northern Shimanto belt) is exposed on the Kii Peninsula, and is characterized by a tectonic stacking of thrust-bounded sedimentary sequences; they consist of bedded chert (lower pelagic unit), siliceous mudstone (middle hemipelagic unit) and silty mudstone and sandstone (upper terrigenous unit).

The Matoya Group has been thought to be Albian to Maastrichtian complexes as a whole based on poor biostratigraphic data (Nakaseko & Nishimura, 1981; Ohase, 1983), therefore age constraints for the evolution of this group are still rare. In order to reveal the origin of the Matoya Group and the timing of its accretion, this research was carried out in the Ijika Section, eastern part of the Kii Peninsula (Toba district), where one of the thrust-bounded sedimentary sequences is well exposed.

The Ijika Section starts with bedded chert of the lower unit (72 m), and is followed by siliceous mudstone of the middle unit (24 m) and silty mudstone of the upper unit (20 m), totally reaching 166 m in thickness. Its basal portion is unknown due to the lack of outcrop, and the silty mudstone is separately located approximately 50 m above the siliceous mudstone through the lack of outcrop. During the mapping, samples collected from eight horizons of this section contained moderately- to well-preserved radiolarian assemblages. They gave the following ages (according to the UAZ of O'Dogherty, 1994).

In the lower unit, four samples were respectively collected from cherts of 30 m, 40 m, 46 m and 59 m above the base of the section. The lower two samples were assigned to UAZ 11 (middle Albian) for the co-occurrence of *Stichomitra japonica* (Nakaseko & Nishimura), *Rhopalosyringium perforaculum* O'Dogherty and *Ultranapora durhami* Pessagno. The upper two samples were probably referable to the interval from UAZ 12 to UAZ 15 (upper Albian to lower Cenomanian) on the basis of the occurrence of *Pseudodictyomitra paronai* (Aliev), *Xitus mclaughlini* Pessagno, and *Thanarla pulchra* (Squinabol).

In the middle unit, two samples of siliceous mudstones were obtained from the horizons of 92 m and 95 m above the base. The lower sample was correlated with UAZ 17 by the last occurrence of *Dictyomitra gracilis* (Squinabol) and *Crolanium triangulare* (Aliev). The other was referable to UAZ 18 for the first occurrence of *Stichomitra stocki* (Campbell & Clark) and *Patellula verteroensis* (Pessagno). The both samples were assigned to the middle Cenomanian.

In the upper unit, two silty mudstone samples, stratigraphically spaced 10 m apart from each other, were collected. The lower sample was correlated with UAZ 20 (lower Turonian) based on the last occurrence of *Dictyomitra montisserei* (Squinabol), and the upper sample was referable to UAZ 21 (lower Turonian) or much younger, probably indicating Coniacian, on the basis of the occurrence of *Pseudoaulophacus floresensis* Pessagno (Schaaf, 1985).

The following conclusions can be drawn from the above preliminary results:

1) The sedimentary sequence of the Ijika Section in the Toba district stratigraphically ranges at least from the middle Albian to the Coniacian.

2) Duration of pelagic sedimentation on the Kula plate seafloor characterized by bedded chert and siliceous mudstone cannot be estimated, for the reason of the lack of any radiolarian evidence from the base of the sequence.

3) Age constraint for the timing of accretion was successfully given by silty mudstone of the upper unit through this research, indicating the Coniacian.

4) To the west of the Toba area, similar sedimentary sequences of the Matoya Group are distributed and were accreted during the Campanian age (Nakae, 2012). This example suggests that the Matoya Group can be divided into several subgroups or units according to the different timing of each accretion.

References

Nakae, S., 2012. Radiolarian dating of the sedimentary sequence on oceanic basalts of Upper Cretaceous Matoya Group in the Shimanto belt, Kii Peninsula, SW Japan. Proceedings of 13th InterRad 233–234.

Nakaseko, K. & Nishimura, A., 1981. Upper Jurassic and Cretaceous radiolaria from the Shimanto Group in Southwest Japan. Science Reports, College of General Education, Osaka Univ. 30, 133–203.

O'Dogherty, L., 1994. Biochronology and paleontology of mid-Cretaceous radiolarians from northern Apennines (Italy) and Betic Cordillera (Spain). Mémoires de Géologie (Lausanne) 21, 415p.

Ohase, M., 1983. The Shimanto Group in eastern part of Shima Peninsula. Abstract Vol. 90th Ann. Meet. Geol. Soc. Japan, 182 (in Japanese).

Schaaf, A., 1985. Un nouveau canevas biochronologique du Crétacé inférieur et moyen: les biozones à radiolaires. Sciences géologique (Strasbourg) Bulletin 38, 227–269.

Key words**:** Cretaceous, Radiolaria, the Matoya Group, the Northern Shimanto belt, Kii Peninsula, southwest Japan.

Early Permian radiolarians from the west of Cambodia

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The maroon chert/shale sequences from several quarries in the east of Pailin town, west of Cambodia contain Early Permian radiolarians including *Psudoalbaillella elegans* Ishiga & Imoto, *P. lomentaria* Ishiga & Imoto , *P. sakmarensis* (Kozur), *P. scalprata* Ishiga, *P. simplex*, *P. u-forma*, *P.* spp., *Longtanella* sp. cf. *L. zhenphanshanesis*, *Letentifistula* sp. This radiolarian fauna is similar to those reported from Japan, Oregon, south China, Malaysia and eastern Thailand which indicates an Early Permian age for the chert sequences. In the Pailin section, the cherts are in contact with a typical oceanic lithosphere igneous assemblage including serpentinized ultramafics, gabbro and pillow basalt. These all occur in one quarry, suggesting that these are part of a dismembered back-arc basin assemblage rather than that of a major ocean basin. The Pailin outcrops are not part of a mélange but their age is consistent with that of the Thung Kabin Mélange found in the Sa Kaeo Suture in the east of Thailand. This finding shows that the back-arc basin extended to the east in Cambodia but its passage through Cambodia still needs to be studied. Further study will provide details in both radiolarians and geochemistry of the chert/shale sequences in order to constrain the depositional environment and tectonic evolution of the terranes.

***Key words*:** Permian, radiolarians, back-arc basin, Cambodia.

Rare earth geochemistry of Late Devonian radiolarian chert/shale sequences from the Truongson Foldbelt, Indochina Terrane; implication to basin evolution

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Late Devonian radiolarian chert and siliceous shale are found in outcrops in the Vilaboury area, Sepon district in the central part of Lao PDR. The locality is part of the Troungson Foldbelt in the eastern margin of the Indochina terrane. The rock samples from this locality, together with the published radiolarian siliceous shale from the Phon Xai section (Thassanapak et al., 2012) further north in the foldbelt were prepared for geochemical analysis in order to understand their depositional environment and the basin evolution.

The fauna from the Vilaboury sections is characterized by a distinctive and moderately well-preserved radiolarian and tentaculitid assemblage. The majority of radiolarians belong to the genus *Trilonche* including *T. davidi*, *T. echinata*, *T. elegans*, *T.hindea*, *T. palimbola* and *T.vetusta* and are assigned to the Frasnian (Late Devonian). Tentaculitids such as *Homoctenus ultimus* and *Costulatostyliolina vesca* are present and also suggest a Frasnian age. These faunas are also common in the Phon Xai section.

The occurrences of these faunas and their similarity to those reported in the South China Block (e.g., Wang, 1990; Wang et al., 2003) imply a common palaeogeography of these terranes during the Late Devonian. Rare earth element (REE) data of Late Devonian chert/shale sequences from the Vilaboury and Phon Xai sections exhibit slightly negative Ce anomalies (Ce/Ce*= 0.44-0.72 with geomean 0.63 and 0.61-0.88 with geomean 0.76, respectively) suggesting the sequences formed in an open marine basin and continental margin environment, respectively. Intermediate ratios of North American Shale Composite (NASC) normalized La_n/Ce_n (1.40-2.42 with geomean 1.59 and 1.11-1.73 with geomean 1.34, respectively) further support this interpretation.

The NASC normalized La_n/Yb_n values (0.48-1.24 with geomean 0.71 and 0.53-1.70 with geomean 0.78, respectively) indicate removal of LREE relative to HREE from the water column and suggest a depositional environment far from terrigenous sources. The Eu/Eu* values is not pronounced and indicates that sedimentation was little influenced by hydrothermal particulates.

The results reveals that open marine (Vilaboury section) and continental margin (Phon Xai section) conditions existed without hydrothermal influence during the Late Devonian along the Truongson Foldbelt. These results imply that the basin closed by latest Devonian-Early Carboniferous, which is supported by the occurrence of thick siliciclastic and carbonate sequences during Late Palaeozoic along the western margin of the foldbelt. Our ongoing research on basin evolution by means of radiolarians and the geochemistry of siliceous rocks and other geological evidence will provide more understanding on the tectonic evolution of the foldbelt.

References

Thassanapak, H., Udchachon, M. & Burrett, C., 2012. Devonian radiolarians and tentaculitids from central Laos. Journal of Asian Earth Science 60, 104-113.

Wang, J.X., 1990. Frasnian tentaculites from Yangti near Guilin City. Acta Micropalaeontologica Sinica (Wei Ti Ku Sheng Wu Hsueh Pao) 7, 1, 61–75.

Wang, Y.J., Aitchison, J.C. & Luo, H., 2003. Devonian radiolarian faunas from south China. Micropaleontology 49, 2, 127–145.

Key words**:** Radiolarian chert, Devonian, rare earth element, the Truongson Foldbelt, the Indochina Terrane, Lao PDR.

Space-time distribution of Radiolaria-bearing carbonate nodules in Jurassic accretionary complexes in Japan and its tectonic interpretation

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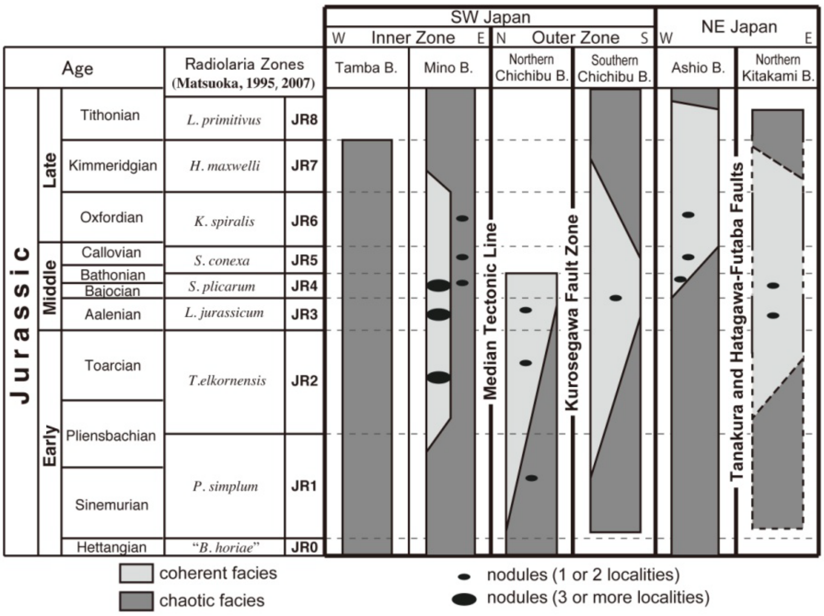
Large parts of the basement of Japanese Islands consist of Jurassic accretionary complexes. They are distributed in several geologic belts, namely Tamba and Mino Belts in the Inner Zone of the SW Japan, Northern and Southern Chichibu Belts in the Outer Zone of the SW Japan and Ashio and Northern Kitakami Belts in the NE Japan. The ages of argillaceous rocks in each belt almost cover whole Jurassic Period except for the Northern Chichibu Belt lacking late Middle to Late Jurassic. Carbonate nodules including well-preserved radiolarian tests have been reported from argillaceous rocks at many localities in these Jurassic accretionary complexes. They provide good materials for faunal analysis and systematic classification of Radiolaria. The age intervals of the reported Jurassic nodules are different between geologic belts as follows (See a compilation by Yamakita & Hori, 2009); Mino Belt: late Early to early Late Jurassic, Ashio Belt: early Middle to early Late Jurassic, Northern Chichibu Belt: early Early to early Middle Jurassic and Northern Kitakami Belt: only early Middle Jurassic. Recently, early Middle Jurassic nodules were reported as the first discovery from the Southern Chichibu Belt (Yamakita & Aita, 2014). No nodules have been found in the Tamba Belt. Thus, early Middle Jurassic nodules have been reported from all belts except for the Tamba Belt, but nodules of other ages are restricted in some belts.

The discovery of nodules is affected by some factors. One is lithology of host argillaceous rocks. If in not-disturbed and well-stratified mudstone in coherent facies, it is quite easy to find nodules. If in mélanges in chaotic facies, however, nodules are confused with other clasts or blocks in muddy matrix and difficult to be found. The reason why no nodules have been reported from the Tamba Belt mainly composed of chaotic facies can be explained in this way. Few reports of Early Jurassic nodules may be due to this reason, because chaotic facies dominate Lower Jurassic units in all these belts. However, we need other explanations for the absence of nodules of late Middle to early Late Jurassic age in the Southern Chichibu and Northern Kitakami Belts, because coherent facies of this age are widely distributed in these belts as well as in Mino and Ashio Belts where nodules occur even in chaotic facies. We should consider that nodules were not formed in this age in the former two belts.

Yamakita & Otoh (2000) reconstructed the tectonic framework of the eastern margin of the Asian continent before the Miocene opening of the Japan Sea and demonstrated the existence of a NNE-trending Cretaceous sinistral wrench fault system composed of the Median Tectonic Line (MTL) and the the Kurosegawa Fault Zone in SW Japan, the Tanakura and the Hatagawa-Futaba Faults in NE Japan and Central Sikhote-alin and the Partizansk Faults in Sikhote-alin, Far East Russia. According to this reconstruction, the Mino and the Ashio Belts with late Middle to early Late Jurassic nodules and southern Chichibu and the northern Kitakami Belts without them were located on the western and the eastern sides of this fault system respectively. The latter two belts are inferred to have been located in lower latitudes than the former in Jurassic time and have been moved northward in Cretaceous. This tectonic model offers an interpretation for the space-time distribution of the nodules. It is that nodules were formed in a wide area of hemipelagic region along the eastern margin of the Asian continent including the lower latitudes in Early to early Middle Jurassic, but some changes in sedimentary conditions stopped the formation of nodules in late Middle Jurassic in lower latitudes, while nodules continued to be formed until early Late Jurassic in the higher latitudes. Although it is not clear what conditions controlled the formation of the nodules yet, this space-time distribution may give us some suggestions to make it clear.



References

Matsuoka, A., 1995. Jurassic and Lower Cretaceous radiolarian zonation in Japan and in the western Pacific. The Island Arc 4, 140-153.

Matsuoka, A., 2007. Updated Jurassic radiolarian zonal scheme and vertical distribution of selected biostratigraphically important species. Abstracts of the 2007 Annual Meeting, Palaeontological Society of Japan 73.

Yamakita, S. & Aita, Y., 2014. The first occurrence of Jurassic radiolarian-bearing carbonate nodules from the Southern Chichibu Belt. Abstracts of the 2014 Annual Meeting, Palaeontological Society of Japan 42.

Yamakita, S. & Hori, R. S., 2009. Early Jurassic radiolarians from a carbonate nodule in the Northern Chichibu Belt in western central Shikoku, southwest Japan. News of Osaka Micropaleontologists, Special Volume 14, 497–505.

Yamakita, S. & Otoh, S., 2000. Cretaceous rearrangement processes of pre-Cretaceous geologic units of the Japanese Islands by MTL-Kurosegawa left-lateral strike-slip fault system. Memoires of the Geological Society of Japan 56, 23–38.

***Key words*:** Radiolaria-bearing nodule, Jurassic, accretionary complex, Japan, Cretaceous tectonics, strike-slip fault.

Radiolarian biostratigraphy solves the tectono-stratigraphic relationships of the Amursky and Kiselevsko-Manominsky accretionary complexes in eastern Russia

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The Amursky and Kiselevsko-Manominsky accretionary complexes developed along the eastern margin of mid Cretaceous Eurasia in response to subduction of the Pacific oceanic plates. The Kiselevsko-Manominsky complex lies in the front of the Amursky, and the two contrast in their lithologies. The Kiselevsko-Manominsky accretionary complex is almost entirely composed of oceanic chert and basalt, whereas accreted oceanic materials are scarce in the Amursky complex predominantly occupied by turbidites. There, offscraped turbidites are tectonically intercalated with the underplated fragments composed of oceanic rocks. The mode of accretion of the Kiselevsko-Manominsky complex is ambivalent. The original relationships and position of the two complexes are also arguable. As emanated from the previous studies, the Kiselevsko-Manominsky complex was situated either in its recent position with respect to the Amursky complex or alternatively, way south to it. In the former model it is related to the mid Cretaceous active continental margin, and in the latter it is associated with the mid Cretaceous volcanic island arc.

New data on radiolarian biostratigraphy help solve the issue and discriminate between the two models. Radiolarian dating of chert, siliceous mudstone and siliciclastic rock units reveals that the frontal part of the Amursky and the Kiselevsko-Manominsky accretionary complex are characterized by comparable stratigraphies, and their stratigraphic records complement each other. This makes it very unlikely that these two complexes have been unrelated and formed far away from each other. They both were accreted virtually simultaneously in the late Aptian to mid Albian interval, and likely retain their original spatial relationships.

The lack of siliciclastic material in the Kiselevsko-Manominsky complex is an intriguing feature not expected for the active continental margin setting, which calls for its thorough consideration. The overall structure of the complex is similar to the underplated slices of oceanic materials scattered in the Amursky complex, and it could be interpreted as its last and most frontal underplated portion derived from the incoming oceanic plate. The only opposing point is a substantial thickness of this portion amounting to10+ km vs. tens to hundreds of meters for the typical underplated fragments in the Amursky complex. Another plausible explanation for the tectonic emplacement of the Kiselevsko-Manominsky complex is its shaping by sinistral strike slip duplexing in the transpressional setting that took over the last stage of subduction.

Session 4
Reconstruction of Paleoenvironmental Conditions and Detection of Climate Changes Through Time Using Radiolarians

Conveners
Giuseppe CORTESE & Qinglai FENG

Universal paleontological system and analysis of species diversity of radiolarians and diatoms

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The accumulation of extensive information on the systematics and distribution of several microfossil groups has resulted in significant difficulties when trying to interpret these, often noisy, data Several information systems (IS) and databases have thus been created in order to store and process micropaleontological data.

The major difficulty in this approach is the absence of a universal data structure for morphologically differing high-rank taxa, and the complexities when dealing with species synonyms. Often, the lack of a synonymy system is responsible for incorrect information on the number of valid species and, in essence, invalidates the use of such information for estimation of species diversity and dynamics.

The paleontological IS we developed is a complex geoinformation system, which maintains and constantly improves the data on extant and extinct organisms. It consists of several independent related blocks: a micropaleontological database, bibliographic data, codes for geological and cartographic units. Each block is a separate IS, which can be used for creation of other databases.

The micropaleontological block is universal and allows the storage of information on any faunal or floral group irrespective of morphological characteristics, age range and ecology. This block includes data on extant and extinct radiolarians, diatoms, silicoflagellates, ebrioideans, actinomycids, coccolithophorids, foraminifers, sponge spicules etc.

An important feature of the program is the possibility of switching to an alternative synonymy of taxa and choosing a particular variant of supergeneric taxonomy.

The space-time distribution block stores data on taxa in any system of binding suitable for the user (administrative, tectonic, etc.), including geographical coordinates, by connecting IS with electronic maps. Information is arranged according to the principle taxon–sample, along with metadata for samples, including levels of reliability of species identification, age and geographical position.

Age encoding allows different variants (stages, formations, zones) and allows estimates of a group range with reference to the zones of other fossil groups, multiple alternative coding etc. The stratigraphic dictionary includes more than 11 000 stratigraphic terms. To transfer age data from the author's sources in a uniform standard geochronological scale, an age interpretation algorithm for 5267 different stratones has been developed.

The bibliographic block is mostly used for transferring the data on sources of information, although it can be used as an independent bibliographic IS. It currently includes 12 000 works, including about 5000 on radiolarians and more than 2000 on diatoms. About half of them contain data on species occurrences through time and are used for calculating species diversity.

The list of radiolarian synonyms contains 20 347 entries for 14 456 species, i.e., a several times greater number than reported in the literature. The constantly decreasing rate of description of new species suggests that, by 2050, new entries to the list of synonyms will not exceed 2000–3000 radiolarian names, i.e., 10% of presently known species. Based on the ratio of synonyms to species, it is possible to assume that, in the Phanerozoic, there were

15000 radiolarians, and stratigraphic range data are available for 95% of them. Such estimates are useful not only for the recognition of general trends, but also for other purposes requiring absolute values. The stored data are for both valid and open nomenclature radiolarian species. The latter amount to less than 20% of the total number of species and approximately 70% of them will likely be synonymized in the future under valid species.

The diatom list exceeds 25 000 synonyms, although the total number of species having paleontological value is less than 3000. Strelnikova (1974, 1992) considerably contributed to the analysis of diatom diversity. We analyzed as many as possible primary sources containing stratigraphic range data for this phytoplankton group, and our results agree with previous studies on changes in diversity through time. Recent reports on diatom occurrences from the Cretaceous, both in marine sediments and continental outcrops, improved our understanding of the evolution of this group during its early developmental stages.

The total number of radiolarian species (Tithonian–Danian) and their age-weighted abundance show a decrease in species diversity by approximately 20 times across this time interval. At the same time, the number of diatom species constantly increased. This asynchronous development is attributable to several factors: the younger group gradually expanded its geographical range, shifting to warmer waters (as it is also evident from migration maps), and, more importantly, outcompeted radiolarians, as diatoms had advantages in the assimilation of silica for the formation of their skeletons.

At the Cretaceous–Paleogene boundary, the number of species in both groups sharply decreased (by 5 times in radiolarians, and by 2 times in diatoms). Subsequently, siliceous phytoplankton began to surpass zooplankton in species diversity and any further changes in diversity were synchronous. This was probably connected with the establishment of a balance in the assimilation of dissolved silica.

References

Strelnikova, N.I., 1974. Diatomei pozdnego mela (Late Cretaceous diatoms of western Siberia), Moskva: Akademia Nauk SSSR 8, 203p.

Strelnikova, N.I., 1992. Diatomei paleogena (Paleogene Diatoms), Saint-Petersburg University Press, Saint-Petersburg, 312p.

***Key words*:** Radiolarians, inform sistems, avolution.

Discussion on the preservation of Miocene radiolarians and sponge spicules at IODP Site 1438 (Amami Sankaku Basin, Northern Philippine Sea)

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During IODP Expedition 351 in the Philippine Sea, a notable spike in radiolarian and sponge spicules abundance and preservation was identified between 136 to 125 mbsf at IODP Site 1438. Radiolarian biochronology and paleomagnetic data indicates that the spike occurred between 16–14 Ma in the early Middle Miocene. This interval of time is concurrent with the Miocene Climatic Optimum (MCO, about 17 to 14 Ma) but it is uncertain whether preservation of siliceous microfossils and the climatic factors are linked.

The factors that control the abundance and preservation of radiolarian and sponge spicules in that interval are very poorly understood at present. We are currently running a multidisciplinary study to investigate the mineralogy, diagenesis and alteration processes which affect the preservation of the silica tests and spicules.

Due to the synchronism of the observed spike and the MCO, another aspect of the study will involve understanding the linkage between that spike and the paleoecologic and paleoceanographic conditions during the middle Miocene in the Philippine Sea. To that end, we will try to combine the radiolarian and sponge silicon isotopes to generate a regional silicon cycling record during that time interval. The preliminary results of both aspects of the study will be presented at the conference.

Key words: Radiolarians, sponge spicules, IODP, Miocene, Philippine Sea.

Norian/Rhaetian radiolarian assemblages related to paleoenvironmental conditions of the Lagonegro Basin (southern Apennines, Italy)

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The Lagonegro Basin was part of the southwestern branch of the western Tethys Ocean during the Late Triassic. The sedimentary environment was a deepening-upward basin, bordered to the north by a system of carbonate platforms (the Apenninic and the Apulian platforms). The Lagonegro succession is characterized by Permian to Miocene formations deposited in shallow to deep basinal environments. The Upper Triassic is comprised of deep-marine sediments belonging to the Calcari con Selce Fm (late Ladinian to late Norian-early Rhaetian) and the Scisti Silicei Fm (late Norian-early Rhaetian to Late Jurassic). Lithologically, the Calcari con Selce Fm changes transitionally upward to the Scisti Silicei Fm through the “Transitional Interval”.

The cherts of the latter unit were formed mainly from radiolarian biosilica, as shown by recovery of abundant radiolarian fossils and geochemical patterns (Amodeo, 1999). The study interval can be assigned to Sevatian to lower Rhaetian on the basis of radiolarian and conodont biostratigraphy (Giordano et al., 2010, 2011).

The Norian/Rhaetian boundary interval records a change in radiolarian assemblages. Radiolarian assemblages in upper Norian beds (*Betraccium deweveri* Zone, UA 1; Carter, 1993) contain abundant spumellarians as pantanellids (*Betraccium*) and saturnalids (*Praemesosaturnalis*), and nassellarians as livarellids (*Citriduma* and *Livarella*) and canoptids. The overlying lower Rhaetian beds (*Proparvicingula moniliformis* Zone, Ass. 1 and 2, UA. 2-23) contain radiolarian assemblages dominated by spumellarians as angulobracchids (*Paronaella*), saturnalids (*Praemesosaturnalis*), paratriassoastrids (*Pseudohagiastrum*), and triarcellinids, with just a few nassellarians as livarellids (*Livarella*) and canoptids. The upper Norian radiolarian assemblages can be referred to a deep water environment, while the Rhaetian assemblages seem to be referable to a less deep water environment because of the scarcity of nassellarians The shift on radiolarian assemblage around the Norian/Rhaetian boundary was accompanied by major environmental changes which however do not correspond to lithological variations.

Deepwater redox conditions, as documented by C_{org}/P, Ce/Ce* and Fe/Al data, shifted from suboxic during the late Norian to well-oxygenated during the early Rhaetian. The transition from the Calcari con Selce to the Scisti Silicei was not synchronous across the basin, occurring earlier in deepwater sections (e.g., Madonna del Sirino, Monte Volturino) compared with shallower section (e.g., Pignola-Abriola). The depth-dependency of this change may have been triggered by a rise in the carbonate compensation depth (CCD) within the Lagonegro Basin, due to (1) a relative sea-level rise, (2) a decrease in productivity by carbonate-secreting organisms, or (3) changes in basin hydrography related to watermass restriction. However, productivity proxies (biogenic Ba and TOC) provide no evidence for productivity changes, and geochemical data (e.g., S, Mo, and U concentrations) document no changes in basinal restriction, during the study interval. We therefore hypothesize that a climate-driven change in CCD elevation, possibly related to continental weathering rates (for which the chemical index of alteration (CIA) provides evidence) was the dominant influence (Casacci et al., submitted). These climatic and oceanic changes may have been related to oceanic spreading in the western Tethyan region during the Late Triassic.

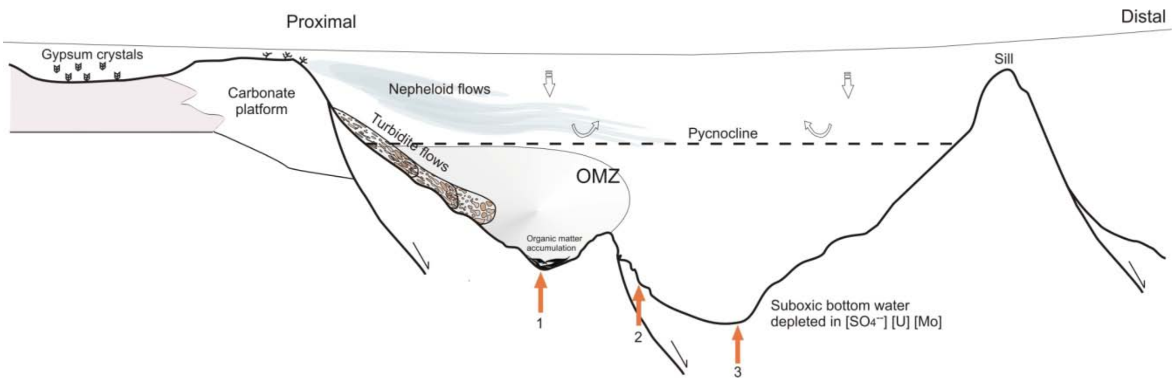

Figure 1. Interpretative depositional model for the Lagonegro Basin during the Late Norian. The three arrows show the position of the studied sections: **1** = Pignola-Abriola, **2** = Monte Volturino, **3** = Madonna del Sirino. OMZ = oxygen minimum zone (after Casacci et al., submitted).

References

Amodeo, F., 1999. Il Triassico terminale - Giurassico del Bacino Lagonegrese. Studi stratigrafici sugli Scisti Silicei della Basilicata (Italia meridionale). Mémoires de Géologie (Lausanne) 33, 160.

Carter, E.S,. 1993. Biochronology and Paleontology of uppermost Triassic (Rhaetian) radiolarians, Queen Charlotte Islands, British Columbia, Canada. Memoires de Geologie (Lausanne) 11, 1–176

Casacci, M., Bertinelli, A., Algeo, T.J. & Rigo, M., submitted. Paleoceanographic changes in the Lagonegro Basin (southern Italy) during the Late Triassic linked to oceanic rifting in the western Tethyan region. Palaeogeography, Palaeoclimatology, Palaeoecology.

Giordano, N., Rigo, M., Ciarapica, G. & Bertinelli, A., 2010. New biostratigraphical constraints for the Norian/Rhaetian boundary: data from Lagonegro Basin, southern Apennines, Italy. Lethaia 43, 573-586.

Giordano, N., Ciarapica, G., Bertinelli, A. & Rigo, M., 2011. The Norian-Rhaetian interval in two sections of the Lagonegro area: the transition from carbonate to siliceous deposition. Ital. J. Geosci. Bollettino del la Società Geologica Italiana 130, 3, 380-393.

Key words: Norian/Rhaetian, the Lagonegro Basin, radiolarian biostratigraphy, geochemistry.

A radiolarian-based modern analogue dataset for paleoenvironmental reconstructions in the southwest Pacific

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Radiolarian species relative abundances have been estimated for a suite of 88 surface sediment samples recovered from a broad area of the southwest Pacific/southern Ocean spanning from 10°S to 65°S in latitude, and 145°E to 170°W in longitude, respectively.

This allowed the documentation of a long environmental gradient (28.8 to -1.4 °C for mean annual sea-surface temperature, SST), and covered the most important surface oceanographic features in the area, including the Subtropical (STF), Subantarctic (SAF) and Antarctic Polar (APF) Fronts.

SST estimates were derived using Factor Analysis and the Modern Analog Technique (MAT). The Factor Analysis model, with a calibration error of ±1.3 ºC, was based on 93 taxa (of the 243 taxa recognised in this study) and 7 factors/assemblages, which explained 87.4% of the total information contained in the dataset. The first five assemblages are readily interpreted in terms of water masses, oceanographic fronts and regions: Subtropical Water/Tasman Front (Factor 1), Circumpolar Surface Water (Factor 2), Equatorial Pacific (Factor 3), Subantarctic Water/Campbell Plateau (Factor 4), and as a subfactor for Subtropical Water (Factor 5).

An example of the application of this modern analogue dataset to relative abundance data from sediment core Y9 is also shown. This record documents past SST changes, and subantarctic water incursions, over last 160ka at the easternmost boundary of the Campbell Plateau, east of New Zealand.

***Key words*:** Pacific Ocean, transfer functions, paleotemperature.

Paleoecology of Middle Triassic low-diversity radiolarian fauna from Mt. Svilaja (External Dinarides, Croatia)

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Ladinian dark grey limestone with chert on Mt. Svilaja in Dalmatia yielded an unusual radiolarian assemblage, characterized by very low diversity of genera, high predominance of spumellarians and entactinarians over nassellarians, and pronounced abundance of spherical radiolarians with spongy cortical shell. The composition of this assemblage is presumably related to specific life conditions in a restricted intraplatform basin.

The Triassic succession in the study area is predominantly composed of shallow-water carbonates. The succession starts with 350 m of Lower Triassic shelf siliciclastics and carbonates, assigned to the Smithian in their lowermost part. The Lower Triassic beds are unconformably overlain by the dolomitic Anisian Otarnik Breccia and then by an approximately 150 m thick succession of pelagic carbonates and pyroclastic rocks ("pietra verde") whose deposition was related to the regionally well-marked rifting phase. Five conodonts zones, from the *Neogondolella constricta* Zone (lower Upper Anisian) to the *Pseudofurnishius murchianus* Zone (upper Ladinian–?lower Carnian), were recognized in this interval (Jelaska et al., 2003). The deeper-water carbonates are capped by an emersion breccia with bauxitic clayey matrix and followed by thick-bedded Norian-Rhaetian limestone and dolomite.

Radiolarians were found 15 m above the main "pietra verde" horizon, in an 18 cm thick bed of dark grey bituminous biomicrite with chert nodules. The associated limestone beds in this part of the section contain silicified calcareous algae, foraminifers, corals, gastropods, brachiopods, crinoids and ammonites. The organic-matter content is generally high and determinable remains of terrestrial plants are also present. On the basis of conodonts and ammonoids, the radiolarian-bearing interval is assigned to the upper Lower Ladinian, that is, to the *Budurovignathus hungaricus* Conodont Zone (Jelaska et al., 2003) and to the *Protrachyceras gredleri* Ammonoid Zone (Balini et al., 2006). Most fossils were transported to the basin from adjacent shallow-water areas. Even among ammonoids, typical genera of open-marine deep-water environments are missing. Instead, the genus *Detonicera*, which has so far been reported only from carbonate-platform related faunas, occurs. The high proportion of organic matter in sediments indicates low oxygen content in bottom waters, probably due to stratified water masses and/or poor open-marine connections.

The radiolarian assemblage comprises 6 spumellarian, 7 entactinarian and 3 nassellarian genera. The generic diversity of well-known Middle Triassic assemblages from the Buchenstein and equivalent formations in the Southern Alps, Dinarides and Carpathians is much greater; well-preserved assemblages contain up to 80 genera. In the sample from Mt. Svilaja, all genera of the spumellarian family Oertlispongidae are missing. Among entactinarians, the absence of Eptingiidae is the most noticeable. Eptingiidae mostly have robust skeletons and are generally common also in poorly-preserved samples. The identified nassellarians have only one, rarely two segments, and all multicyrtid nasselarians are missing. In usual high-diversity Middle Triassic assemblages, nassellarians are approximately as abundant as spumellarians and entactinarians, but their abundance in the sample from Mt. Svilaja is less than 5 % of all radiolarian specimens.

The composition of radiolarian assemblages is strongly dependent upon bathymetry of sedimentary basins, availability of nutrients and feeding strategies of radiolarians. Research on laboratory cultured radiolarians showed a clear correspondence between morphology of radiolarian skeletons and feeding mechanisms, and the same relationships can be assumed for fossil species (Matsuoka, 2007). Four types of feeding behavior were recognized by Matsuoka (2007): multi-segmented nassellarians are the most demanding and capture relatively large prey; some other nassellarians and solitary spumellarians collect tiny prey and may bear symbiotic algae as well. The fourth group is colonial radiolarians than can live exclusively on symbiotic algae; however, this group is not known from the Mesozoic. The structure of the planktonic food web is thus an important factor controlling relative abundances of morphologically different groups of radiolarians.

The majority of highly diversified Middle Triassic radiolarian assemblages from the western Tethys were reported from sediments of relatively shallow basins with water depths not exceeding a few hundred meters. The Buchenstein Formation, which contains the best-known "normal" high-diversity faunas, represents only a short pelagic episode within a succession of platform carbonates. The relatively shallow water depth can thus not be the main reason for specific composition of the assemblage from Mt. Svilaja. It is more likely that such impoverished assemblages are characteristic of restricted basins that were separated from the open ocean by topographic barriers. A similar although less drastically reduced assemblage was described from the San Giorgio Dolomite in the westernmost part of the Southern Alps; the inferred depositional environment of this dolomite is also an intraplatform basin (Stockar et al., 2012).

In restricted basins, plankton production was limited to the upper part of the water column. Deeper water masses were stratified, oxygen deficient and sparsely populated. If photosynthetic nano- and picoplankton prevailed among primary producers in surface waters, smaller nassellarians and especially spumellarians prospered. The most fortunate were symbiont-bearing radiolarians. The conditions were apparently unfavorable for multicyrtid nassellarians that were specialized in larger prey and may have suffered from lack of appropriate food. To gain a better insight into the ecosystem of the Mt. Svilaja sedimentary basin, radiolarian research will be complemented with more detailed sedimentological studies and geochemical analyses.

References

Balini, M., Jurkovšek, B. & Kolar-Jurkovšek, T., 2006. New Ladinian ammonoids from Mt. Svilaja (External Dinarides, Croatia). Rivista Italiana di Paleontologia e Stratigrafia 112, 3, 383–395.

Jelaska, V., Kolar-Jurkovšek, T., Jurkovšek, B. & Gušić, I., 2003. Triassic beds in the basement of the Adriatic-Dinaric carbonate platform of Mt. Svilaja (Croatia). Geologija 46, 2, 225–230.

Matsuoka, A., 2007. Living radiolarian feeding mechanisms: new light on past marine ecosystems. Swiss Journal of Geosciences 100, 273–279.

Stockar, R., Dumitrica, P. & Baumgartner, P.O., 2012. Early Ladinian radiolarian fauna from the Monte San Giorgio (Southern Alps, Switzerland): systematics, biostratigraphy and paleo(bio)geographic implications. Riv. It. di Paleontologia e Stratigrafia 118, 3, 375–437.

***Key words*: Low diversity, intraplatform basin, Middle Triassic.**

Low-diversified earliest Jurassic (Hettangian) radiolarian assemblages from the Hashirimizu Complex in the Outer zone of southwest Japan

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Earliest Jurassic (Hettangian) radiolarian assemblages were recovered from mudstone in the Hashirimizu Complex in the Outer zone of southwest Japan. The Hashirimizu Complex, which is distributed in western Kyushu and is one of the Early Jurassic accretionary complexes in Japan, is composed of deformed muddy matrix containing exotic blocks of chert, basalt, gabbro, and seamount-type limestone. The Hettangian radiolarians were obtained from two samples collected from the mudstone matrix.

These radiolarian assemblages are mostly dominated by species belonging to the family Canoptidae and are accompanied by small amount of individuals of genus *Bipedis* and spherical spumellarians. Although most species of Canoptidae in the assemblages are unnamed, several known species, *Canoptum merum* Pessagno & Whalen, *C. praeanulatum* Pessagno & Whalen, *Relanus reefensis* Pessagno & Whalen, and *Pseudocanoptum* cf. *ampulla* Suzuki, were identified. *R. reefensis* is age indicative, as its stratigraphic range of this species is confined within the Hettangian Stage of the Queen Charlotte Islands (Carter et al., 1998).

Suzuki (1993, 1995) has reported assemblages mostly composed of the genus *Canoptum* and named them "*Canoptum* assemblage". The *Canoptum* assemblage has been recovered from terrigenous mudstone and hemipelagic siliceous mudstone of Early Jurassic accretionary complexes in Japan, whereas it hasn't been recorded either in the Lower Jurassic pelagic chert (e.g., the Mino Belt; Carter & Hori, 2005), or in siliciclastic strata of shelf margin facies (e.g., the Kurosegawa Belt; Ishida, 2007). The depositional environment of the *Canoptum* assemblage is considered to be trench and trench-slope, along the subduction zone in the western margin of Panthalassa.

The relationship between the activity of the Central Atlantic Magmatic Province (CAMP) volcanism around the Triassic-Jurassic boundary and the low-diversified radiolarian assemblages is still unclear. While the influence of the CAMP volcanism has certainly been detected in the Panthalassa region as a discontinuous radiolarian faunal transition across the boundary (Carter & Hori, 2005) and Osmium spikes (Kuroda et al., 2010), there is no appropriate record for the regional occurrences of the *Canoptum* assemblage. One plausible cause of the low diversity is an inhibitor released from the accretionary complexes, such as dissociated methane gas and hydrogen sulfide, caused by an abrupt warming after the increase in CAMP volcanism.

References

Carter, E.S. & Hori, R.S., 2005. Global correlation of the radiolarian faunal change across the Triassic–Jurassic boundary. Canadian Journal of Earth Science 42, 777–790.

Carter, E.S., Whalen, P.A. & Guex, J., 1998. Biochronology and Paleontology of Early Jurassic (Hettangian and Sinemurian) radiolarians from the Sandilands Formation, Queen Charlotte Islands. Bulletin of Geological Survey of Canada 496, 1–162.

Ishida, N., 2007. Triassic-Jurassic unconformable boundary in the Kurosegawa Terrane, northern Itsuki area, western Kyushu. Journal of the Geological Society of Japan 113, 83–94.

Kuroda, J., Hori, R.S., Suzuki, K., Gröcke, D.R. & Ohkouchi, N., 2010. Marine osmium isotope record across the Triassic-Jurassic boundary from a Pacific pelagic site. Geology 38, 1095–1098.

Suzuki, H., 1993. The *Canoptum* Assemblage (Radiolaria) from the Umenoki Unit (the Northern Chichibu Belt) in the Kamikatsu Town area, Tokushima Prefecture, southwest Japan. News of Osaka Micropaleontologists, Special Volume no. 9, 109–117.

Suzuki, H., 1995. Das Verbreitungsmuster der Canoptum-Vergesellschaftung (jurassische Radiolarien) in der grauen Tonstein-Abfolge vom Kanoashi-Komplex, Sudwest Japan. Journal of the Geological Society of Japan 101, 451–461.

***Key words*: Canoptidae, *Canoptum* assemblage, Hettangian, Triassic-Jurassic boundary event.**

Middle to late Pleistocene changes of radiolarian assemblages in the Japan Sea: Their response to global climate and sea-level variations

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The Japan Sea (3,700 m maximum water depth) is a marginal sea of the northwestern Pacific, connected to adjacent marginal seas and the Pacific Ocean through four shallow straits (<130 m sill depth). The only oceanic water entering the sea is derived from the Tsushima Warm Current (TWC), which enters through the Tsushima Strait (130 m in depth) in the south. The Japan Sea Proper Water (JSPW) is relatively homogeneous deep water that occupies depths below 400 m and is characterized by low temperatures (0–0.6 °C) and high dissolved-oxygen content (220–280 μmol/kg) as well as a high salinity (34.05–34.08). Due to this semi-enclosed setting, the faunal composition of microorganisms in the Japan Sea sensitively responds to water conditions related to environmental changes over East Asia and the North Pacific.

The unique assemblage of recent polycystine radiolarians in the Japan Sea is characterized by the lack of deep-water species (e.g., *Cornutella profunda*), which typically occur in the deep-sea of the world (e.g., Casey et al., 1979), instead being dominated in the deep water by *Cycladophora davisiana* Camp; *Actinomma boreale* group that usually live in subsurface or intermediate depths in the high latitude oceans (Itaki, 2003). Warm-water species characterize the assemblage in the TWC (Itaki et al., 2010). According to studies using relatively short sediment cores, such unique assemblage was formed through significant oceanic changes during the last deglacial to Holocene periods (e.g., Itaki et al., 2004). Millennial to orbital scale changes of radiolarians have been reported for the past 220 kyr (Itaki et al., 2007), and we here document a further long record of radiolarian assemblage changes covering the past 640 kyr in sediment core MD01-2407 (58 m long) obtained from the southern Japan Sea.

A total of 136 species or species groups of radiolarians were recognized in the examined core. Species diversity tends to increase during interglacials and decrease during glacials. Such higher diversity during interglacial periods is the result of the appearance of warm water species related to the TWC. Similarly, relative abundance of typical warm-water species (e.g., *Tetrapyle octacantha* group and *Dictyocoryne truncatum/profunda*) increased during every interglacial period, indicating significantly increased inflow of TWC water with the eustatic sea-level rise and deepening of the Tsushima Strait. Low species diversity is associated to the predominance of cold-water species, such as *Ceratospyris borealis*, S*tylochlamydium venustum* and *Amphimelissa setosa*, during glacial periods, when the Japan Sea was mostly isolated from the adjacent seas due to lower eustatic sea level. The abundance of *Cycladophora davisiana* showed millennial-scale changes during MIS (marine isotope stage) 5 to MIS 1, possibly related to the intrusion of oxygen and organic materials into deeper waters. Higher abundances of *C. davisiana* were also recognized in MIS 7, 9 and 12, while absence of this species through MIS16 to 13 was probably caused by the prevalence of oxygen-poor deep- deep-water in the Japan Sea.

References

Casey, R., Spaw, J.M., Kunze, F., Reynolds, R., Duis, T., McMillen, K., Pratt, D. & Anderson, V., 1979. Radiolarian ecology and the development of the radiolarian component in Holocene sediments, Gulf of Mexico and adjacent seas with potential paleontological applications. Trans. Gulf Coast Assoc. Geol. Soc. 29, 228-237.

Itaki, T., 2003. Depth-related radiolarian assemblage in the water-column and surface sediments of the Japan Sea. Marine Micropaleontology 47, 253-270.

Itaki, T., Ikehara, K., Motoyama, I. & Hasegawa, S., 2004. Abrupt ventilation changes in a marginal sea of the NW Pacific over the last 30 kyr: Evidence from deep-dwelling Radiolaria in the Japan Sea. Paleogeography, Paleoclimatology, Paleoecology 208, 263-278.

Itaki, T., Komatsu, N. & Motoyama, I., 2007. Orbital- and millennial-scale changes of radiolarian assemblages during the last 220 kyrs in the Japan Sea. Palaeogeography, Palaeoclimatology, Palaeoecology 247, 115-130.

Itaki, T., Kimoto, K. & Hasegawa, S., 2010. Polycystine radiolarians in the Tsushima Strait in autumn of 2006. Paleontological Research 14, 19-32.

Key words**:** Paleoceanography, marginal sea, North Pacific, IMAGES, orbital cycles.

Distribution and provincialism of *Pseudotormentus* De Wever & Caridroit

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The Permian Period is paleogeographically characterised by the presence of superoceans: the Panthalassa and the Paleotethys. Permian fossil distributions of some taxa, such as nekton (e.g., conodonts) and benthos (e.g., foraminifera; brachiopods), have been discussed, but few studies have dealt with distributions of Permian plankton. Radiolarians were representative planktonic microfossils in the Permian paleocean, and some studies investigated their distributions and paleobiogeography. Wonganan & Caridroit (2006) suggested that the geographical range of *Follicucullus charveti* was confined to the western Panthalassa in the tropical paleoequator realm. Meanwhile, Wang et al. (2006) speculated that late Palaeozoic radiolarian paleobiogeography is characterised by a single Paleotethys planktonic faunal realm, because the Lopingian radiolarian fauna in several areas in both the Panthalassa and the Paleotethys are quite similar.

There is an important perspective from which to consider Permian radiolarian distributions: differences in value as index fossils among Permian radiolarian taxa. Generally, a cosmopolitan, short-range and rapidly evolving taxon is a useful index fossil. Albaillellaria, which meets the aforementioned requirements, is an index fossil in most of the Upper Palaeozoic radiolarian zones but, being cosmopolitan, this taxon has a limited value for paleobiogeographic studies. Other radiolarian endemic taxa may have greater potential value for paleobiogeographic studies than Albaillellaria.

This study focuses on the distribution of *Quadriremis* Nazarov & Ormiston in addition to that of *Pseudotormentus* De Wever & Caridroit. This is because *Pseudotormentus* and *Quadriremis* have been relatively unnoticed because of their perceived low value as index fossils. Furthermore, they have similar size and form. These facts indicate that the occurrence ratios of *Pseudotormentus* to *Quadriremis* have been influenced by few researcher-caused, taphonomic, sample and treatment biases.

We compiled literature data for the Pacific Rim and used quantitative data from samples of our previous studies (Ito et al., 2013a, b). These data showed an uneven distribution of *Pseudotormentus* in the Permian paleocean. This uneven distribution appears to depend on a difference between the Panthalassa and the Paleotethys. A previous paleobiogeographical study of Permian benthic organisms described faunal differences between the Panthalassa and the Paleotethys (Shen et al., 2009). The presence of these faunal differences in Permian planktonic microorganisms as well is shown in this study.

Although there are few obvious differences between the Panthalassa and the Paleotethys in terms of environmental variables, the South China block and some other continental blocks were located between them. It has been suggested that a strong westward equatorial current had been blocked by these continental blocks (Winguth et al., 2002). Based on these results, we hypothesise that *Pseudotormentus* was strongly affected by an equatorial current in the Panthalassa, i.e., *Pseudotormentus* is a facies genus of a Panthalassan warm current.

References

Ito, T., Feng, Q.L. & Matsuoka, A., 2013a. Radiolarian faunal change in the Middle Permian Gufeng Formation in the Liuhuang section, Chaohu, South China. Science Reports of Niigata University (Geology) 28, 39-49.

Ito, T., Zhang, L., Feng, Q.L. & Matsuoka, A., 2013b. Guadalupian (Middle Permian) radiolarian and sponge spicule faunas from the Bancheng Formation of the Qinzhou Allochthon, south China. Journal of Earth Science 24, 145-156.

Shen, S.Z., Xie, J.F., Zhang, H. & Shi, G.R., 2009. Roadian–Wordian (Guadalupian, Middle Permian) global palaeobiogeography of brachiopods. Global and Planetary Change 65, 166–181.

Wang, Y.J., Yang, Q., Cheng, Y.N. & Li, J.X., 2006. Lopingian (Upper Permian) radiolarian biostratigraphy of south China. Palaeoworld 15, 31–53.

Winguth, A.M.E., Heinze, C., Kutzbach, J.E., Maier-Reimer, E., Mikolajewicz, U., Rowley, D., Rees, A. & Ziegler, A.M., 2002. Simulated warm polar currents during the Middle Permian. Paleoceanography 17, 9-1–9-15.

Wonganan, N. & Caridroit, M., 2006. Middle to Upper Permian radiolarian faunas from chert blocks in Pai area, northwestern Thailand. Eclogae Geologicae Helvetiae 99, 133-139.

***Key words*:** Paleobiogeography, Paleotethys, Panthalassa, Permian Radiolaria, *Pseudotormentus*, *Quadriremis*.

Radiolarian biostratigraphic research near Zhongba county, along the Yarlung-Tsangpo Suture Zone and its applications in paleogeographic significance and Neo-Tethys evolution

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The Yarlung-Tsangbo Suture Zone (YTSZ), as the southernmost and youngest amongst the sutures which subdivide the Tibetan Plateau into several east-west trending blocks, marks where the Neo-Tethys was consumed as Indian continent approached northward and finally collided with Eurasia. Radiolarian dating has been used extensively to determine the time of the ophiolite formation and to interprete the evolutionary processes of the Neo-Tethys before the Indian continent collided with Eurasia continent.

Although many investigations on radiolarians along the YTSZ have been reported (Wu, 1986; Kojima et al., 2001; Matsuoka et al., 2002; Ding, 2003; Li, 2007; Zyabrev et al., 2008; Baxter et al., 2010; Liang et al., 2012), the precise radiolarian biostratigraphic research in the western part of the suture zone is still scarce. Our research area is located near Zhongba country.

During the field investigation, we collected nearly 380 samples for radiolarian research. The rock samples were treated following the standard techniques. Radiolarian extracted with 5% diluted hydrofluoric acid for about 20 hours. Binocular microscope, light microscope and SEM imaging were implemented for picking and observation.

The tectonic units which can yield radiolarian fossils in our research area are ophiolitic mélange, sedimentary mélange and the north Tethys Himalaya from north to south. The ophilitic mélanges are composed of serpentinized ultramafic rocks, pyroxenite and sedimentary-volcanic member. The sedimentary mélanges are siliceous mudstone matrix with blocks of sandstone, chert, limestone, basalt. The north Tethys Himalaya which belongs to the Indian passive continental margin sediment is composed mainly of rhythmic cherts, siliceous mudstone and sandstone.

Based on the radiolarian assemblages, we can find radiolarian assemblages belong to the *Kilinora spiralis* Zone, *Hsuum maxwelli* Zone, *Loopus primitiva* Zone, *Pseudodictyomitra carpatica* Zone, *Cecrops septemporatus* Zone (Matsuoka, 1995), *Eucyrtis columbarius* assemblage (Renz, 1974) Zone, *Buryella tetradica* (RP5) Zone and *Bekoma campechensis* (RP6) Zone (Hollis, 1997). According to these, we can infer the age of the strata are range from Oxfordian, Late Jurassic to Aptian, Early Cretaceous and mudstones belong to the Indian passive continental margin can get well preserved Late Paleocene radiolarians.

The radiolarian assemblages found in our research area combining with other reports along the suture zone will shed light on the evolution of the previous vast ocean. By quantitative analysis of the constitution of radiolarian assemblage and comparing them with coeval faunas whose original positions are known, we can get some information about paleo-latitudinal affinities of the sediments in our research area.

References

Baxter, A.T., Aitchison, J.C., Ali, J.R. & Zyabrev, S.V., 2010. Early Cretaceous radiolarians from the Spongtang massif, Ladakh, NW India: implications for Neo-Tethyan evolution. Journal of the Geological Society, London 167, 511–517.

Ding, L., 2003. Paleocene deep-water sediments and radiolarian faunas: Implications for evolution of Yarlung-Zangbo foreland basin, southern Tibet. Science in China 46, 1, 84-96.

Hollis, C.J., 1993. Latest Cretaceous to Late Paleocene radiolarian biostratigraphy: A new zonation from the New Zealand region. Marine Micropaleotology 21, 3, 195-327.

Kojima, S., Ahmad, T., Tanaka, T., Triloki, N.B., Miwnal, M., Rohtash, K., Rafiqul, I. & Prampal, K., 2001. Early Cretaceous radiolarians from the Indus Suture Zone, Ladakh, northern India. News of Osaka Micropaleontologists 12, 257-270.

Li, Y.L., 2007. Characteristics of Early Eocene radiolarian assemblages of the Saga area, southern Tibet and their constraint on the closure history of the Tethys. Chinese Science Bulletin 52, 2108-2114.

Liang, Y.P., Zhang, K.X., Xu, Y.D., He, W.H., An, X.Y. & Yang, Y.F., 2012. Late Paleocene radiolarian fauna from Tibet and its geological implications. Canadian Journal of Earth Sciences 49, 1364-1371.

Matsuoka, A., 1995. Jurassic and Lower Cretaceous radiolarian zonation in Japan and in the western Pacific. Island Arc 4, 2, 140-153.

Matsuoka, A., Yang, Q., Kobayashi, K., Takei, M., Nagahashi, T., Zeng, Q.G., Wang, Y.J. & 2002. Jurassic-Cretaceous radiolarian biostratigraphy and sedimentary environments of the Ceno-Tethys: records from the Xialu Chert in the Yarlung-Zangbo Suture Zone, southern Tibet. Journal of Asian Earth Sciences 20, 277-287.

Renz, G.W., 1974. Radiolaria from leg 27 of the deep sea drilling project. Initial Reports of the Deep Sea Drilling Project 769-841.

Wu, H.R., 1986. Some new genera and species of Cenomanian radiolaria from southern Xizang (Tibet). Acta Micropalaeontologica Sinica 4, 347-354.

Zyabrev, S.V., Kojima, S. & Ahmad, T., 2008. Radiolarian biostratigraphic constraints on the generation of the Nidar ophiolite and the onset of Dras are volcanism: Tracing the evolution of the closing Tethys along the Indus - Yarlung-Tsangpo suture. Stratigraphy 5, 99-112.

Key words**:** Radiolaria, the Yarlung-Tsangpo Suture Zone, paleogeographic significance.

Paleoenvironmental implication of radiolarian fauna and geochemical variation from the Gufeng Formation (Middle Permian) in western Hubei Province, south China

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The study area is located 80 km northeast of Enshi City, western Hubei, south China and is on the western margin of the Yangtze platform during the Late Paleozoic (Yin et al., 1999). A homoclinal carbonate ramp system was developed during the Guadalupian on the Yangtze block (Flügel, 2004). Owing to the influence of oceanic upwelling events (Shang et al., 2008), a cherty formation (the Gufeng Formation) was deposited in the western marginal basins of the Yangtze Block (Feng et al., 1993). The section, 19 m in thickness, is exposed in a quarry close to Luojiaba Village. It is divided into eight beds and 3 formations, i.e., the Maokou, the Gufeng and the Wuxue formations, in ascending order. Abundant radiolarian faunas, associated with conodonts, were obtained from the bedded chert sequence of the Gufeng Formation. For radiolarians, 21 species belonging to 10 genera were identified. According to their stratigraphic distributions, three radiolarian zones were recognized in the Guadalupian strata, including *Pseudoalbaillella globosa* Zone, *Follicucullus monacanthus* Zone, and *Follicucullus scholasticus* Zone, in ascending order (Ma & Feng, 2012). In the same strata, 5 species of conodonts, belonging to 3 genera had been identified and three conodont zones were proposed, namely *Jinogondolella nankingensis gracilis* Zone, *Jinogondolella aserrata* Zone, and *Jinogondolella postserrata* Zone. The discovery of coexisting radiolarian and conodont faunas in the same set of samples provided precise biostratigraphic and chronostratigraphic correlation between radiolarian and conodont zones, thus improving geochronostratigraphic correlation among Middle Permian carbonate and chert sequences.

Geochemical proxies integrated with well-preserved radiolarian faunal data, provide insights into paleoenvironment and paleoproductivity in the Gufeng Formation. V, Ni, U, Th, Ce as redox-sensitive trace metals can be used as paleo-redox indicators in ancient oceanic sediment (Jones & Manning, 1994; Murray, 1994). Several geochemical indexes (V/(Ni+V), U/Th, Ce/Ce*), from the section indicate that oxic-suboxic condition occur in the lower part, anoxic condition in the middle part, while suboxic-anoxic conditions can be observed in the upper part of the section. All of the examined samples plot in the non-hydrothermal area of a Al-Fe-Mn diagram.

Excess SiO_2 ($SiO_{2\,(ex)}$), total organic carbon (TOC) and Al in the ocean sediments can be used as proxies of primary productivity (Tribovillard et al., 2006). A comparison between the radiolarian faunal data and geochemical data indicates that the spherical polycystine to albaillellids ratio has systematically varied from the lower to the upper parts of the Gufeng Formation. In the upper part, higher TOC, $SiO_{2\,(ex)}$, Al, radiolarian richness, and abundances of spherical polycystines are prevalent. On the contrary, the lower part is characterized by a fauna dominated by albaillellids, along with a lower radiolarian total abundance, higher diversity, and less TOC, $SiO_{2\,(ex)}$ and Al. Spherical polycystine abundance is highly correlated with the geochemical productivity indicators, showing that spherical radiolarians can be used as an indicator of primary productivity in the Gufeng Formation.

References

Feng, Z.Z., He, Y.B. & Wu, S.H., 1993. Lithofacies and paleogeography of Middle Permian and Lower Yangtze Region. Acta Sedimentologica Sinica 11, 3, 13-24.

Flügel, E., 2004. Microfacies of carbonate rocks: Analysis, interpretation and application. Springer, Heidelberg, 976p.

Jones, B. & Manning, D.A.C., 1994. Comparison of geochemical indices used for the interpretation of palaeoredox conditions in ancient mudstones. Chemical Geology 111, 111-129.

Ma, Q.F. & Feng, Q.L., 2012. Taxonomy and biostratigraphy of the Middle Permian radiolarian fauna from the Gufeng Formation in Luojiaba, west Hubei Province. Acta Micropalaeontologica Sinica 29, 4, 402-415.

Murray, R.W., 1994. Chemical criteria to identify the depositional environment of chert: general principles and applications. Sedimentary Geology 90, 3-4, 213-232.

Shang, H.J., Zhang, N. & Xia, W.C., 2008. Mixed conodont faunas from the base-Guadalupian boundary interval at Pingxiang section, Guangxi. Geological Science and Technology Information 27, 5, 47-53.

Tribovillard, N., Algeo, T. J., Lyons, T. & Riboulleau, A., 2006. Trace metals as paleoredox and paleoproductivity proxies: An update. Chemical Geology 232, 12-32.

Yin, H.F., Wu, S.B., Du, Y.S. & Peng, Y.Q., 1999. South China defined as part of Tethyan Archipelagic ocean system. Earth Science Journal of China University of Geosciences 24, 1, 1-12.

***Key words*:** Radiolarians, the Gufeng Formation, paleoenvironment, paleoproductivity, paleoredox.

Expansion of Southern Ocean radiolarian fauna linked to a late Eocene cooling event

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The Eocene climate (54-34Ma) underwent major changes from an early Eocene 'greenhouse' to an 'ice-house' climate at the Eocene-Oligocene (E-O) transition. This long-term cooling trend was interrupted by a short-lived warming event at ~40 Ma, the middle Eocene Climatic Optimum (MECO) and a short-lived cooling event in the early Late Eocene (~37 Ma). Because the region encompasses likely sources of Antarctic deep-water formation, spans the transition from polar to tropical water masses and lies adjacent to a major gateway for circum-Antarctic circulation, paleoceanographic changes in the southwest Pacific Ocean are important for understanding the causes and consequences of the long-term cooling trend and these short-lived climate perturbations.

We are using radiolarian assemblages to reconstruct oceanic changes during the Eocene across a transect from high to low latitudes in the southwest Pacific from the South Tasman Rise and Campbell Plateau (DSDP Sites 277, 280, 281, 283) to the Lord Howe Rise and Coral Sea (DSDP Sites 206-210), including on-shore New Zealand sections in eastern Marlborough (e.g. Mead Stream) and published radiolarian assemblage data from ODP Site 1172, East Tasman Plateau (Suzuki et al., 2009).

Despite the near-tropical SST estimates for the SW Pacific in the Middle to Late Eocene that have been derived from geochemical proxies (Bijl et al., 2009; Hollis et al., 2009; Liu et al., 2009; Bijl et al., 2010), coeval radiolarian assemblages from Sites 277, 283 and 1172 lack low-latitude taxa and do not support the presence of warm subtropical or warmer waters in the southern Southwest Pacific (>60°S) at this time.

Distinct Southern Ocean elements are evident in radiolarian assemblages from the Middle Eocene at these sites, and especially so at Site 1172. A pronounced change in diversity, abundance and preservation of radiolarians occurs in the middle Late Eocene (36.4 Ma) at Site 277 with the appearance of many taxa with strong Southern Ocean affinities, such as: *Larcopyle hayesi*, *L. polyacantha*, *Lithomelissa ehrenbergi*, *L. gelasinus*, *L. sphaerocephalis*, *Siphocampe acephala* gr., *L. longiventer* and Antarctic morphotypes of *Lophocyrtis aspera*, *L. keraspera*, *Aphetocyrtis gnomabax* and *A. rossi*. This radiolarian event is accompanied by the first significant appearance of diatoms and silicoflagellates and is linked to a positive shift on planktic $\delta^{18}O$ (Shackleton & Kennett, 1975). New stable oxygen isotope data for this site show a cooling event at ~37 Ma, which can be identified as the Priabonian Oxygen Isotope Maximum event (PrOM), first described at ODP Site 738 (the Kerguelen Plateau, Southern Ocean (Scher et al., 2014)). This cooling event immediately precedes the expansion of Southern Ocean radiolarians at Site 277.

We conclude that a distinctive Southern Ocean fauna first occurred in the late Eocene, probably triggered by the preceding cooling event, which was interpreted as an episode of ice-sheet expansion.

References

Bijl, P. K., Houben, A. J., Schouten, S., Bohaty, S. M., Sluijs, A., Reichart, G.-J., Damsté, J. S. S. & Brinkhuis, H., 2010. Transient middle Eocene atmospheric CO_2 and temperature variations. Science 330(6005), 819-821.

Bijl, P. K., Schouten, S., Sluijs, A., Reichart, G.-J., Zachos, J. C. & Brinkhuis, H., 2009. Early Palaeogene temperature evolution of the southwest Pacific Ocean. Nature 461(7265), 776-779.

Hollis, C. J., Handley, L., Crouch, E. M., Morgans, H. E., Baker, J. A., Creech, J., Collins, K. S., Gibbs, S. J., Huber, M. & Schouten, S., 2009. Tropical sea temperatures in the high-latitude South Pacific during the Eocene. Geology 37, 2, 99-102.

Liu, Z., Pagani, M., Zinniker, D., De Conto, R., Huber, M., Brinkhuis, H., Shah, S.R., Leckie, R.M. & Pearson, A., 2009. Global cooling during the Eocene-Oligocene climate transition. Science 323 (5918), 1187-1190.

Scher, H. D., Bohaty, S. M., Smith, B. W. & Munn, G. H., 2014. Isotopic interrogation of a suspected late Eocene glaciation. Paleoceanography 29, 6, 2014PA002648. doi: 10.1002/2014PA002648

Shackleton, N. & Kennett, J., 1975. Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: oxygen and carbon isotope analyses in DSDP Sites 277, 279, and 281. Initial Reports of the Deep Sea Drilling Project 29, 743-755.

Key words**:** Radiolaria, Southern Ocean fauna, SW Pacific, late Eocene, Antarctic glaciations.

Climatic changes during Mid-Late Holocene in the southern Gulf of California

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A multiproxy record has been generated from core DIPAL I K47, recovered from La Paz Basin, in the southwestern Gulf of California. Species abundances of polycystine radiolarians, X-ray fluorescence and total organic carbon are used to track climatic changes in the tropical climate system at sub-centennial time scales over the past 7300 yr.

Polycystine radiolarian remains were identified in 82 samples along the core and, based on factor analys, two assemblages were identified, accounting for more than 71% of the total information in the radiolarian dataset.

Factor 1 “Gulf of California water” explains 67.2% of the total radiolarian data. It is particularly abundant between ~7300 and 5700, and from ~2700 to 900 cal yr BP, with several, additional peaks at 4500, 3900, 3200 and 2800 cal yr BP. This assemblage is dominated by *Arachnocorallium calvata*, *Lithomelissa setosa*, *Lithomelissa thoracites* and *Peridium longispinum*. These species inhabit the mixed layer above the thermocline, associated with eutrophic zones and upwelling processes, and some of them have been related to the Gulf of California Water (GCW). The observed variability in this assemblage suggests that during the above-mentioned periods GCW was prevalent in this region. GCW is formed by winter convection in the northern Gulf of California and flows to the entrance of the gulf during winter and spring, when high productivity increases due to the intensification of NW winds and, promote that surface waters away and can cause the thermocline to rise towards, or even into, the euphotic zone, hence leading to increased primary production. Furthermore, the presence of GCW has been reported during the summer close to the southern Baja California peninsula, where cyclonic gyres and coastal jets are common, induce vertical mixing, and thus promote the enrichment in nutrients of the water column.

Factor 2 “Tropical water” explains 4.8% of the total data variability. This assemblage is most abundant in the interval from ~5600 to 2900 cal yr BP, and it is characterized by *Phorticium pylonium* group, *Tetrapyle octacantha* group, and *Clathrocircus stapedius*. The assemblage suggests the persistence and dominance of incursions of the tropical, warm, surface-water layer in the region during this period. These environmental conditions are analogue to those observed during the summer-monsoon in the region, when the SST of the Gulf of California increases most rapidly. One of the largest oceanographic features associated to the summer monsoon is a warm and narrow band of warm water exiting the Gulf alongside the tip of the Baja California peninsula. This feature appears to be recurrent, occurring most years.

In addition to the factors analysis, we examine radiolarian environmental groups categorized as: 1) upwelling taxa and, 2) cooling taxa. The distribution of these groups throughout the core can be used as a guideline to tease out the affinities of radiolarian species to specific oceanic conditions, presumably linked to the radiolarian assemblages extracted by factor analysis. We found a very good match to the environmental conditions suggested above. We also observe that the relative abundance of upwelling taxa correlates fairly well with TOC, although down-core pattern of variations can be complex and shift over time.

The variability observed in biogenic sediments is associated with the dynamic oceanography of the southern Gulf of California and its relation to changes occurring in the tropical Pacific Ocean. In particular, productivity is relatively high all year around, due to upwelling and mesoscale gyres.

***Key words*: Gulf of California, mid-late Holocene, paleoproductivity.**

Radiolarians, diatoms and the Cenozoic Si and C cycles

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Biogenic silica deposition is the only significant output of the marine geochemical silica cycle (Tréguer et al., 1995). Today, diatoms are the main silica exporter to the deep sea, yet, at the beginning of the Cenozoic, they were just a minor component of the plankton. Additionally, marine planktonic diatoms play an important role today as one of the world's main primary producers and most significantly the main organic carbon exporter to the deep sea. It has been speculated (e.g. Pollock, 1997) that they may have significantly altered the carbon cycle on a geological timescale. Harper & Knoll (1975), and later Lazarus et al. (2009), also hypothesized the possibility of a competition between radiolarians and diatoms for silica availability on a geological timescale, based on the thinning of radiolarian shells throughout the Cenozoic, correlating with an increase of diatom diversity.

In this study, we tried to quantify the imprint of radiolarians and diatoms on the marine Si cycle, but also, through the diatoms, the imprint of biogenic silica on the C cycle. As part of a preliminary quantitative review of biogenic silica deposition during the Cenozoic we analyzed the abundance and paleogeographic patterns of siliceous microfossils in sediments, based on a review of the literature and a new quantitative analysis of the cumulative global DSDP and ODP smear slides descriptions (ca. 100K data records), using the NSB Neptune age model library.

Our study confirms that radiolarians dominated quantitatively the deposits of biogenic silica until the Eocene/Oligocene boundary, after which the diatom took over. Interestingly, the two main diatom abundance peaks during the Cenozoic correlate with known drops in atmospheric pCO_2 (Beerling & Royer, 2011) as well as the main changes in the global silicate weathering regime (based on Sr and Os isotopes), hinting at a scenario in which new sources of silicate (erosion of the Antarctic continent by the spread of the East Antarctic Ice sheet near the Eocene-Oligocene boundary, and the erosion of the Himalayas during the Mid-Miocene) drove expansion of the diatoms but not of radiolarians; the diatoms, in turn, thanks to their role in the biological pump, lowered atmospheric pCO_2 and thus contributed significantly to cooling the Cenozoic climate.

References

Beerling, D. & Royer, D., 2011. Convergent Cenozoic CO_2 history. Nature Geosciences 4, 418-420.

Harper, Jr, H. & Knoll, A., 1975. Silica, diatoms, and Cenozoic radiolarian evolution. Geology 3, 175-177.

Lazarus, D., Kotrc, B., Wulf, G. & Schmidt, D., 2009. Radiolarians decreased silicification as an evolutionary response to reduced Cenozoic ocean silica availability. PNAS 106, 23, 9333-9338.

Pollock, D., 1997. The role of diatoms, dissolved silicate and Antarctic glaciation in glacial-interglacial climatic change: a hypothesis. Global and Planetary Change 14, 113-125.

Tréguer, P. J., Nelson, D. M., Van Bennekom, A. J., DeMaster, D. J., Leynaert, A. & Quéguiner, B., 1995. The silica balance in the world ocean: a reestimate. Science 268, 375-379.

***Key words*:** Geochemical cycles, Cenozoic, diatoms, Radiolaria, climate studies.

The environment of the southern Indian Ocean over the last 40ka from radiolarian proxies

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Rogers & De Deckker (2011) reconstructed the palaeoenvironment of the southern Indian Ocean between the Polar and Subtropical Fronts. The quality of the reconstruction was limited by the difficulty in deciding which of the closely-correlated oceanographic variables (temperature, salinity, nutrients, etc.) determined radiolarian species distributions. The addition of new samples from the Kerguelen Plateau and Ocean Compared Study (KEOPS) mission (January–February, 2005) (Blain et al., 2007) to the existing surface-sediment database (Rogers & De Deckker, 2007) has helped to alleviate this problem.

Of particular note are the distributions of *Cycladophora davisiana davisiana* and *Arachnocorallium* spp., a group of unisegmented Plagoniidae (Boltovskoy et al., 1996) in the four cores studied (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]). The percentages of both species are high through MIS-2 and then fall sharply from about 17.5ka. The Antarctic Cold Reversal is very evident in the *C.davisiana* relative abundances; less so, but still present, in those for the *Arachnocorallium* group. As expected of a cold, stratified, waters indicator (Morley & Hays, 1983; Okazaki et al., 2006), *C. davisiana davisiana* percentages fall to approximately MIS-1 levels during MIS-3, whilst the *Arachnocorallium* group percentages rise, suggesting higher nutrient levels in MIS-3 than in either MIS-1 or 2.

Consideration is also given to indications of the movements of the ocean fronts over the 40ka studied. The principal conclusion is that, during the latter half of MIS-3 and throughout MIS-2, the region’s water masses moved eastwards or north-eastwards, driven by strong westerly winds, until constrained by the Southeast Indian Ridge.

References

Blain, S., Quéguiner, B., Armand, L., Belviso, S., Bombled, B., Bopp, L., Bowie, A., Brunet, C., Brussaard, C., Carlotti, F., Christaki, U., Corbière, A., Durand, I., Ebersbach, F., Fuda, J.-L., Garcia, N., Gerringa, L., Griffiths, B., Guigue, C., Guillerm, C., Jacquet, S., Jeandel, C., Laan, P., Lefèvre, D., Lomonaco, C., Malits, A., Mosseri, J., Obernosterer, I., Park, Y.-H., Picheral, M., Pondaven, P., Remeny, T., Sandroni, V., Sarthou, G., Savoye, N., Scouarnec, L., Souhaut, M., Thuiller, D., Timmermans, K., Trull, T., Uitz, J., van-Beek, P., Veldhuis, M., Vincent, D., Viollier, E., Vong, L. & Wagener, T., 2007. Impacts of natural iron fertilization on the Southern Ocean. Nature 446, 1070-1074.

Boltovskoy, D., Uliana, E. & Wefer, G., 1996. Seasonal variations in the flux of microplankton and radiolarian assemblage compositions in the northeastern tropical Atlantic at 2195 m. Limnology and Oceanography 41, 615-635.

Morley, J.J. & Hays, J.D., 1983. Oceanographic conditions associated with high abundances of the radiolarian *Cycladophora davisiana*. Earth and Planetary Science Letters 66, 63-72.

Okazaki, Y., Seki, O., Nakatsuka, T., Sakamoto, T., Ikehara, K. & Takahashi, K., 2006. *Cycladophora davisiana* (Radiolaria) in the Okhotsk Sea: a key for reconstructing glacial ocean conditions. Journal of Oceanography 62, 639-648.

Rogers, J & De Deckker, P., 2007. Radiolaria as a reflection of environmental conditions in the eastern and southern sectors of the Indian Ocean: A new statistical approach. Marine Micropaleontology 65, 137-162.

Rogers, J. & De Deckker, P., 2011. Environmental reconstructions of the upper 500 m of the southern Indian Ocean over the last 40 ka using Radiolarian (Protista) proxies. Quaternary Science Reviews 30, 876-886.

***Key words*:** Palaeoenvironment, Indian Ocean, nutrients.

Radiolarian faunal transition in the Triassic-Jurassic boundary strata, Nadanhada Terrane, NE China

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The Triassic-Jurassic (T-J) biotic event is included in the "Big Five" mass extinctions of the Phanerozoic, with at least half (probably up to more than 70%) of marine and terrestrial species going extinct. Recent theories suggest that the severe environmental perturbations leading to this event were caused by large volcanic eruptions and/or asteroid impact. According to Carter & Hori (2005) and Pálfy et al. (2007), T-J boundary strata (chert, siliceous mudstone and micritic carbonate facies) of shelf-slope to deep basin facies are characterized by rapid radiolarian species extinctions and much reduced and morphologically dwarfed survival faunas after the T-J event.

The Triassic and Jurassic radiolarian assemblages reported by Mizutani et al. (1986), Kojima & Mizutani (1987), Zhang (1990, 1992), Yang et al. (1992, 1993) and Yeh & Yang (2006) are among the few well-preserved, open marine, T-J boundary records (chert and siliceous mudstone) uncovered so far, and are thus useful for further characterizing the oceanic type T-J biotic events. According to Kojima (1989), the Nadanhada terrane, together with terranes of Sikhote-Alin (Far East Russia) and southwest Japan, represent oceanic terranes of the paleo-Pacific plate accreted to the east margin of the Asian continent during late Mesozoic time. Zhang (1992) suggested that the Late Triassic radiolarian assemblages were characterized by abundant larger individuals with coarse skeletons and complex ornamental features which were named "*Pseudheliodiscus* Assemblage". This assemblage was considered as typical of tropical, open marine environment, while the lower Jurassic radiolarians of the "*Parahsuum* Assemblage" featured more spumellarians and less nassellarians, and was characteristic of higher latitude or deeper water environment.

Yang et al. (1992; also see Yang, 1993; Yang et al., 1993) reported continuous radiolarian zones crossing the T-J boundary from a chert/siliceous mudstone section in the Nadanhada Terrane. The radiolarian faunas found in these deposits were referred to the *Capnuchosphaera-Capnodoce* Assemblage (Upper Triassic, Norian), *Livarella-Canoptum rhaeticum* Assemblage (Upper Triassic, upper Norian-Rhaetian), *Bipedis*-Heliosaturnalids Assemblage (Lower Jurassic, Hettangian to lower Pliensbachian) and *Trillus* sp. cf. *T. elkhornensis* Assemblage (Lower Jurassic, upper Pliensbachian) in Yang et al. (1993). Two of these assemblage zones (the *Livarella-Canoptum rhaeticum* Ass. and the *Bipedis*-Heliosaturnalids Ass.), apparently cross the T-J boundary (concordant with the last appearance of conodonts). The siliceous mudstones separating the two representative samples (i.e., MZ90-026 and MZ90-027, Yang et al., *ibid.*) for the two biozones are about 1.5 m. According to sedimentary rate estimates of the Triassic and Lower Jurassic radiolarian cherts in the Mino Terrane, central Japan (2m/Ma, Matsuda & Isozaki, 1991), which are well correlated with coeval siliceous sediments in the study area, the strata separating MZ90-026 and MZ90-027 probably represent a time interval of about 3 m.y. There are apparent sedimentary changes across the T-J from relatively pure chert to more clay-rich siliceous mudstones, probably representing increasing proximity to the East Asian continent, and/or global environmental perturbations at the T-J boundary.

Radiolarian associations across the T-J boundary can be characterized by: 1) abrupt change in faunal composition with majority of the Late Triassic taxa going extinct, including species of *Livarella*, *Ferresium*, *Deflandrecyrtium*, spumellarians with massive twisted spinal ridges, finely porous *Canoptum* (lacking latticed circumferential ridges) and massive ring-type parasaturnalids; 2) no pronounced individual size reduction for common spumellarians and nassellarians, except for a few taxa including the ring-forms; 3) the lack of a pronounced diversity change in the NE China assemblages. As it is possible that the observations could be biased due to relatively low stratigraphic resolution in this analysis, it is, therefore, suggested that future studies use higher resolution biostratigraphy in order to more precisely characterize the response in the pelagic ecosystem to the T-J mass extinction event recognized in other marine environment and on land.

References

Carter, E.S. & Hori, R.S., 2005. Global correlation of the radiolarian faunal change across the Triassic–Jurassic boundary. Canadian Journal of Earth Sciences 42, 777–790.

Kojima, S., 1989. Mesozoic terrane accretion in Northeast China, Sikhote-Alin and Japan regions. Palaeogeography, Palaeoclimatology, Palaeoecology 69, 213-232.

Kojima, S. & Mizutani, S., 1987. Triassic and Jurassic Radiolaria from the Nadanhada Range, Northeast China. Transactions and Proceedings Palaeontological Society of Japan 148, 256-275.

Matsuda, T. & Isozaki, Y., 1991. Well-documented travel history of Mesozoic pelagic chert in Japan: from remote ocean to subduction zone. Tectonics 10, 475-499.

Mizutani. S., Kojima, S., Shao, J. & Zhang, Q.L., 1986. Mesozoic radiolarians from the Nadanhada area, Northwest China. Proceedings of the Japan Academy, Series B: Physical and Biological Sciences 62, 9, 337-340.

Pálfy, J., Demény, A., Haas, J., Carter, E.S., Görög, Á., Halász, D., Oravecz-Scheffer, A., Hetényi, M., Márton, E., Orchard, M.J., Ozsvárt, P., Vető, I. & Zajzon, N., 2007. Triassic–Jurassic boundary events inferred from integrated stratigraphy of the Csővár section, Hungary. Palaeogeography, Palaeoclimatology, Palaeoecology 244, 11–33.

Yang, Q., 1993. Radiolarian assemblages from the T-J boundary strata in the Nadanhada Terrane, northeast China. Palaeoworld 2, 270-294.

Yang, Q., Wang, Y. & Liu, R., 1992. T/J boundary strata in Nadanhada Terrane, Heilongjiang Province. Kexue Tongbao 547-549.

Yang, Q., Mizutani, S. & Nagai, H., 1993. Biostratigraphic correlation between the Nadanhada terrane, northeast China, and the Mino terrane, central Japan. Journal of Earth Science of Nagoya University 40, 27-43.

Yeh, K.-Y. & Yang, Q., 2006. Radiolarian assemblages from T/J boundary strata, Nadanhada Terrane, NE China. Acta Micropalaeontologica Sinica 23, 4, 317-360.

Zhang, Q., 1990. Triassic and Jurassic radiolarian fauna in Nadanhada Range, northeast China. Bulletin of Shenyang Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences 21, 157-191.

Zhang, Q., 1992. Ecologic characteristics of radiolarian fauna from the Nadanhada Terrane. Memoirs of Shenyang Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences 1, 18-22.

Key words: Triassic-Jurassic event, radiolarian faunal transition, Nadanhada, northeast China.

Possible causes of a Lower Jurassic oceanic chert gap in Neotethys

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Oceanic remnants of the different branches of Neotethys are preserved in the Dinarides and Hellenides as ophiolitic complexes including radiolarian-rich biosiliceous cherts and siliceous mudstones. Extensive work on radiolarian biostratigraphy of the last 20 years has demonstrated 3 major age groups of these biosiliceous sediments (Baumgartner et al., 2010; Bortolotti et al., 2013): 1. *Middle to Late Triassic* (late Anisian to Rhaetian). This age group is associated with MORB-type basalts and these rocks have been interpreted as remnants of the Maliac Ocean (Ferrière et al., 2012). 2. *Middle Jurassic* (Bajocian- Callovian). This age group is associated with MORB-type, IAT-type and SSZ-type basalts and boninites, but is also present in ophiolitic mélanges. This group documents the formation of an intraoceanic accretion - subduction zone. 3. A *Late Jurassic* age group documents the emplacement of ophiolitic units onto the Pelagonian microcontinent. The radiolarites of the Guevgueli back arc arc ophiolite units thrust onto the European margin of Middle to Late Jurassic age (Danelian et al., 1996).

Early Jurassic radiolarian-bearing sediments are almost unknown in this context (Chiari et al., 2012), with a notable exception in the Argolis Peninsula (Greece), where Mn-impregnated nodules furnished Pliensbachian to Toarcian radiolarian assemblages (Chiari et al., 2013). Second, poorly preserved probably Early Jurassic sample was found in the Migdhalitsa Unit in the Central Argolis Peninsula (Bortolotti et al., 2003), now interpreted as an intraoceanic accretionary mélange, emplaced onto the Pelagonian. It contains blocks of N-MOR basalts with associated Late Triassic radiolarites. It also contains Middle Jurassic siliceous mudstones, ophiolitic sandstones and breccias considered as the deformed sediment apron of an intraoceanic prism. The near absence of Early Jurassic radiolarites in the oceanic realms preserved in the Dinarides-Hellenides needs to be explained. Three arguments will be mentioned here.

1. *Radiolarian productivity*. Early Jurassic radiolarites definitely formed in Panthalassa. They are preserved in several Circumpacific accreted terranes. However, the thin chert-shale couplets can be interpreted as low burial rate, due to low productivity or preservation of radiolarians. Lower Jurassic ribbon cherts in the Kiso River sections (Inuyama, Mino Terrane, central Japan) have an average bed thickness of 20 mm and is lower than Triassic chert in the same area (Ikeda & Tada, 2014). Pliensbachian radiolarites in the Santa Rosa Accretionary Complex of the Santa Elena Peninsula (N-Costa Rica) have an average bed thickness of 20-30 mm (Bandini et al., 2011). In the Franciscan Complex of N-California thin bedded Pliensbachian–Toarcian radiolarites are present in the Marin Headlands Terrane etc. (Murchey 1984) Early Jurassic ribbon-bed thickness is 2-3 times thinner than the one of Late Triassic or Middle Jurassic cherts. If chert thickness is interpreted as controlled by Milankovich cyclicity, then biogenic burial rate was low in the Early Jurassic in Panthalassa (Ikeda et al., 2010) and perhaps also in Neotethys (Ikeda et al., submitted).

2. *Land derived detrital input*. In the radiolarites of Central Panthalassa the land-derived detrital component is scarce (Matsuda & Isozaki, 1991). However, in the narrow branches of the Early Jurassic Neotethys sedimentation was dominated by terrigenous clays (e.g. Pélites de Kasteli of the Pindos realm, De Wever & Origlia-Devos, 1982) and/or by redeposited/periplatform limestone in the vicinity of carbonate margins. Hence, radiolarian preservation is rare and may be restricted to diagenetic chert nodules found in limestones or exceptionally in tectonically deformed siliceous clay- to mudstones.

3. *Tectonic deformation and emplacement.* Early Jurassic radiolarian –poor siliceous claystones were likely to be the youngest, still unconsolidated, lithology involved in intraoceanic accretion. These lithologies were therefore subject to intense deformation and accelerated silica diagenesis, resulting in nearly total destruction of the radiolarian content. Highly sheared siliceous shales rarely contain determinable radiolarians. The late Middle to Late Jurassic obduction of the intraoceanic mélanges caused additional deformation and diagenetic overprint to the shales,

Conclusion: The near absence of Early Jurassic radiolarian assemblages form oceanic remnants of Neotethys can be explained by: 1. low primary productivity and/or low preservation/burial of radiolarians during the Early Jurassic, combined with 2. intense deformation and diagenesis of clay-rich lithologies during initial accretion and later emplacement of units onto the Pelagonian microcontinent. Middle Jurassic radiolarian assemblages are more commonly found in ophiolitic mélanges, because radiolarian productivity/burial increased since the early Bajocian in Neotethys (Baumgartner, 2013), with frequent appearance of early diagenetic chert. In addition, Middle Jurassic biosiliceous sediments may have largely escaped initial accretion and hence, underwent less deformation and diagenesis.

References

Bandini, A.N., Baumgartner, P.O., Flores, K., Dumitrica, P. & Jackett, S.-J., 2001. Early Jurassic to early Late Cretaceous radiolarians of the Santa Rosa Accretionary Prism (north-western Costa Rica). Ofioliti 36, 1, 1–35.

Baumgartner, P.O., 2013. Mesozoic radiolarites – Accumulation as a function of sea surface fertility on Tethyan margins and in ocean basins. Sedimentology 60, 1, 292-318.

Baumgartner, P.O., Gorican, S. & Chiari, M., 2010. Ophiolites in the Dinarides and Hellenides: the contribution of radiolarian biochronology to the understanding of their formation and emplacement. XIX Congr. Carpathian-Balkan Geol. Ass. Thessaloniki. Geologica Balcanica 39, 1-2, 40-41.

Bortolotti., V., Carras., N., Chiari, M., Fazzuoli., M., Marcucci, M., Photiades, A. & Principi, G., 2003. The Argolis Peninsula in the paleogeographic and geodynamic frame of the Hellenides. Ofioliti 28, 79–94.

Bortolotti, V., Chiari, M., Marroni, M., Pandolfi, L., Principi, G. & Saccani, E., 2013. Geodynamic evolution of ophiolites from Albania and Greece (Dinaric-Hellenic belt): one, two or more oceanic basins? International Journal of Earth Sciences (Geol. Rundsch.) 102, 783-811.

Chiari, M., Baumgartner, P.O., Bernoulli, D., Bortolotti, V., Photiades, A., Principi, G. & Treves, B., 2012. Rare occurrences of Early Jurassic ages in the radiolarian cherts of the Dinaric-Hellenic Belt (Serbia, Albania and Greece) an open problem. Interrad XIII 215-216.

Chiari, M., Baumgartner, P.O., Bernoulli, D., Bortolotti, V., Marcucci, M., Photiates, A. & Principi, G., 2013. Late Triassic, Early and Middle Jurassic Radiolaria from ferromanganese-chert 'nodules' (Angelokastron, Argolis, Greece): evidence for prolonged radiolarite sedimentation in the Maliac-Vardar Ocean. Facies 59, 391–424.

Danelian, T., Robertson, A.H.F. & Dimitriadis, S., 1996. Age and significance of radiolarian sediments within basic extrusives of the marginal basin Guevgueli Ophiolite (northern Greece). Geol. Mag. 133, 127–136

De Wever, P. & Origlia-Devos, I., 1982. Datation par les Radiolaires des niveaux siliceux du Lias dela Série du Pinde–Olonos (Formation de Drimos, Péloponnèse et Grèce continentale). C. R. Acad.Sci. Paris, sér. II 294, 1191-1198,

Ferrière J., Chanier F. & Ditbanjong P., 2012. The Hellenic ophiolites: eastward or westward obduction of the Maliac Ocean, a discussion. International Journal of Earth Sciences 101, 1559-1580.

Ikeda, M. & Tada, R., 2014. A 70 million year astronomical time scale for the deep-sea bedded chert sequence (Inuyama, Japan): Implications for the Triassic-Jurassic geochronology. Earth Planet Science Letters 399, 30-43.

Ikeda, M., Bôle, M. & Baumgartner, P. O., submitted. Orbital-scale changes in oxygenation levelredox condition and productivity/detrital fluxes of the Middle Jurassic Radiolarite in Tethys (Sogno, Italy).

Ikeda, M., Tada, R. & Sakuma, H., 2010. Astronomical cycle origin of bedded chert; middle Triassic bedded chert sequence, Inuyama, Japan. Earth and Planetary Science Letters 297, 369-378.

Matsuda, T. & Isozaki, Y., 1991. Well-documented travel history of Mesozoic pelagic chert in Japan: from remote ocean to subduction zone. Tectonics 10, 475–499.

Murchey, B., 1984. Biostratigraphy and lithostratigraphy of cherts in the Franciscan Complex, Marin Headlands, California. In: Franciscan Geology of Northern California - Pacific Section (Blake, M., Ed.), Society of Economic Paleontologists and Mineralogists, Los Angeles 43**,** 51-70.

Key words**:** Early Jurassic, low biogenic silica burial, radiolarites, Neotethys, the Maliac-Vardar oceans, accretion, obduction.

Middle Jurassic radiolarite facies of Tethys as a function of paleoproductivity

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Middle Jurassic radiolarites are quite common in the Tethys with two different facies (Baumgartner, 2013). The Basal Radiolarites are almost lime-free, have a green color and were deposited from late Bajocian to Bathonian-Callovian. The overlying Knobby Radiolarites are red, sometimes calcareous, and grade upsection into siliceous limestones of the Rosso ad Aptici Formation. The red lithologies formed during Callovian/Oxfordian to early Tithonian.

The color in radiolarites seems related to the presence of ferrous minerals in different oxidation states (Matsuo et al., 2003). Hematite tends to give a reddish color to radiolarites whereas pyrite is responsible of the green color. The green color of Basal Radiolarites is compatible with reducing conditions and the Bajocian occurrence of numerous black shale deposits around the Tethys (Zaton et al., 2008). Tribovillard et al. (2012) pointed out that semi restricted basins were present in the Western Tethys. Restriction was more important in the western part, and also dependent of the basin geometry.

Our analysis of trace elements in both Panthalassan and Tethyan radiolarites have shown that Mo, V, U are enriched in black cherts which is typical for organic matter preservation under oxygen-poor conditions (Tribovillard et al., 2006). On the other hand, the enrichment factor of many trace elements increases with the proportion of biogenic SiO_2 in the sediment. Co-variation of the calculated biogenic silica and trace element content can be taken as a proxy of biogenic productivity. This paleoproductivity trend is particularly well marked by the Barium enrichment in the Basal Radiolarites.

Continuous anoxic or dysoxic conditions in the water column during the deposition of the Bathonian-Bajocian Basal Radiolarites can be excluded on the basis of trace element enrichment. It rather suggests reducing conditions within the sediment (U/Th and V/Cr proxy). The higher productivity might be related to a climatic change from arid to humid conditions around the Tethys during the Bajocian (Ghandour et al., 2002; Hesselbo et al., 2003) supplying more nutriments to the ocean.

References

Baumgartner, P.O., 2013. Mesozoic radiolarites-accumulation as a function of sea surface fertility on the Tethyan margins and in ocean basin. Sedimentology 60, 292-318.

Ghandour, I.M., Masuda, H. & Maejima, W., 2002. Mineralogical and chemical characteristics of the Bajocian-Bathonian shales, G. Al-Maghara, North Sinai, Egypt: Climatic and environmental significance. Geochemical Journal, 37, 87-108.

Hesselbo, S.P., Morgans-Bell, H.S., McElwain, J.C, Rees, P.M., Robinson, S.A. & Ross, C.E., 2003. Carbon-Cycle Perturbation in the Middle Jurassic and Accompanying Change in the Terrestrial Paleoenvironment. The Journal of Geology 111, 259-276.

Matsuo, M., Kubo, K. & Isozaki, Y., 2003. Mössbauer spectrocopic study on characterization of iron in the Permian to Triassic deep-sea chert from Japan. Hyperfine Interaction (C) 5, 259-272.

Tribovillard, N., Algeo, T.J., Lyons, T. & Riboulleau, A., 2006. Trace metals as paleoredox and paleoproductivity proxies: An update. Chemical Geology 232, 12-32.

Tribovillard, N., Algeo, T.J., Baudin, F. & Riboulleau, A., 2012. Analysis of marine environmental conditions based on molybdenum-uranium covariance-Applications to Mesozoic paleoceanography. Chemical Geology 324-325, 46-58.

Zatton, M., Marynowski, L, Szczepanik, P., Bond, D.P.G. & Wignall, P.B., 2009. Redox conditions during sedimentation of the Middle Jurassic (upper Bajocian-Bathonian) clay of the Polish Jura (south-central Poland). Facies 55, 103-114.

Key words: Tethys, trace elements, Middle Jurassic.

Taxonomic composition of some Boreal radiolarian assemblages of Mesozoic

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Radiolarians have long ago attracted attention as parameters of paleoenvironments. The huge diversity of radiolarian forms is frequently considered to be associated with adaptations of this group to the depth, distance from the coast, hydrodynamic mode, and paleotemperature mode. The idea of reconstruction of some paleoenvironmental factors based on the study of morphological features of radiolarians and taxonomic features of their assemblages was very attractive. Mesozoic radiolarians of high-latitude basins are of particular interest in connection with the questions of Boreal–Tethyan correlation and Mesozoic paleobiogeography.

Distinctions of radiolarian assemblages of different latitudes are manifested in the taxonomic composition at the generic and species level. In general, the higher latitudes are investigated the lower taxonomic diversity of assemblages is observed. Moreover, it is shown that many taxa, including superspecific, do not penetrate into high-latitude regions and occur only in low-latitude or tropical associations. The taxonomic composition of an assemblage seems a clear and reliable criterion for its paleoclimatic characteristics, but each period of Mesozoic is characterized by distinctive type of Boreal radiolarian assemblages (Bragin & Bragina, 2013).

Triassic Boreal assemblages (Bragin, 2011b) display strong domination of spherical morphotypes that are frequently represented by forms with spines having apophyses (*Kahlerosphaera* and *Dumitricasphaera*), with hollow spines (*Capnuchosphaera*), and with bladelike spines (*Zhamojdasphaera*). It should be noted that genus *Capnodoce* is absent in Boreal assemblages. Significant role is played by forms with a pylome like genus *Glomeropyle* with bipolar distribution (Aita & Bragin, 1999). In Late Triassic (Late Carnian–Early Norian) assemblages, prunoid forms with polar main spines are common (*Pseudostylosphaera*, *Spongotortilispinus*, *Spongopallium*, and *Dumitricasphaera*). Saturnalids are rare in Boreal Triassic. In Triassic assemblages, simple discoidal forms are represented by the genus *Tetraspongodiscus*, and stauraxonic discoidal forms (genus *Paronaella*) are very rare. Nassellarians are rare.

Late Jurassic to Earliest Cretaceous Boreal assemblages (Pessagno et al., 1987; Bragin, 1997, 2011a) are characterized by almost equal presence of spherical forms, discoids and cyrtoid nassellarians. Significant feature of Boreal Late Jurassic is presence of *Parvicingula* and *Praeparvicingula* with distinctive apical horn, and relatively rare presence of Pantanelliidae – they are represented only by phylogenetic line of *Pantanellium meraceibaense* Pessagno & MacLeod and can be found only in Southern Boreal areas. The Echinocampidae with numerous spines in apical part of test are common for Boreal (including Southern Boreal) regions, but still unknown in Southern Hemisphere. Many taxa common in Tethyan Realm are absent in Boreal Late Jurassic (Saturnalidae, Parvicingulidae without apical horns like *Mirifusus* and *Ristola*).

Late Cretaceous Boreal and sub-Boreal assemblages (Bragina et al., 1999; Amon, 2000; Olfer'ev et al., 2007; Vishnevskaya, 2011) display abundance and domination of the prunoid morphotypes without polar spines (*Amphibrachium* and *Prunobrachium*), common presence of simple discoidal forms represented by *Orbiculiforma* and *Spongodiscus*, and of stauraxonic discoidal forms represented by *Crucella*, *Histiastrum*, *Pentinastrum*, and *Septinastrum*. Spherical morphotypes are relatively rare. Pylomate forms are present

(*Spongopyle*), although they play a subordinate role. Saturnalidae are rare. Cyrtoid nassellarians are common (*Dictyomitra*, *Stichomitra*), but bell-shaped and strongly ornamented nassellarians are almost absent.

During history of radiolarians, high-latitude assemblages were significantly changed. Boreal assemblages were dominated not only by different taxonomic groups, but also by different morphotypes. Certain uniform and general morphological characters that could have described Boreal radiolarian assemblages of the Mesozoic are absent. Each period of the Mesozoic display assemblages with different morphological appearance and domination of different taxonomic groups. Therefore, if we want to use radiolarians for reconstructions of paleoclimate and paleogeography of certain geological time, we need detailed knowledge of Boreal radiolarians assemblage of this time and cannot use any criterions or features of earlier or later assemblages. Due to state of present knowledge radiolarian taxonomic and morphological features can be used only with high accuracy and caution. This work was supported by RFBR Grant 13-05-00447A.

References

Aita, Y. & Bragin, N.Yu., 1999. Non-Tethyan Triassic Radiolaria from New Zealand and northeastern Siberia. Geodiversitas 21, 4, 503–526.

Amon, E.O., 2000. Verkhnemelovye radiolyarii Urala (Upper Cretaceous Radiolaria of the Ural Mountains). Yekaterinburg: Inst. Geol. Geokh. Ural. Ross. Akad. Nauk, 1-209.

Bragin, N.Yu., 1997. Radiolaria from the phosphorite basal horizons of the Volgian Stage in the Moscow Region (Russia). Revue de Micropaléontology 40, 4, 283–296.

Bragin, N.Yu., 2011a. Radiolarians of the Volgian and Berriasian stages of the North of Central Siberia. Stratigraphy and Geological Correlation 19, 2, 173-187.

Bragin, N.Yu., 2011b. Triassic radiolarians of Kotel'nyi Island (New Siberian Islands, Arctic). Paleontological Journal 45, 7, 711–778.

Bragin, N.Yu. & Bragina, L.G., 2013. Morphological characteristics of Boreal radiolarians from the Triassic and Late Cretaceous: Comparative analysis. Paleontological Journal 47, 4, 351-362.

Bragina, L.G., Ben'yamovskii, V.N. & Zastrozhnov, A.S., 1999. Radiolarians, foraminifers and stratigraphy of the Upper Cretaceous beds of the southeastern Russian Plate (right bank of the Volgograd Volga Region). Stratigraphy and Geological Correlation 7, 5, 84–92.

Olfer'ev, A.G., Ben'yamovskii, V.N., Vishnevskaya, V.S. et al., 2007. Upper Cretaceous deposits of the northwestern Saratov Region: 1. Section near the village of Vishnevoe, litho- and biostratigraphic analysis. Strat. and Geological Correlation 15, 6, 62–109.

Pessagno, E.A., Jr., Longoria, J.F., Macleod, N. et al., 1987. Studies of North American Jurassic Radiolaria: Part I. Upper Jurassic (Kimmeridgian–Upper Tithonian) Pantanelliidae from the Taman Formation, East–Central Mexico: Tectonostratigraphic, chronostratigraphic and phylogenetic implications. Cushman Foundation for Foraminiferal Research Special Publication 20, 1–55.

Vishnevskaya, V.S., 2011. New Radiolarians of the family Prunobrachidae from the upper part of the Upper Cretaceous of the eastern slope of the Polar Urals. Paleontological Journal 4, 19–25.

***Key words*:** Radiolaria, Boreal realm, paleogeography, paleoclimate, Mesozoic.

Radiolaria from lower Aptian deposits of the Shilovka section (Middle Volga Region, Eastern European Platform)

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Well-preserved Radiolaria were found for the first time from lower Aptian of Middle Volga Region (Eastern European Platform). They were studied from Shilovka section south from Ulianovsk Town (Opornye…, 2010). Here we give short description of section.

1. Rhythmical intercalation of dark-grey clays, alevrites and fine-grained quartz-glauconite sandstones with sideritic concretions. Unit is characterized by ammonites of *Deshayesites tenuicostatus* Zone (lower Aptian) (Baraboshkin & Mikhailova, 2002). Apparent thickness is about 1 m.

2. Black, thin-bedded clays and black combustible shales that are foliated and ferruginate. Unit is characterized by ammonites of *Deshayesites volgensis* Zone (*Volgoceratoides shilovkensis* Subzone, lower Aptian) (Baraboshkin & Mikhailova, 2002). On the basal part of unit fragments of wood, shell detritus and phosphatic concretions are common, and two erosional levels are present. Large concretions of grey clayey limestone form single solid bed (0,5 m thick) located 20-30 cm above base of unit (so-called "Aptian plate"). This level is characterized by assemblage with *Pantanellium* sp.–*Spongodiscus quasipersenex*. Assemblage has important feature – presence of *Pantanellium* (the last appearance of this genus is Aptian). Nassellaria are represented by only one taxon – *Crolanium* sp. cf. *C. pulcher* Pessagno. Other forms are *Archaeospongoprunum* sp. ex gr. *A. carrierensis* Pessagno, *Conocaryomma* ? sp. A, *Paronaella* sp., *Rhombastrum* (?) sp., *Spongodiscus quasipersenex* Bragina and *Triactoma* sp. A. Horizon of small flatbread-like concretions of dark-grey and brownish-grey bituminous limestone is present 2 m above base of unit. This level yields assemblage with *Staurosphaeretta longispina*–*Amphipyndax stocki* (both species have their first appearance in Aptian). Here are present *Dactyliodiscus cayeuxi* Squinabol, *Hexinastrum* sp. ex gr. *H. cretaceum* Lipman, *Phantum* sp. ex gr. *Ph. insperatum* Hull and other taxa. Tethyan radiolarian zonation (O'Dogherty, 1994) cannot be traced here.

Aptian time was characterized by OAE-1. Unit 2 of the Shilovka section has numerous beds of black combustible shales with extra-thin laminar layering and enrichment of various microelements. They are interpreted as results of anoxic event OAE-1 (Baraboshkin & Mikhailova, 2002). Radiolaria are present in concretions that lay directly within these shales. Assemblage with *S. longispina*–*A. stocki*, recovered from unit 2, is represented by numerous taxa with large tests (like *Archaeoplegma pontidae* Bragina, *Pseudoacanthosphaera galeata* O'Dogherty and *Ps. magnifica* (Squinabol). It should be noted that all taxa of assemblage are represented by specimens with tests of normal size. Therefore Radiolaria display absence of any negative influence during OAE-1. It is interesting that OAE-2 (Cenomanian–Turonian boundary) did not have any negative influence to radiolarian evolution and morphology (Bragina, 2011). Therefore we can conclude that Radiolaria are tolerant to the events like OAE-1 and OAE-2. It gives opportunity to use them for stratigraphy of anoxic deposits where planktonic foraminifers are rare or absent.

Studied assemblages are characterized by: 1) domination of Spumellaria represented by species with Tethyan affinity: *Acaeniotyle longispina* (Squinabol), *Cavaspongia cilindrica* O'Dogherty, *Dactyliodiscus cayeuxi* Squinabol, *Pseudoacanthosphaera galeata* O'Dogherty, *Ps. magnifica* (Squinabol), *Staurosphaeretta longispina* (Squinabol), *Triactoma tithonianum* Rüst; 2) absence of nassellarian genera *Hiscocapsa*, *Pseudodictyomitra*, *Thanarla*, *Turbocapsula* that are typical from low-latitudes, and absence of widespread genera: *Archaeodictyomitra* and *Xitus* that are present in the territory of Eastern European Platform from Albian (Vishnevskaya et al., 2005; Danelian, 2008).

Biostratigraphic and paleogeographic distribution of several species was detailed after study of taxonomical composition of assemblages. For example, *Cavaspongia cilindrica* O'Dogherty and *Archaeospongoprunum klingi* Pessagno were not known from deposits older then Albian. *C. cilindrica* was not indicated outside of Tethyan Realm. *Spongodiscus quasipersenex* Bragina was known from the Cenomanian of Sakhalin and India (Bragina, 2003; Bragina & Bragin, 2013), and not it is for the first time found in Eastern European Platform, from lower Aptian. *Archaeoplegma pontidae* Bragina is known from Northern Turkey and Crimean Mountains (middle Cenomanian–lower Turonian) (Bragina, 2004), but now we know that genus *Archaeoplegma* is present from Aptian–lower Turonian of Tethys-North Peritethys. Genus *Cuboctostylus* (Bragina, 1999) is known from Upper Cretaceous (Cenomanian–Campanian) of Tethys (northern Turkey, Crimean Mountains, Cyprus, Serbia) and in Northern Peritethys (Eastern-European Platform, Sakhalin, Кamchatka, Shikotan Island) (Bragina, 2013). Here this genus was in the first time indicated from Lower Cretaceous, lower Aptian. All these data have importance for Boreal-Tethyan correlation of Cretaceous. This work was supported by RFBR grant 12-05-00690-a and RFBR grant 13-05-00447A.

References

Baraboshkin, E.Y. & Mikhailova, I.A., 2002. New stratigraphic lower Aptian of the Middle Volga Region. Stratigraphy and Geological Correlation 10, 6, 82-105.

Bragina, L.G., 2003. New radiolarian species from the Upper Cretaceous Naiba Reference Section (Southern Sakhalin). Paleontological Journal 37, 3, 244-251.

Bragina, L.G., 2004. Cenomanian–Turonian radiolarians of northern Turkey and the Crimean Mountains. Paleontological Journal 38, 4, 325-456.

Bragina, L.G., 2011. Refined age of the anoxic level in the Cenomanian–Turonian transition of the Mt. Sel'-Bukhra Section (Crimean Mountains, Ukraine): Implications of radiolarian analysis. Stratigraphy and Geological Correlation 19, 1, 515-525.

Bragina, L.G., 2013. Late Cretaceous radiolarians of the genera *Cuboctostylus* Bragina and *Hexacromyum* Haeckel: Their stratigraphic significance and paleobiogeographical distribution. Stratigraphy and Geological Correlation 21, 1, 79-95.

Bragina, L.G. & Bragin, N.Yu., 2013. New data on the Albian–Cenomanian radiolarians from the Karai Formation (South India). Stratigraphy and Geological Cor. 21, 5, 515-530.

Danelian, T., 2008. Diversity and biotic changes of Archaeodictyomitrid Radiolaria from the Aptian/Albian transition (OAE1b) of southern Albania. Micropal. 54, 1, 3-13.

O'Dogherty, L., 1994. Biochronology and paleontology of Mid-Cretaceous radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). Mém. Géol. Laus. 21, 1-413.

Opornye razrezyi verkhnei yurji i nidznego mela g. Uljanovska (Key-sections of Upper Jurassic and Lower Cretaceous of Unianovsk Town). 2010. Guidebook of excursions of 5 All-Russian Conference "Cretaceous system of Russia and adjacent countries: problems of stratigraphy and paleogeography. Ulianovsk: UlGU, 38.

Vishnevskaya, V.S., Kazintsova, L.I. & Kopaevich, L.F., 2005. Radiolarians across the Albian–Cenomanian Boundary (Examples from the Russian Platform). Stratigraphy and Geological Correlation 13, 4, 438-452.

Key words**:** Radiolaria, Cretaceous, Aptian, Oceanic anoxic event – 1.

Using radiolarian paleobiogeography to validate model- and proxy-based climate reconstructions for the early Paleogene of the Southwest Pacific

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Current evidence from geochemical proxies for temperature and paleontology suggests that for a few million years during the Eocene, the tropical ocean lapped the poles; where ice sheets are now, crocodiles basked amongst palm trees! If this is true, the oceans must have become unbearably warm for those organisms that preferred cooler waters.

We are using radiolarian paleobiogeography to test the hypothesis that *tropical conditions prevailed in high-latitude regions during periods of extreme global warmth in the Eocene*, specifically during three episodes in which global sea temperatures increased to 5°C above background: the Paleocene-Eocene thermal maximum (PETM), and the early and middle Eocene climatic optima (EECO, MECO). This hypothesis is based on geochemical and paleontological proxies for past climate (Eberle et al., 2012; Hollis et al., 2012; Pross et al., 2012), both of which rely to varying degrees on the assumption that modern ecology and ocean chemistry can be applied to past ocean states. The hypothesis is controversial because a high-latitude surface ocean that was warmer than 20°C conflicts with the physics of ocean circulation and the atmospheric dynamics that underpins climate models. If we are to understand how the planet functions in a greenhouse climate, we need to determine whether the temperature proxies are unreliable or the current generation of climate models are missing a fundamental parameter that causes extreme amplification of polar temperatures.

It is well established that the biogeographic distribution of radiolarians reflects meridional temperature gradients in the present and in the ancient ocean. Therefore, the distribution of radiolarians can be used to assess the veracity of proxy-based and model-based climate reconstructions for the Eocene ocean. In order to make this assessment we will:

i. Determine the variation within radiolarian assemblages in Paleocene-Eocene pelagic sediment records that represent a paleo-latitudinal transect from the Pacific sector of the Southern Ocean to the North Atlantic (65°S to 40°N), including deep sea sediment cores and outcrops in New Zealand;
ii. Identify trends in latitudinal distribution of fossil plankton species between times of relatively cool conditions in the late Paleocene and Eocene and episodes of extreme global warmth, with an emphasis on quantifying the poleward expansion of tropical plankton ranges and the concomitant contraction of polar ranges;
iii. Establish if global warming was linked to extinctions of cool-water radiolarians and originations of new warm-water taxa and, if so, how did a return to cooler conditions affect the newly evolved warm-water plankton?

Preliminary results indicate that there is a problem with the geochemical proxies, perhaps a bias towards summer temperatures. There is a small increase in low-latitude radiolarian species in higher latitude sites, such as Mead Stream and DSDP Site 277, during the PETM and EECO but the assemblages are best described as warm temperate to cool subtropical. Similarly, high-latitude Paleocene taxa, such as *Buryella granulata*, decrease in abundance during the PETM but persist into the early Eocene. There are too few definitive high latitude taxa to distinguish long-term warming from background faunal turnover as a cause for their eventual demise.

We note that low-latitude species are common in the Paleocene and Eocene in the North Atlantic cores recovered by IODP Expedition 342 (~40°N; Norris et al., 2014). Liu et al. (2011) argued that the occurrence of such taxa in the Paleocene in this region indicated that they were not a reliable guide to warm-water conditions. We argue the converse: namely that the abundance of species with low-latitude affinities in the North Atlantic from Paleocene to at least middle Eocene times implies that the region was bathed by subtropical-tropical water through the early Paleogene.

References

Eberle, J.J. & Greenwood, D.R., 2012. Life at the top of the greenhouse Eocene world: A review of the Eocene flora and vertebrate fauna from Canada's High Arctic. Geological Society of America Bulletin, doi: 10.1130/b30571.1.

Hollis, C.J., Taylor, K.W.T., Handley, L., Pancost, R.D., Huber, M., Creech, J., Hines, B., Crouch, E.M., Morgans, H.E.G., Crampton, J.S., Gibbs, S., Pearson, P. & Zachos, J.C., 2012. Early Paleogene temperature history of the Southwest Pacific Ocean: reconciling proxies and models. Earth and Planetary Science Letters 349-350, 53-66.

Liu, J., Aitchison, J.C. & Ali, J.R., 2011. Upper Paleocene radiolarians from DSDP Sites 549 and 550, Goban Spur, NE Atlantic. Palaeoworld 20, 218-231.

Norris, R.D., Wilson, P.A., Blum, P. & Expedition 342 Scientists, 2014. Proceedings of the IODP. 342, doi:10.2204/iodp.proc.2342.2014.

Pross, J., Contreras, L., Bijl, P.K., Greenwood, D.R., Bohaty, S.M., Schouten, S., Bendle, J.A., Rohl, U., Tauxe, L., Raine, J.I., Huck, C.E., van de Flierdt, T., Jamieson, S.S.R., Stickley, C.E., van de Schootbrugge, B., Escutia, C. & Brinkhuis, H., 2012. Persistent near-tropical warmth on the Antarctic continent during the early Eocene epoch. Nature 488, 73-77.

***Key words*: Paleogene, paleoclimate, paleobiogeography.**

Nassellaria/Spumellaria ratio *vs.* palaeoproductivity proxies in the Middle–Upper Jurassic radiolarian-bearing deposits of the western Tethys Fatricum Domain (Poland and Slovakia)

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Middle–Upper Jurassic radiolarian-bearing limestones and radiolarites were studied in the Krížna Nappe of the Tatra Mountains (Central Western Carpathians, southern Poland and northern Slovakia). This nappe belongs to the Fatricum Domain, which during most of Jurassic time, was one of the domains lying between the Alpine Tethys to the north and the Meliata Ocean to the south (Schmid et al., 2008).

Magnetic susceptibility (MS), carbon isotope, geochemistry, carbonate content and diversity of radiolarian assemblages were studied in six sections. The succession studied shows a strong similarity to Jurassic successions of other Tethyan basins.

The upper Bathonian–upper Kimmeridgian radiolarian-bearing deposits are 30 m thick. The middle Callovian–lower Oxfordian interval is characterised by drastically reduced carbonate content in all studied sections, whereas an increase occurs in the middle Oxfordian–upper Kimmeridgian. This phenomenon, recorded in the western Tethys, is interpreted as a result of climate warming which led to favourable conditions for carbonate producers (Rais et al., 2007). The older (upper Bathonian–lower Oxfordian), and more siliceous, part of the sequence is characterised by grey spotted and green facies, whereas the younger, more calcareous, deposits are first variegated and then red. This color change reflects redox conditions in the depositional and early diagenetic environment from oxygen depleted to oxic.

MS positively correlates with lithogenic elements (Al; Al-normalized Ti, K and Zr) as well as with Ba, which is a productivity indicator (Al-normalized Ba). Such coincidence may indicate a relationship between detrital input and high productivity. The values are low in the late Bathonian, then high in the latest Bathonian–early Oxfordian interval (UAZ 7–8) with a prominent maximum in the middle/late Callovian, low again in the middle Oxfordian, then high in the latest Oxfordian and low in the early Kimmeridgian.

The Nassellaria/Spumellaria (N/S) ratio fluctuates, following a similar pattern to the one displayed by MS and the above listed elements. The observed pattern might be related to the ecological requirements of these two groups of radiolarians. Spumellaria, which tend to be predominantly symbiont bearing, thrive in lower productivity settings and live in near-surface waters, whereas Nassellaria, which are deeper dwelling, non-symbiotic forms, inhabit higher productivity environments (Lazarus, 2002).

Such a coincidence may be explained by a fluctuating input of nutrients, caused most probably by climate change-mediated processes, such as enhanced continental weathering and runoff (Baumgartner, 2013). Increased input of nutrients during humid climate leads to seawater eutrophication, whereas decreased input leads to oligotrophication.

References

Baumgartner, P.O., 2013. Mesozoic radiolarites – accumulation as a function of sea surface fertility on Tethyan margins and in ocean basins. Sedimentology 60, 292–318.

Lazarus, D.B., 2002. Environmental control of diversity, evolutionary rates and taxa longevities in Antarctic Neogene Radiolaria. Palaeontologia Electronica 5, 1, 32p.

Rais, P., Louis-Schmid, B., Bernasconi, S.M. & Weissert, H., 2007. Palaeoceanographic and palaeoclimatic reorganization around the Middle–Late Jurassic transition. Palaeogeography, Palaeoclimatology, Palaeoecology 251, 527–546.

Schmid, M.S., Bernoulli, D., Fügenschuh, B., Matenco, L., Schefer, S., Schuster, R., Tischler M. & Ustaszewski, K., 2008. The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. Swiss Journal of Geosciences 101, 1, 139–183.

Key words**:** Radiolaria, N/S ratio, paleoproductivity proxies, Middle-Upper Jurassic, Tatra Mountains.

Radiolarian assemblage changes across the mid-Pleistocene transition in southern Japan (IODP Exp. 314/315 Site C0001, Holes E & F)

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During the mid-Pleistocene Transition (MPT), spanning from 0.8 to 1.2 Ma, the prevailing 41 kyr glacial cycles were replaced by longer cycles with a period of ca. 100 kyr. This event was also accompanied by important climate changes, as an expansion of the Northern Hemisphere Ice Sheet (McClymont et al., 2013). In southern Japan, where the Kuroshio Current flows, this event is poorly documented because of a lack of long cores recovering the MPT. In this context, the impact of the MPT on the Kuroshio Current remains unknown. Because of the poor preservation of calcareous microfossils, polycystine radiolarians, abundant and well preserved in this area, constitute an excellent alternative proxy for reconstructing past climate changes. Indeed, numerous studies on the modern radiolarian species geographic distribution were conducted, and enable the definition of several radiolarian assemblage groups depending on climatic conditions (e.g., equatorial to sub-arctic assemblage group) (Lombari & Boden, 1985; Pisias et al., 1997; Kamikuri et al., 2008; Boltovskoy et al., 2010). In this study, we will use this type of biogeographic information to determine the impact of the MPT on the Kuroshio Current in southern Japan.

We used Integrated Ocean Drilling Program (IODP) Expedition 314/315 Site C0001 E/F deep sea core samples. The studied samples were drilled by the R/V Chikyu at a depth of 2198 meters off Kii Peninsula, on the slope of the Nankai accretionary prism (33°14’N, 136°42’E and 33°18’ N; 136°38). The age model of Site C0001 Holes E and F is based on biostratigraphy and chemostratigraphy (Matsuzaki et al., 2014). A total of 222 samples were used for radiolarian assemblage study. Based on biostratigraphy and chemostratigraphy, a hiatus/ unconformity/ disconformity whatever has been recognized in the portion of the core younger than MIS 15. However between MIS 15 (0.5 Ma) and MIS 63 (1.82 Ma), the stratigraphy is not disturbed.

We used the ecological affinities of ten significant radiolarian speciesto reconstruct regional paleoceanographic changes between 0.5 Ma and 1.82 Ma. Our most significant result is that the Kuroshio Current gyre fauna (*Didymocyrtis tetrathalamus* and *Polyselonia spinosa*/*lappacea* group) relative abundance increases drastically during the MPT, which may indicate a northward shift of the Kuroshio Current. On the other hand, Oyashio/Kuroshio Current mixed-water species (*Rhizosphaera mediana*) relative abundances also increase during this interval. Our data may indicate that the Oyashio Current has shifted southwards synchronously to a northward shift of the Kuroshio Current during the MPT.

References

Boltovskoy, D., Kling, S., Takahashi, K. & Bjørklund, K., 2010. World atlas of distribution of recent polycystina (Radiolaria). Paleontologia Electronica 13, 1-229.

Kamikuri, S., Motoyama, I. & Nishimura, A., 2008. Radiolarian assemblages in surface sediments along longitude 175°E in the Pacific Ocean. Marine Micropaleontology 69, 151–172.

Lombari, G. & Boden, G., 1985. Modern radiolarian global distributions. Cushman Foundation for Foraminiferal Research 16, 1–24.

Matsuzaki, K.M., Nishi, H., Hayashi, H., Suzuki, N., Ikehara, M., Gyawali, B.R., Tanaka, T. & Takashima, R., 2014. Radiolarian biostratigraphic scheme and stable oxygen isotope stratigraphy in southern Japan (IODP Expedition 315 Site C0001). Newsletters on Stratigraphy 47/1, 107-130.

McClymont, E.L., Sosdian, S.M., Rosell-Melé, A. & Rosenthal, Y., 2013. Pleistocene sea-surface temperature evolution: Early cooling, delayed glacial intensification, and implications for the mid-Pleistocene climate transition. Earth-Science Reviews 123, 173-193.

Pisias, N.G., Roelofs, A. & Weber, M., 1997. Radiolarian-based transfer functions for estimating mean surface ocean temperatures and seasonal range. Paleoceanography 12, 3, 365-379.

Key words: Kuroshio, paleoceanography, Radiolaria, southern Japan.

Radiolarian *Cycladophora davisiana* and the last glacial ventilation of the intermediate water in the Subarctic Pacific

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The North Pacific ventilation was reconstructed using the past distribution of the radiolarian species *Cycladophora davisiana*. This species may be the main proxy of the cold, well-oxygenated intermediate water in areas of active ventilation on the intermediate depths in the modern Sea of Okhotsk (Abelmann & Nimmergut, 2005).

In modern sediments from the subarctic North Pacific (107 samples from literature, and our new counts from 70 samples), *C. davisiana* generally represents > 10% of the radiolarian assemblage with >20% secondary peaks (max. 28-29%) in the northwestern central and southwestern parts of the Sea of Okhotsk. Two limited areas with lower than average abundances (ca. 5%) are found on the northern slope of the Bering Sea, and in the northwestern corner of the Subarctic Pacific, along the Aleutian and Kuril Islands. Moreover, high species percentages of 20-45% were found in the modern sediments from the northern and western Japan Sea (Shastina, 1993; Itaki, 2003) where the seasonal mixing from the surface creates well-ventilated and poorly-stratified water column.

In last glacial sediments (46 sediment cores from literature, and our counts from 11 cores), *C. davisiana* is abundant over the Subarctic Pacific: > 10% north of 40-45°N, >20 % in the Alaskan Bay, and along the Aleutian Islands, > 30% within the North-West Gyre, and in the marginal seas. The last glacial maximum of *C. davisiana* percentages (40-50%) lies in the Sea of Okhotsk.

The geographic distribution of high abundances of *C. davisiana* in last glacial maximum (LGM) sediments may seems to suggest that four areas were particularly important for the formation and distribution of ventilated intermediate water during the LGM over the most Subarctic Pacific: in the Bering Sea, Sea of Okhotsk, North-West Gyre, and Alaskan Bay. Our results support the findings of isotope/modeling studies, suggesting a possible enhanced ventilation of intermediate water in the last North Pacific during the LGM (Kim & Park, 2008; Wainer et al., 2012).

References

Abelmann, A. & Nimmergut, A., 2005. Radiolarians in the Sea of Okhotsk and their ecological implication for paleoenvironmental reconstructions. Deep-Sea Res. II 52, 2302-2331.

Itaki, T., 2003. Depth-related radiolarian assemblage in the water-column and surface sediments of the Japan Sea. Mar. Micropal. 47, 253-270.

Kim, S.-J. & Park, Y.-G., 2008. Glacial ocean circulation and property changes in the North Pacific. Atmosphere-Ocean 46, 257–275.

Shastina, V.V., 1993. Neogene-Quaternary assemblages of radiolarians of Japan Sea. Ph. D. Thesis. Vladivostok, Far East Geological Institute, 245p. (in Russian).

Wainer, I., Goes, M., Murphy, L.N. & Brady, E., 2012. Changes in the intermediate water mass formation rates in the global ocean for the Last Glacial Maximum, mid-Holocene and pre-industrial climates. Paleoceanography 27. PA3101, doi:10.1029/2012PA002290.

On the Cenozoic radiolarian assemblages from different environments

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Antarctic radiolarian assemblages in the six sea areas of the Southern Ocean of °S60 were already reported from the top sediment samples at 146 sites in six areas around Antarctica (Nishimura & Nakaseko, 2011). These Antarctic radiolarian assemblages are compared with other Cenozoic radiolarian assemblages in three different areas: the Nankai Trough of the northwest Pacific, the northwest Atlantic at Site 384 and the Osaka Bay. The highest of them in diversity is the radiolarian assemblage in the Nankai Trough. The second highest of them is the Paleocene radiolarian assemblage in the northwest Atlantic. The typical Antarctic pelagic assemblage is lower in diversity than above-mentioned assemblages in two areas. The lowest one is the radiolarian assemblage in the Osaka Bay. The Antarctic coastal assemblage is also low in diversity. Both significant dominant coastal species have very similar skeletal element.

The following results were brought out by comparison of the number of radial spines on the outer shell of the Actinommidae in each radiolarian assemblage. Dominant genus or species are different in the Actinommidae of each area. In the radiolarian assemblage of the Nankai Trough, they are forms with many radial spines, as *Hexacontium*, *Actinomma*, *Cladococcus* and *Haeckeliella*. In the typical Antarctic pelagic radiolarian assemblage, they are forms with two polar spines, as *Stylatractus* and forms with a large pylome. The Paleocene radiolarian assemblage contains many forms with two, three, four, five and six radial spines.

References

Nishimura, A., 1992. Paleocene radiolarian biostratigraphy in the northwest Atlantic at Site 384, Leg 43 of the Deep Sea Drilling Project. Micropaleontology 38, 317-362.

Nishimura, A. & Nakaseko, K., 2011. Characterization of radiolarian assemblages in the surface sediments of the Antarctic Ocean. Palaeoworld 20, 232-235.

Nishimura, A. & Yamauchi, M., 1984a. Radiolarians from the Nankai Trough in the Northwest Pacific. News of Osaka Micropaleontologists, Special Volume 6, 1-148.

Nishimura, A. & Yamauchi, M. 1984b. Radiolarians. Geological Survey of the Submarine Strata at the Kansai International Airport in Osaka Bay, Central Japan. Report of the Calamity Science Institute 69-74 (In Japanese).

Key words: Radiolarian assemblage, diversity, Actinommidae.

The palaeoenvironment of the tropical eastern Indian Ocean

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Radiolarian proxies have been used to reconstruct the palaeoenvironmental conditions in the tropical eastern Indian Ocean using a section of deep-sea core Fr10/95-GC17 covering the last 34ka. The location of Fr10/95 GC17 (22°07.74S 113°30.11E) was the main reason for its selection for this study as the core lies at the edge of the Indo-Pacific Warm Pool, an area of major transfer of heat and moisture from the ocean to the atmosphere. During most of the Holocene, the upper portion of the water column above the core site has been provided by the seasonal warm and low-salinity Leeuwin Current, a southward-flowing continuation of the Indonesian Throughflow which brings warm waters from the West Pacific Ocean to the Indian Ocean (Pearce & Cresswell, 1985; Cresswell, 1991; Smith et al., 1991). The lower portion of the water column consists mainly of the northward-flowing Western Australian Current (Pearce, 1991) but is also influenced by the seasonal Capes and other coastal currents which give rise to upwelling conditions along the west Australian coast (Pearce & Cresswell, 1985; Pearce, 1991; Pearce & Pattiaratchi, 1999).

Core Fr10/95-GC17 has been subjected to an extensive range of analyses including the micropalaeontology of planktic and benthic foraminifera and coccoliths, stable isotope analysis of foraminifera, and investigation of the clay content, sediment composition, and pollen abundances (De Deckker et al., 2014). However, the present study is the first to consider the core's radiolarians, which constitute virtually the entirety of the preserved siliceous biota. These data are primarily intended to establish the strength of the Leeuwin Current over the last 34ka, using the known depth preferences of various radiolarian species. This study also examines the relationships between radiolarian species distributions and the oceanographic conditions resulting from the land-sea interactions reported by De Deckker et al. (2014). De Deckker et al. (2014) found a major climatic change at 13ka BP. Prior to that time, sea-surface temperatures (SST) were low and low rainfall over NW Western Australia resulted in low river discharge. After that time, the Indo-Australian Monsoon started, land and sea temperatures increased dramatically, and a low-salinity cap formed at the top of the water column, after 5ka the ENSO increased in the area.

References

Cresswell, G., 1991. The Leeuwin Current - observations and recent models. Journal of the Royal Society of Western Australia 74, 1-14.

De Deckker, P., Barrows, T. & Rogers, J., 2014. Land-sea correlations in the Australian region: post-glacial onset of the monsoon in northwestern Western Australia. Quaternary Science Reviews 105, 181-194.

Pearce, A., 1991. Eastern boundary currents of the southern hemisphere. Journal of the Royal Society of Western Australia 74, 35-45.

Pearce, A. & Cresswell, G., 1985. Ocean Circulation off Western Australia and the Leeuwin Current. CSIRO Information Service 16, 3.

Pearce, A. & Pattiaratchi, C., 1999. The Capes Current: a summer countercurrent flowing pass Cape Leeuwin and Cape Naturaliste, Western Australia. Con. Shelf Res. 19, 401-420.

Smith, R., Huyer, A., Godfrey, J. & Church, J., 1991. The Leeuwin Current off Western Australia, 1986-1987. Journal of Physical Oceanography 21, 323-345.

***Key words*:** Core FR10/95 GC17, the Leeuwin Current, the Western Australian Current.

Neogene Radiolarian biostratigraphy and palaeoceanographic interpretations of the Costa Rican eastern equatorial Pacific offshore

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The Integrated Ocean Drilling Program Expedition 344 drilled a transect across the convergent margin off Costa Rica (Fig. 1). During the expedition, which lasted seven weeks, five sites were drilled. The first site (U1381) is located ~4.5 km seaward of the deformation front on the incoming Cocos plate, offshore Osa Peninsula (8°25.7027′N, 84°9.4805′W, 2064.6 m water depth). 109 meters of sediment were recovered in this site. In the second site (U1414; 8°30.2304′N, 84°13.5298′W, 2459 m water depth), which was also located on the incoming plate, 383.9 meters of sediments and basalts were recovered. Three more sites were drilled in the upper Caribbean plate: U1380 (8°35.9979′N, 84°4.3918′W, 502.7 m water depth) in which the coring reached 202.4 meters of sediments; U1412 (8°29.1599′N, 84°7.7512′W, 1965 m water depth), which involved the drilling of four holes with a maximum recovery of 247.23 and U1413 (8°44.4593′N, 84°6.8095′W, 540 m water depth), where 528.6 meters of sediments were recovered.

Two sites from the Cocos plate were selected to obtain a detailed biostratigraphy of the sediment sequence: Sites U1381C and U1414A. The sediments acquired from the two sites consist mainly of calcareous nannofossil ooze with foraminifera, diatoms and radiolarians. At both localities, radiolarian assemblages were in general well-preserved and abundant. In order to obtain a representative faunal spectrum, one third (100) of the samples prepared (295) were selected to count a total of 300 radiolarian individuals per sample.

A middle Miocene to Recent age (RN 6 to RN16) was determined for the sites, the oldest age is marked by the presence of *Diartus pettersoni* and the youngest by *Collosphaera tuberosa*. The age model was based on the radiolarian zonation for the tropics (Riedel et al., 1978) and further correlated with the nannofossil zonation and paleomagnetic data made by other scientists of the expedition.

We deduced that the sites U1414A and U1381C were initially deposited during the Miocene far away from the current location, more precisely slightly south of the Equator. This, considering the northward movement of the Cocos plate motion (7,3 cm/year, Mann et al., 2007). This fact suggests that the fauna of these sites has been subjected to different currents and sources of nutriments (Baumgartner, 2013). Indeed, influences from both the cold tongue of South Equatorial Current and the warm North Equatorial Countercurrent are expected. Therefore, the data of this and other studies performed in neighboring locations (Kamikuri et al., 2009a, 2009b), will be used to trace faunal changes since Miocene to Recent.

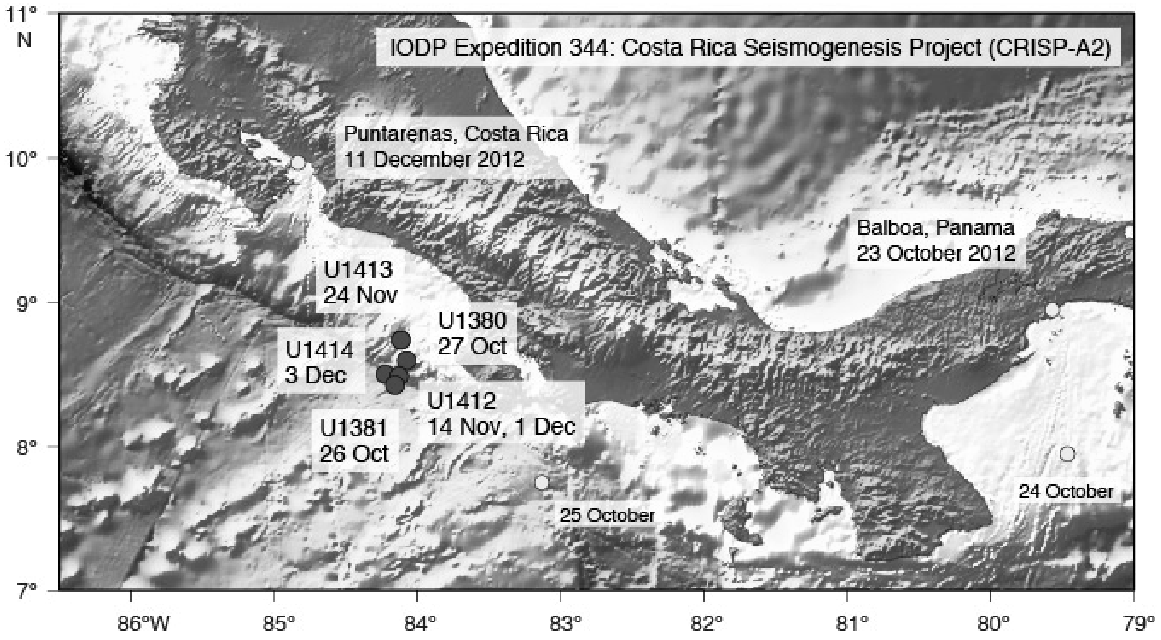

Figure 1. Location of the drilled sites of IODP 344 Expedition off Costa Rica.

References

Baumgartner, P.O., 2013. Mesozoic radiolarites – accumulation as a function of seasurface fertility on Tethyan margins and in ocean basins. Sedimentology 60, 292−318.

Kamikuri, S., Motoyama, I., Nishi, H. & Iwai, M., 2009a. Neogene radiolarian biostratigraphy and faunal evolution rates in the eastern equatorial Pacific ODP Sites 845 and 1241. Acta Palaeontol. Polonica 54, 4, 713–742.

Kamikuri, S., Motoyama, I., Nishi, H. & Iwai, M., 2009b. Evolution of Eastern Pacific Warm Pool and upwelling processes since the middle Miocene based on analysis of radiolarian assemblages: Response to Indonesian and Central American Seaways. Palaeogeography, Palaeoclimatology, Palaeoecology 280, 469–479.

Mann, P, Rogers, R. & Gahagma, L., 2007. Overview of plate tectonic history and its unresolved tectonic problems. In: Central America Geology, Resources and Hazards (Bundschuh, J. & Alvarado, G. E., Eds.), Taylor & Francis, 201-238.

Nigrini, C. & Sanfilippo, A., 2001. Cenozoic radiolarian stratigraphy for low and middle latitudes. Technical Note 27 Ocean Drilling Program Texas A & M University 495.

Riedel, W.R., Sanfilippo, A. & Westberg-Smith, M.J., 1978. Cenozoic Radiolaria, Stratigraphy and Evolution of Tropical Cenozoic Radiolarians. Micropaleontology 24, 1, 61-96.

Key words**:** Radiolarians, the Cocos Plate, Cenozoic, Miocene, IODP 344 Expedition, Costa Rica, Eastern tropical Pacific.

Millennial-scale paleoceanographic records based on radiolarian assemblages in the Northern Bering Sea since the Last Glacial Maximum

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The Bering Sea, the only water passage connecting the North Pacific and Arctic oceans, is a key region for paleoceanographic studies. Siliceous organisms are the main biogenic component of sediments in the Bering Sea, and thus represent important tools for paleoceanographic reconstructions. Radiolarian assemblages have been investigated in 31 surface sediment samples and along one sediment core, collected from the Bering Sea during the Chinese National Arctic Research Expeditions.

Radiolarian assemblages in surface sediments show that the dominant species in the Bering sea are: *Stylochlamydium venustum, Antarctissa* ? sp. 1, *Spongodiscidae* (juvenile) and other 6 species. The first three taxa show high abundance in the shelf margin/continental slope region, mirroring high primary productivity in the “Bering Sea Green Belt”.

Retrieved near the Northern Bering Slope, Core ARC1-B4-2 represents an archive for the study of millennial-scale paleoceanographic changes since the Last Glacial Maximum. High abundances of *Rhizoplegma boreale* at 4-3 ka indicate a late Holocene melt-water event in the Northern Bering Sea. *Actinomma boreale/leptodermum* abundances increased during the Younger Dryas cooling event, suggesting a sea-ice expansion during this interval. *Stylochlamidium venustum* fluctuated frequently between 18 ka and 2 ka, possibly suggesting productivity changes. *Cycladophora davisiana* decreased rapidly in abundance at the onset of the Bølling/Allerød warm period, and this may indicate that North Pacific Intermediate Water formation shifted away from the Bering Sea to the Okhotsk Sea.

***Key words*:** Radiolaria, the Bering Sea, Last Glacial Maximum productivity, melt water, NPIW.

Variations in radiolarian assemblages in the Bering Sea since the Pliocene and their implications for paleoceanography

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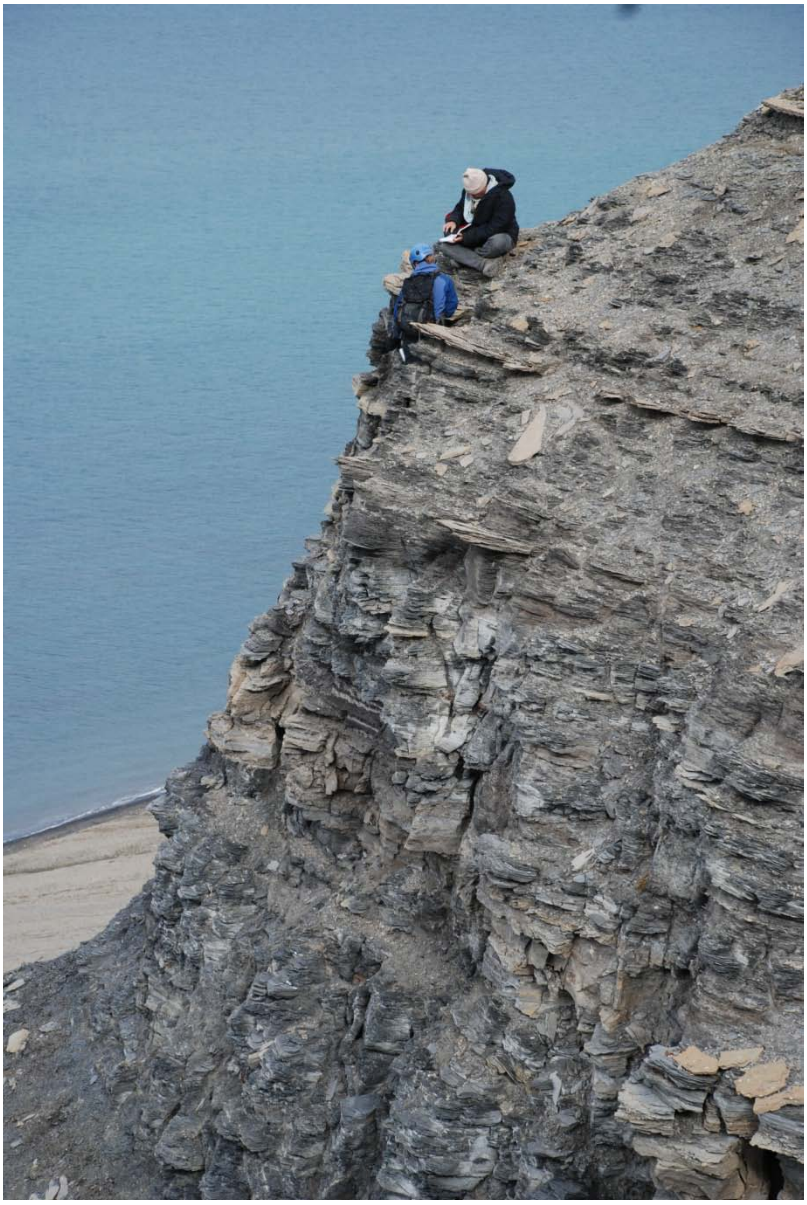
Radiolarian assemblages were analyzed using samples from IODP Site U1340 to reconstruct paleoceanographic conditions in the Bering Sea. Based on the characteristic faunal changes, the radiolarian evolution at Site U1340 was divided into four major intervals from Stages I to IV, with Stage IV divided into Substages IVa and IVb. The radiolarians in each stage recorded significantly different paleoenvironmental conditions. In general, the Bering Sea was characterised by stable warm and saline surface water during Stage I (4.15 Myr to 3.91 Myr). The environment in the Bering Sea fluctuated strongly during Stage II (3.91 Myr to 2.75 Myr) and was strongly affected by cold-water masses and sea ice during Stage III (2.75 Myr to 1.07 Myr), with the gradual development of cold and well-ventilated intermediate water. Stage IVa (1.07 Myr to 0.47 Myr) was a transitional period characterized by the enhanced formation of cold subsurface and intermediate water as well as of the oxygen-rich deep water. During Stage IVb (after 0.47 Myr), the Bering Sea was mainly characterized by enhanced warmth during interglacial episodes and well-developed water layers that were generally comparable to those of the modern Bering Sea. This suggests how the vertical water-mass structure of the modern Bering Sea began to form since 0.47 Ma. Every Stage boundary in the studied core was marked by notable changes in the radiolarian assemblages. These changes corresponded to the climatic cooling event at ~ 3.91 Ma, the intensification of Northern Hemisphere glaciation at ~ 2.75 Ma, the beginning of the middle Pleistocene transition at ~ 1.07 Ma, and the low-latitude radiolarian ecology event at ~ 0.47 Ma. In addition, the relative abundance pattern of *Cycladophora davisiana* indicates that the Bering Sea was the main source of the precursor to North Pacific Intermediate Water at ca. 0.85 Ma (MIS22), ca. 0.63 Ma (MIS16), and ca. 0.18 Ma (MIS6), just as it was during the last glacial maximum.

***Key words*:** The Bering Sea, Site U1340, Pliocene, radiolarian assemblages, paleoenvironment changes.

Session 5
Biological and Ecological Characteristics of Recent Radiolarians



Conveners
Demetrio BOLTOVSKOY & Atsushi MATSUOKA

Living Phaeodaria from surface water offshore Kashiwajima, southwestern Shikoku, Japan

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Phaeodaria, which were traditionally classified among the Radiolaria, are currently considered to belong to Cercozoa on the basis of phylogenetic analyses (e.g. Howe et al., 2011). Phaeodarian skeletons are much more fragile and less resilient to dissolution than those of the Polycystine (Takahashi, 1991), and therefore do not well preserve in the sediments. The oldest record of Phaeodarian fossils is that from the Upper Triassic (Hori et al., 2009), but its appearance is assumed to be much older, maybe in Paleozoic time.

In a surface plankton sample near Kashiwajima, southwestern Shikoku, Japan in December 2013, we obtained a rich living assemblage including both Phaeodaria and Nassellaria. The plankton consisted of a mixture of Kuroshio Current (warm) and middle latitude organisms, and is therefore highly diverse. From this sample, we isolated Phaeodaria and Radiolaria specimens individually with a pipette under a binocular microscope, and transferred them to culture-wells in laboratory of Ehime University, recording their behavior, including movements and feeding.

Most phaeodarian specimens consist of an oval cephalis with six feet, and porous shell, possessing the similar features of the genus *Medusetta*, but there are several differences. The specimens contained brown particles within their cephalis and a thin film between the spiny feet (Fig. 1). Each specimen has one pseudopod (axoflagellum?) which extends and captures food particles, mostly diatoms (especially Centrales). In this presentation, we will show their movement-images and characteristics of phaeodarian skeletons studied.

This study has benefited from the collaboration of Bch and PD students of Ehime University, and was supported by Kuroshio-Jikkan Center, Kashiwajima, southwestern Shikoku, Japan.

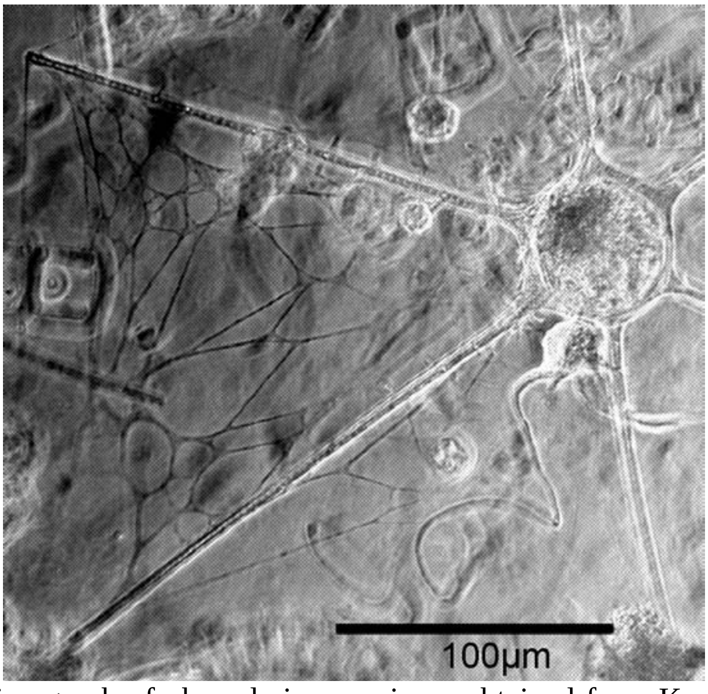

Figure 1. A photomicrograph of phaeodarian specimen obtained from Kashiwajima sample, southwestern Shikoku, Japan. Apical view.

References

Hori, R. S., Yamakita, S. & Dumitrica, P., 2009. Late Triassic Phaeodarian Radiolaria from the northern Chichibu Belt, Shikoku, Japan. Paleontological Research 13, 1, 53-63.

Howe, A. T., et al., 2011. Novel cultured protists identify deep-branching environmental DNA clades of cercozoa: New Genera Tremula, Micrometopion, Minimassisteria, Nudifila, Peregrinia. Protist 162, 332-72.

Takahashi, K., 1991. Radiolaria: Flux, Ecology, and Taxonomy in the Pacific and Atlantic.303p. Ocean Biocoenosis Series, 3, Woods Hole Oceanographic Institute Press, Woods Hole, Massachusetts.

Key words: Phaeodaria, Cercozoa, Kashiwajima, Shikoku, Japan.

Seasonal and annual flux changes of Radiolaria under the seasonally sea-ice covered conditions in the western Arctic Ocean

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Seasonal flux variations and vertical distribution of radiolarians were investigated by using time series sediment trap system moored at Station NAP (75°00'N, 162°00'W, bottom depth 1,975 m) in the western Arctic Ocean. Sediment traps were deployed at 180-260 m and 1,300-1,360 m during 4th October 2010–28th September 2011 and during 4th October 2011–18th September 2012. A vertical multiple plankton sampler with a 62 μm mesh size was also towed from 4 layers (100, 250−100, 500−250 and 1,000−500 m water dep ths) at the Northwind Abyssal Plain and southwestern Canada Basin in September 2013. Total radiolarian flux in the western Arctic Ocean was comparable to that in the North Pacific Oceans. The dynamics of sea ice was a major factor affecting the productivity, distribution, and composition of radiolarian fauna in the western Arctic Ocean. *Amphimelissa setosa* and Actinommidae spp. juvenile forms were dominant taxa in the western Arctic Ocean, and had different nutritional niches depending on seasonal ice cover. The radiolarian fauna showed a low productivity but with a high diversity under the sea-ice, associated with the seasonal changes of solar radiation. *Ceratocyrtis histricosus*, which today is associated with the warm water in the Norwegian Current, has in the Northwind Area in recent years extended its habitat into the Pacific Winter Water, which maybe can be related to the recent warming of the Pacific Winter Water. Annual variations in the radiolarian faunal composition and fluxes reflected influx of oligotrophic water caused by the recent intensification of currents in the Beaufort Gyre, related to the drastic sea-ice reduction during the last decade.

Key words**:** The western Arctic Ocean, sea-ice, Beaufort Gyre, sediment trap.

Living radiolarian vertical distribution in the northern East China Sea

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Ecological properties of radiolarians are useful for reconstructing past marine environment changes in North Pacific Ocean (Lombari & Boden, 1985; Boltovskoy et al., 2010). However, marginal seas where oceanographic conditions differ from North Pacific Ocean, radiolarian information remains limited except in the Japan Sea and Sea of Okhotsk (Itaki et al., 2004, 2010; Okazaki et al., 2004). In this study we will focus on East China Sea (ECS) where living radiolarian vertical distributions are poorly known at this time. The ECS is relatively shallow because 70% of the ECS is occupied by continental shelf shallower than 200 m. The shallow waters of ECS are fed by warm-saline water from the Kuroshio Current (KC) and the Taiwan Warm Current (TWC). In the northern Okinawa Trough, fresh water is also delivered by the Huanghe and Yangtze rivers, which emerge from the Chinese mainland. Those fresh waters are mixed with the KC and TWC surface water. The deep and intermediate water of the ECS could be influenced by the North Pacific Deep Water and the North Pacific Intermediate Water. In this study, plankton samples from the northern ECS are analyzed in order to clarify the vertical distributions of living radiolarian and the influence of the regional water masses on these distributions.

Plankton samples were obtained from the northern ECS. Here, five stations were analyzed from the ECS continental shelf to region directly influenced by the KC (31°40.9’N, 129°1.6’E to 31 °30.1’N, 126 °30.0’E). In this context, vertical tows were carried out with a closing net (63-µm) over a maximum of 8 intervals: 0-20 m, 20-50 m, 50-100 m, 100-150 m, 150-200 m, 200-300 m, 300-500 m, 500-700 m. Radiolarians were rare in stations located on the ECS continental shelf. However in stations influenced by the KC, radiolarians were abundant and assemblages were diverse (more than 100 taxa). In order to better understand the interaction of regional water masses and the vertical distribution of radiolarians, R-mode cluster analysis was conducted using the statistics software PAST (Hammer et al., 2001). Based on the R-mode cluster analysis, four distinct radiolarian assemblages were identified: Group A: surface dwellers (0-50 m) (e.g. *Tetrapyle octacantha* group), Group B: upper sub-surface dwellers (50-100 m), (e.g. *Spongosphaera streptacantha*), Group C: lower sub-surface dwellers (100-200 m) (e.g. *Eucecryphalus gegenbauri*) and Group D: intermediate water dwellers (200-500 m) (e.g. *Eucecryphalus* sp.). After comparison with CTD data conducted in all stations, species recorded in Group A could be related to high sea surface temperature and relatively low salinity water, suggesting that Group A dwellers may be related to the KC and shelf fresh water mixing. The Group B dwellers appear to indicate high chlorophyll content in the water, while the Group D dwellers indicate cold and saline water. Concerning Group C, it seems that this group is an intermediate step between high chlorophyll content to cold-saline water masses.

References

Boltovskoy, D., Kling, S., Takahashi, K. & Bjørklund, K., 2010. World atlas of distribution of recent polycystina (Radiolaria). Paleontologia Electronica 13, 1-229

Hammer, O., Harper, D. & Ryan, P.D., 2001. PAST. Paleontological Statistic Software Package for Education and Data Analyses. Paleontologia Electronica 4, 9.

Itaki, T., Ikehara, K., Motoyama, I. & Hasegawa, S., 2004. Abrupt ventilation changes in the Japan Sea the last 30 ky: evidence from deep-dwelling radiolarians. Paleogeography, Paleoclimatology, Paleoecology 208, 263-278.

Itaki, T., Kimoto, K. & Hasegawa, S., 2010. Polycystine radiolarians in the Tsushima Strait in autumn of 2006. Paleontological Research 14, 19-32.

Lombari, G. & Boden, G., 1985. Modern radiolarian global distributions. Cushman Foundation for Foraminiferal Research 16, 1–24.

Okazaki, Y., Takahashi, K., Itaki, T. & Kawasaki, Y., 2004. Comparison of radiolarian vertical distributions in the Okhotsk Sea near the Kuril Island and in the northwestern North Pacific off Hokkaido Island. Marine Micropaleontology 51, 57-284.

Key words: Radiolaria, East China Sea, vertical distribution, temperature, salinity.

Morpho-genetic phylogeny and distribution pattern of phaeodarians (Cercozoa)

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Phaeodarians are a group of unicellular protists, most of which have hollow siliceous skeleton. They are heterotrophic holoplankton and widely distributed in world oceans from the surface to deep seas. This group has long been treated as member of Radiolaria, however, they are now classified as the subclass Phaeodaria under the class Thecofilosea of phylum Cercozoa according to the molecular studies (Polet et al., 2004; Nikolaev et al., 2004; Adl et al., 2012). Their high abundance has occasionally reported in the North Pacific and its adjacent seas (Takahashi & Honjo, 1983; Gowing & Coale, 1989; Steinberg et al., 2008; Nakamura et al., 2013). The cell size of phaeodarians is generally larger than that of polycystines, therefore these cercozoans can have larger impact in silica cycle of the ocean. Although phaeodarians are phylogenetically and ecologically interesting, the basic information, such as the intra-group relationship and the distribution, is still limited. The present study is conducted in order to clarify the morpho-genetic diversity and the ecology of this group.

Plankton samples were collected during 2011-2014 from the surface to deep seas (e.g. 3000 m) in six sea areas of the Northern Hemisphere (the Mediterranean Sea, the Bering Sea, the Sea of Japan, the East China Sea and the western and eastern North Pacific). Phaeodarian specimens were isolated under microscope, and their 18S rDNA were analyzed by single-cell PCR. A total of 40 phaeodarian sequences belonging to 29 species, 10 families and 8 orders were obtained. The species composition was calculated by counting the number of each plankton taxon for some plankton samples collected in the Sea of Japan and the western North Pacific. The phaeodarian sequences formed a single large clade together with other cercozoans in the phylogenetic tree of 18S rDNA, suggesting that almost all members of the group Phaeodaria belong to the phylum Cercozoa. The clade of phaeodarian sequences was separated from other cercozoans, and the monophyly of this group was strongly supported from genetic viewpoint. The branching pattern within the phaeodarian clade did not correspond to the families and the orders of the current classification of this group, therefore the classification system probably needs to be reconsidered. The proportion of a phaeodarian species with respect to the total plankton biomass was the second largest, following that of copepods, in 250–3000 m layer of the Sea of Japan. Careful analysis of morphology and 18S rDNA sequence revealed that this phaeodarian was an unknown species, despite its large contribution to total biomass. The species was described as *Aulographis japonica* (Nakamura et al., 2013).

References

Adl, S.M., Simpson, A.G., Lane, C.E., Lukeš, J., Bass, D., Bowser, S.S., Brown, M.W., Burki, F., Dunthorn, M., Hampl, V., Heiss, A., Hoppenrath, M., Lara, E., Le Gall, L., Lynn, D.H., McManus, H., Mitchell, E.A., Mozley-Stanridge, S.E., Parfrey, L.W., Pawlowski, J., Rueckert, S., Shadwick, R.S., Schoch, C.L., Smirnov, A. & Spiegel, F.W., 2012. The revised classification of eukaryotes. Journal of Eukaryotic Microbiology 59, 5429–493.

Gowing, M.M. & Coale, S.L., 1989. Fluxes of living radiolarians and their skeletons along a northeast Pacific transect from coastal upwelling to open ocean waters. Deep-Sea Research 36, 550–565.

Nakamura, Y., Imai, I., Yamaguchi, A. Tuji, A. & Suzuki, N., 2013. *Aulographis japonica* sp. nov. (Phaeodaria, Aulacanthida, Aulacanthidae), an abundant zooplankton in the deep sea of the Sea of Japan. Plankton and Benthos Research 8, 3, 107–115.

Nikolaev, S.I., Berney, C., Fahrni, J.F., Bolivar, I., Polet, S., Mylnikov, A.P., Aleshin, V.V., Petrov, N.B. & Pawlowski, J., 2004. The twilight of Heliozoa and rise of Rhizaria, an emerging supergroup of amoeboid eukaryotes. PNAS 101, 218066–8071.

Polet, S., Berney, C., Fahrni, J. & Pawlowski J., 2004. Small-subunit ribosomal RNA gene sequences of Phaeodarea challenge the monophyly of Haeckel's Radiolaria. Protist 155, 53–63.

Steinberg, D.K., Cope, J.S., Wilson, S.E. & Kobari, T., 2008. A comparison of mesopelagic mesozooplankton community structure in the subtropical and subarctic North Pacific Ocean. Deep-Sea Research II 55, 1615–1635.

Takahashi, K. & Honjo, S., 1983. Radiolarian skeletons: size, weight, sinking speed, and residence time in tropical pelagic oceans. Deep-Sea Research 30, 5543–568.

***Key words*: Phaeodaria, Cercozoa, rDNA, single-cell PCR, plankton.**

Improved method for collecting and culturing live polycystine cells

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Polycystine fossils are widely used for paleoceanographic and stratigraphic analysis, but little is known about their biology and ecology. One reason for this is the difficulty of collecting and culturing live polycystine cells.

Several studies have attempted to culture live polycystine cells (Anderson, 1978; Anderson et al., 1989, 1990; Rivkin & Lessard, 1986; Sugiyama & Anderson, 1997; Swanberg & Harbison, 1980). In most of these studies, the culturing periods of polycystine cells was few days, but Anderson et al. (1989, 1990) successfully cultured cells for more than 20 days. Matsuoka (2002) summarized the standard methods of collecting and culturing such cells as follows: 1) collection of live cells with a plankton net, 2) selection of polycystine cells within 1 h from collection, 3) placement of cells into cell culture plates with seawater, and 4) placement of the cell culture plate into an incubator. However, this method has some problems. Sugiyama & Anderson (1997) indicated that other small organisms grew during culturing. Matsuoka (2002) mentioned that the collected cells became weak if they were selected more than 1 h after collection. Furthermore, many collected cells cannot live more than 1 day, as their pseudopodia stick to the wall of culture vessels, and rapid changes in the culturing environment can weaken polycystine cells.

To resolve these problems, we revised the culturing method as follows: 1) culture the cells in filtered seawater to remove other microorganisms from the seawater, 2) collect the live cells on a research ship with a laboratory to select the cells immediately after collection, 3) leave the selected cells in an incubator for 1 day and then remove the weakened cells, 4) culture the live cells in a 40 mL vessel to prevent pseudopodia from sticking to the wall, and 5) change half of the volume of seawater every 2 days to remove other microorganisms from the culture solution.

We used this revised method to culture live polycystine cells. The materials were collected from June to July, 2012, onboard the Oshoro-Maru, a training ship from Hokkaido University. From the collected material, we selected 26 *Didymocyrtis tetrathalamus* Haeckel cells, 14 *Euchitonia elegans* Ehrenberg cells, 12 *Dictyocoryne profunda* Ehrenberg cells, 2 *Dictyocoryne truncatum* Ehrenberg cells, and 3 *Spongaster tetras tetras* Ehrenberg cells for culturing.

The polycystine cells lived for an average of 7.5 days. Few cells died within 1 day and most lived for more than 1 week. The culturing period of *E. elegans* averaged 7.1 days with a maximum of 14 days. No cells of this species died within the first 2 days. The *D. tetrathalamus* cells lived for an average of 10.3 days with a maximum of 23 days. Both of these periods were longer than for any other examined species. The culturing period of *D. truncatum* averaged 5.0 days with a maximum of 9 days. Almost half of the examined cells lived for 9 days. *S. tetras tetras* lived for an average of 9.7 days with a maximum of 16 days.

The culturing period of *D. truncatum* averaged 5.0 days with a maximum of 7 days. The average culture period of this species is not known.

The culturing period in our study tended to be shorter than in previous studies. Anderson et al. (1990) successfully cultured *D. tetrathalamus* for 40 days and Anderson et al. (1989) cultured *D. truncatum* and *S. tetras tetras* cells for 37 days. The reasons for our shorter culture periods may include the frequent observation and rough seas when we worked. The vibration of the culture vessels during observation and rough weather may have damaged the cells. Indeed, despite our efforts to prevent it, the cells still touched the walls of the culture vessels. Furthermore, although we used filtered seawater for our cultures, other organisms increased within a few days. Sterilization of the tools was not enough to prevent this, and we could not completely remove the small organisms from among the polycystine cells.

References

Anderson, O.R., 1978. Fine structure of a symbiont-bearing colonial radiolarian *Collosphaera globularis* and 14C-isotopic evidence for assimilation of organic substances from its zooxanthellae. Journal of Ultra-structural Research 62, 181–189.

Anderson, O.R., Bennett, P. & Bryan, M., 1989. Experimental and observational studies of radiolarian physiological ecology: 3. Effects of temperature, salinity and light intensity on the growth and survival of *Spongaster tetras tetras* maintained in laboratory culture. Marine Micropaleontology 14, 275–282.

Anderson, O.R., Bryan, M. & Bennett, P., 1990. Experimental and observational studies of radiolarian physiological ecology: 4. Factors determining the distribution and survival of *Didymocyrtis tetrathalamus tetrathalamus* with implications for paleoecological interpretations. Marine Micropaleontology 16, 155–167.

Matsuoka, A., 2002. Method and research instruments for living radiolarian studies. Fossil 71, 19–27 (in Japanese).

Rivkin, R.B. & Lessard, E.J., 1986. Photoadaptation of photosynthetic carbon uptake by solitary Radiolaria: comparisons with free-living phytoplankton. Deep-Sea Research 33, 1025–1038.

Sugiyama, K. & Anderson, O.R., 1997. Experimental and observational studies of radiolarian physiological ecology, 6. Effects of silicate-supplemented seawater on the longevity and weight gain of spongiose radiolarians *Spongaster tetras* and *Dictyocoryne truncatum*. Marine Micropaleontology 29, 159–172.

Swanberg, N.R. & Harbison, G.R., 1980. The ecology of *Collozoum longiforme* sp. nov., a new colonial radiolarian from the equatorial Atlantic Ocean. Deep-Sea Research 27A, 715–732.

***Key words*:** Living Radiolaria, culturing method.

Significance of radiolarians in the middle Eocene Arctic basin for determining the degree of the connection to the Atlantic Ocean

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The Integrated Ocean Drilling Program (IODP) Arctic Coring Expedition (ACEX) 302 to the central Arctic Ocean yielded dark grey to black colored middle Eocene sediments high in organic matter with abundant siliceous microfossils. The environmental conditions of the middle Eocene Arctic basin have thus been reconstructed based primarily on the abundant siliceous microfossils and $\delta^{34}S$ as follows: semi-closed, sluggish surface circulation, reasonably shallow, anoxic below photic zone (euxinic), dysoxic at the bottom of fresh-brackish-sea water layers, photic zone present above aphotic zone of primarily anoxic, and highly productive (e.g., Brinkhuis et al., 2006; Moran et al., 2006; Stickley et al., 2008; Waddell & Moore, 2008; Onodera et al., 2008; Onodera & Takahashi, 2009a, b; Ogawa et al., 2009; Backman & Moran, 2009). The main constituent of the siliceous microfossils includes: diatoms, silicoflagellates, ebridians, and crysophytes.

Radiolarians are sporadically present in the middle Eocene samples, ranging from 48.7 Ma to 44.4 Ma. They were extremely rare, with preservation extent of medium to poor levels often with only fragmented specimens. Fully intact specimens were very rare, making mostly taxonomical identification difficult. The abundances of radiolarians ranged from 1 to 129 specimens/microslide when present. Their absolute abundances were 10^{-4} and 10^{-5} (specimens/mg dry wt. sed.) proportions of the absolute abundances of silicoflagellates and ebridians, respectively. Nevertheless, they represent excellent proof that seawater entered into the Arctic basin. On top of what is depicted above environmental conditions, the radiolarians can add useful information regarding the types of pelagic/hemipelagic waters that must have entered into the basin from the out side ocean. Based on the observed small number of specimens relative to a large number of other microfossils such as diatoms and silicoflagellates it appears that the middle Eocene Arctic radiolarians were nonindigenous, but sporadically transported into the basin and preserved there. The highest numbers of specimens were found at 48.7 Ma when only a single species of a nassellarian was observed. Such a monospecific assemblage continued onto ca. 47 Ma, with many radiolarian barren samples in between the presence record. From ca. 46.7 Ma to ca. 45.6 Ma another taxon of nassellarian monospecific assemblage appeared, also with many barren samples here and there. It was ca. 45.5 Ma when a spumellarian started to appear, indicating an environmental change. Two to three spemellarian forms constituted preserved radiolarian assemblages in a given sample, by 44.4 Ma which represents nearly the top of the ACEX middle Eocene samples, illustrating a further environmental change.

The initial appearance of monospecific nassellarian assemblage at 48.7 Ma is coincidental with the salinity minimum of 16-21 psu published by Waddell & Moore (2008). The changes from Nassellaria to Spumellaria as well as the monospecific to multiple specific assemblages hint the types of brackish marine water mass that must have entered into the Arctic. A hypothesized presence of a “buffer basin”, prompted by the monospecific nassellarian assemblage, is proposed herein. The environmental conditions can be analogous to those described by Boltovskoy et al. (2003) in the Rio de la Plata estuary. In the la Plata example, a monospecific radiolarian population of single taxon *Lophophaena rioplatensis* Boltovskoy et al. 2003 was well documented with salinity of as low as 15.4 psu, which was a similarly low value as what was published in the middle Eocene Arctic by Waddell & Moore (2008). Furthermore, Norwegian fjord examples (e.g., Bjorklund, 1974) should also serve as good comparisons. As the Arctic-Atlantic connection becomes more extensive as evident in the silicoflagellate assemblages (Onodera & Takahashi, 2009a), the multiple radiolarian taxa were dwelling in slightly deeper and more pelagic type environments than in the earlier time interval. Thus, consequently the Arctic basin was connected to the adjacent outside basin which allowed to have multiple radiolarian taxa. With the disappearance of the Buffer basin, what occurred was a slightly better connection to the Atlantic than earlier interval.

References

Backman, J. & Moran, K., 2009. Expanding the Cenozoic paleoceanographic record in the Central Arctic Ocean: IODP Expedition 302 Synthesis. Cent. Eur. J. Geosci. 1, 2, 157-175.

Bjorklund, K. R., 1974. The seasonal occurrence and depth zonation of radiolarians in Korsfjorden, western Norway. Sarsia 56, 13-42.

Boltovskoy, D., Kogan, M., Alder, V.A. & Mianzan, H. 2003. First record of a brackish radiolarian (Polycystina): *Lophophaena rioplatensis* n. sp. in the Rio de la Plata estuary. Journal of Plankton Research 25, 12, 1551–1559.

Brinkhuis, H., Schouten, S., Collinson, M.E., Sluijs, A., Sinninghe Damsté, J.S., Dickens, Huber, M., Cronin, T.M., Onodera, J., Takahashi, K., Bujak, J.P., Stein, R., van der Burgh, J., Eldrett, J.S., Harding, I.C., Lotter, A.F., Sangiorgi, F., van Konijnenburg-van Cittert, H., de Leeuw, J.W., Matthiessen, J., Backman, J., Moran, K., & the Expedition 302 Scientists, 2006. Episodic fresh surface waters in the Eocene Arctic Ocean. Nature 441, 606-609. DOI 10.1038/nature04692.

Moran, K., Backman, J., Brinkhuis, H., Clemens, S.C., Cronin, T., Dickens, G.R., Eynaud, F., Gattacceca, J., Jakobsson, M., Jordan, Michael Kaminski, M., King, J., Koc, N., Krylov, A., Martinez, N., Matthiessen, J., McInroy, D., Moore, T.C., Onodera, J., O'Regan, M., Pälike, H., Rea, B., Rio, D., Sakamoto, T., Smith, D.C., Stein, R., St John, K., Suto, I., Suzuki, N., Takahashi, K., Watanabe, M., Yamamoto, M., Farrell, J., Frank, M., Kubik, P., Jokat, W. & Kristoffersen, Y., 2006. The Cenozoic palaeoen. of the Arctic Ocean. Nature 441, 601-605.

Ogawa, Y., Takahashi, K., Yamanaka, T. & Onodera, J., 2009. Significance of euxinic condition in the middle Eocene paleo-Arctic basin: A geochemical study on the IODP Arctic Coring Expedition 302 sediments. Earth and Planet. Science Letters 285, 190–197.

Onodera, J. & Takahashi, K., 2009a. Taxonomy and biostratigraphy of silicoflagellates in the middle Eocene Arctic Ocean. In: The Arctic Coring Expedition (IODP 302): Micropaleontology at the North Pole (Kaminski, M. & Takahashi, K., Eds.), Micropaleontology 55, 2-3, 209-248.

Onodera, J. & Takahashi, K., 2009b. The middle Eocene ebridians in the central Arctic Ocean, IODP Expedition 302 (ACEX). In: The Arctic Coring Expedition (IODP 302): Micropaleontology at the North Pole (Kaminski, M. & Takahashi, K., Eds.), Micropaleontology 55, 2-3, 187-208.

Stickley, C.E., Koç, N., Brumsack, H.-J., Jordan, R.W. & Suto, I., 2008. A siliceous microfossil view of middle Eocene Arctic paleoenvironments: A window of biosilica production and preservation. Paleoceanography 23, 1-19, PA1S14.

Waddell, L.M., & Moore, T.C., 2008. Salinity of the Eocene Arctic Ocean from oxygen isotope analysis of fish bone carbonate. Paleoceanographys 23, 1-14.

***Key words*:** Middle Eocene, Arctic basin, Atlantic connection, monospecific, brackish water.

Turing patterns on the spherical surface as an initial construction of skeletal structure of spherical radiolarians

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Recently, it revealed that structures of cortical shell of Mesozoic radiolarian *Pantanellium* show various ones from the viewpoint of polyhedron geometry (Matsuoka et al., 2012; Yoshino et al., 2014b). This fact brings us a new question: why does the structure vary? This problem is not for cortical shell of *Pantanellium* but also ones whose initial skeletal structure can be approximated to spherical one. Varea *et al.* (1999) showed the results of numerical simulation of Turing system on spherical surface and discussed the problem of the variation of skeletal structures. The results, however, were a few cases and not selected the values of parameters systematically so that the question is still not clear. In this study, we show the numerical results using systematically selected parameters.

The Turing system considered in this study is as follows:

$$\frac{\partial u}{\partial t} = \frac{D}{R^2}\nabla^2 u + \alpha u(1 - r_1 v^2) + v(1 - r_2 u),$$

$$\frac{\partial v}{\partial t} = \frac{1}{R^2}\nabla^2 v + \beta v \left(1 + \frac{\alpha r_1}{\beta} uv\right) + u(\gamma + r_2 v).$$

Detailed explanation of the system is omitted here. The system produces either of spot pattern or stripe pattern as stable patterns. We restrict our consideration to a set of parameters that produces a pattern of spots because the stripe pattern is not suitable for skeletal structure. We focused on the parameter *R* because this parameter corresponds to radius of the sphere. Figure 1 show the results of different values of *R* using same initial values and parameter values. The results show that the size of each spot is almost same and number of spots is dependent on the value of *R*. For this reason, we obtained the results of numerical simulations by setting the different values of *R* systematically, and analyzed the structure from the viewpoint of polyhedron geometry. The results are dependent on both of the value of *R* and initial condition. Therefore, we carried out the simulations eight times by changing the seed of random number generator in order to change the initial value distribution.

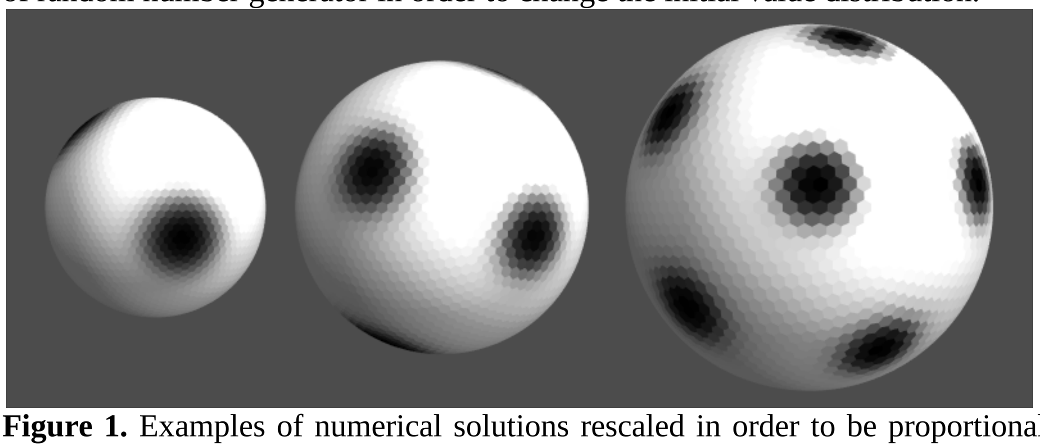

Figure 1. Examples of numerical solutions rescaled in order to be proportional to *R*. From left to right, the images correspond to *R*= 6, 8, and 10.

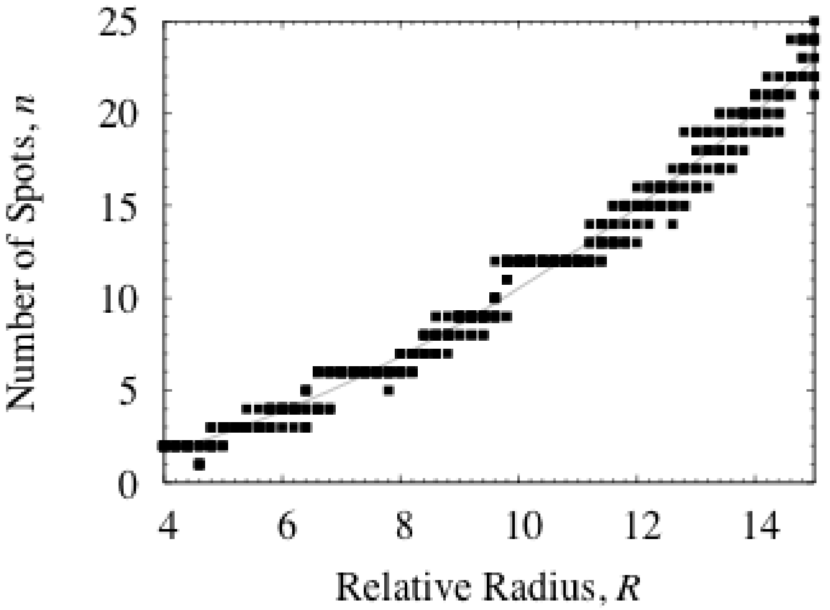

Figure 2. Dependence of the number of spots on the relative radius.

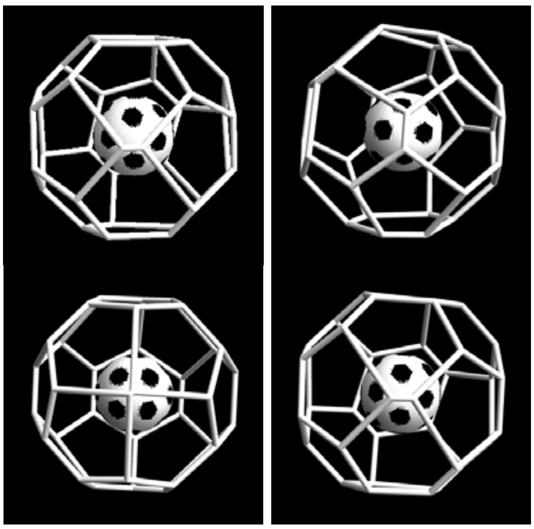

Figure 3. Examples of structural difference in cases of 19 spots

In order to analyze the spot patterns, we approximated the patterns to convex polyhedrons using the method introduced by Yoshino et al. (2014a). We determined the number of spots (number of pores) and variation of polyhedrons (pore distributions) for same number of spots.

The number of spots was not determined by the value of *R* and it varied in different distribution of initial values for fixed value of *R*. Figure 2 shows the *R* dependence of number of spots. The number of spots tends to increase with an increase of *R*, however, it does not determined only by the value of *R*. The different number of spots was observed for same value of *R*. For small number of spots such as 4, 5, 6, and 7, the variation of structure was not observed. On the other hands, the variation of structures was observed for larger number of spots such as 18, 19 and 20. Figure 3 shows the variation in a case of 19 spots.

The results of our simulation show that the spot pattern on spherical surface varies by the small differences of radius of sphere and initial condition. These results indicate that the small difference of the environment which spherical skeleton forms causes the difference of the skeletal structure.

References

Matsuoka, A., Yoshino, T., Kishimoto, N., Ishida, N., Kurihara, T., Ki-moto, K. & Matuura, 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.

Varea, C., Aragón, J. L. & Barrio, R. A., 1999. Turing patterns on a sphere. Physical Review E60, 4588-4592.

Yoshino, T., Kishimoto, N., Matsuoka, A., Ishida, N., Kurihara, T. & Kimoto, K., 2014a. Direct determination of pore holes of spherical radiolaria skeleton from three dimensional data. Forma 29, 21-27.

Yoshino, T., Matsuoka, A., Kurihara, T., Ishida, N., Kishimoto, N., Kimoto, K. & Matsuura, S., 2014b. Polyhedron geometry of skeletons of Mesozoic radiolarian *Pantanellium*. Revue de Micropaléontologie.

***Key words*: Skeletal structure, spherical structure, turing pattern.**

Rhizaria, the elusive stars of the ocean

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Oceanic ecosystems are centrally important for the ecology of our planet. Within oceanic ecosystems, large plankton play pivotal roles as top-end consumers in planktonic food webs, as links to higher trophic-level resources, and as key vectors for carbon sequestration in the ocean interior (Beaugrand et al., 2010). Because of their abundance, robustness, and therefore visibility, the scientific community has focused on studying the taxonomy, distribution, physiology, and role in marine ecosystems of crustacean copepods (Rombouts et al., 2009). In contrast, the biology and ecology of planktonic Rhizaria, unicellular but often large organisms that comprise one of the main eukaryotic super-kingdoms, is poorly studied. Preservation of the sometimes wonderfully elaborate, often star-shaped, siliceous or calcareous skeletons of certain rhizarian in marine sediments provides evidence of their abundance in the past. Hints as to the importance of living Rhizaria in contemporary oceanic ecosystems are ubiquitous, from sediment trap studies to environmental molecular surveys (Not et al., 2007; Lampitt et al., 2009). Nevertheless, as plankton nets tend to severely damage these delicate organisms, they have been overlooked in classical surveys and the global distribution and role in the ecosystem of extant Rhizaria is not well resolved.

We conducted a worldwide survey of the abundance and biomass of zooplankton larger than 1.5 mm using the in situ imaging Underwater Vision Profiler technology in 11 oceanographic cruises (2008-2013) corresponding to 1487 vertical profiles across global oceans. The data show that the contribution of Rhizaria to zooplankton biomass was similar to that of copepods in vast oligotrophic inter-tropical open oceans (40°N to 20°S). These mainly oligotrophic inter-tropical open oceans are among the largest ecosystems on the planet. In the upper 500m of the water column of world oceans, we estimated the biomass of Rhizaria larger than 1.5 mm to represent a standing stock of 0.209 x109 Tg of carbon. This huge biologically active reservoir, representing nearly 10% of the total standing stock of biotic carbon in the oceans, has been almost completely overlooked in ecosystemic models of the marine environment. The main contributors to rhizarian biomass were the colonial Collodaria (most of which host symbiotic microalgae) in surface waters and solitary non-symbiotic Phaeodaria in deeper waters. While copepods are undoubtedly major players in polar and temperate seas, the substantial contribution of large Rhizaria to global plankton community structure provides a new and radically different perspective on marine ecosystem functioning in vast oligotrophic open oceans. Climate models tend to show that mid-latitude oligotrophic oceans will expand with global warming, which implies that the range and impact of large Rhizaria will increase in the future.

References

Beaugrand, G., Edwards, M. & Legendre, L., 2010. Marine biodiversity, ecosystem functioning, and carbon cycles. Proceedings of the National Academy of Sciences of the United States of America 107, 10120–10124.

Lampitt, R.S., Salter, I. & Johns, D., 2009. Radiolaria: Major exporters of organic carbon to the deep ocean. Global Biogeochemical Cycles 23, GB1010, doi:10.1029/2008GB003221.

Not, F., Gausling, R., Azam, F., Heidelberg, J.F. & Worden, A.Z., 2007. Vertical distribution of picoeukaryotic diversity in the Sargasso Sea. Environmental Microbiology 9, 5, 1233–1252.

Rombouts, I., Beaugrand, G., Ibanez, F., Gasparini, S., Chiba, S. & Legendre, L., 2009. Global latitudinal variations in marine copepod diversity and environmental factors. Proceedings of the Royal Society B 276, 3053–3062.

***Key words*: Rhizaria, biomass, underwater video Profiler.**

Living and dead radiolarians in spring in the South China Sea and their responses to environmental factors

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The South China Sea (SCS) has special geological location and typical regional environment which make the SCS become one of the best experimental region to study radiolarians and biogenical sediments. A total of 51 plankton tows were made between 0 and 300 m at 12 sites using a closing-type net with 62 μm mesh size. The plankton tow depths were set at 0–25 m (upper part of surface water), 25–50 m (lower part of surface water), 50–75 m (upper part of subsurface water), 75–150 m (lower part of subsurface water), and 150–300 m (upper intermediate water). All plankton samples were preserved in 5% buffered formalin, and stained with Rose Bengal to distinguish living specimens from dead ones. Our major objectives are to study the composition and distribution of living and dead radiolarians along the two sections of the SCS, to discuss the responses of ecological distribution of living and dead radiolarians to marine environmental parameters, and to identify sensitive indicator species for tropical environmental factors. These results would increase our knowledge of living and dead radiolarians in the SCS and provide new information for reconstructing paleoceanography and paleoenvironment.

Vertically, the highest abundance of living radiolarians generally occurred at the depth range of 25–75 m, where the chlorophyll-*a* maximum and the highest primary productivity were. In contrast, the maximum values are in the top 25 m from the cold eddies (upwelling) in the open seas and decreased with depth. The promotion effect of mesoscale cold eddies on primary productivity in the euphotic zone was abount 29.5% (Hu et al., 2014), which could explain the sensitive response of living radiolarians to the cold eddies. However in the cold eddy off the Mekong River mouth, the living radiolarian abundance is significantly low, where the surface salinity was only 32.42 psu, with >0.5 psu lower than those station regions, indicating that the inhibition effect of changing salinity (due to continental freshwater runoffs) on living radiolarians was much stronger than the promotion effect of mesoscale cold eddies. The dominant species composition consisted of tropical-subtropical warm species. We identified some indicator species for tropical environments. Living *Didymocyrtis tetrathalamus tetrathalamus* could be an indicator for tropical surface water or mixed-layer water, and even for tropical oligotrophic water. Living *Tetrapyle octacantha* could be used to indicate tropical thermocline and eutrophic environment. Living *Acanthodesmia vinculata* could indicate tropical surface and subsurface waters. *T. octacantha* and *A. vinculata* should only be used as indicators for upwelling in the open seas, i.e., far away from river mouths. Living *Siphonosphaera polysiphonia*, a colonial species, may be related to the effect of warm eddies. Living *Cyrtopera laguncula* and living *Cornutella profunda* surprisingly occurred in the tropical upper layer, even in the surface waters, suggesting that they are not be limited to live in the intermediate and deep waters.

Our results showed that the dead radiolarians in spring of the SCS were relative abundant, increasing with depth, and the highest abundance generally occurred at depths of 75-300m, i.e., below the chlorophyll-a maximum and the highest density of living radiolarians. By analyzing data, we found that the deep distribution of dead radiolarian abundance was affected by the lateral advection of ocean current; The difference on species composition and abundance distributions between in upper waters in spring and in the surface sediments was due to two significant causes of the seasonal variance of modern radiolarians and the lateral advection of ocean current. Interestingly, *Cycladophora davisiana* was found in 150-300m depth, and we concluded that the typical cold species *C. davisiana* could be brought to the upper-middle level waters from the below-middle level waters by the meridional overturning circulation.

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Reference

Hu, Z.F., Tan, Y.H., Song, X.Y., et al., 2014. Influence of mesoscale eddies on primary production in the South China Sea during spring inter-monsoon period. Acta Oceanologica Sinica 33, 118-128.

Key words: South China Sea, living and dead radiolarians, mesoscal eddy, lateral advection and meridional overturning circulation.

In honor of Nutthawut Wonganan, a friend, a geologist, a radiolarist who left us too early!

Martial CARIDROIT[1], Carine RANDON[2], Benjamin MUSAVU-MOUSAVOU[3]
with the support of some his numerous friends of the University of Lille 1 (France): Elisabeth LOCATELLI[1], Taniel DANIÉLIAN[1], Alain BLIECK[1], Daniel VACHARD[1], Thomas SERVAIS[1], Sébastien CLAUSEN[1], Régine NETTER[1]

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Nutthawut Wonganan was born October 13, 1975 in Phayao (Northern Thailand). He trained in geology and palaeontology at the University of Chiang Mai. Excellent student, he got a fellowship for a PhD abroad. He chose France: Laboratory of Palaeontology (LP3) of the University of Lille 1. He defended this thesis on January 14, 2005. During this period of thesis and during other stays in Lille, all his colleagues appreciated his serious research, his good humor and his kindness. Back to the Chiang Mai University, he became lecturer and took important administrative burdens while continuing his research on radiolarians and supervising students. Many "radiolarists" met him at various INTERRAD congress and enjoyed his company.

He passed away August 2, 2013 after a nasty disease and **we all regret his absence!** The proposed poster presents his too short career and some of his scientific results.

Nutthawut in his office in the University of Chiang Mai.

AUTHOR INDEX

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