RADIOLARIA

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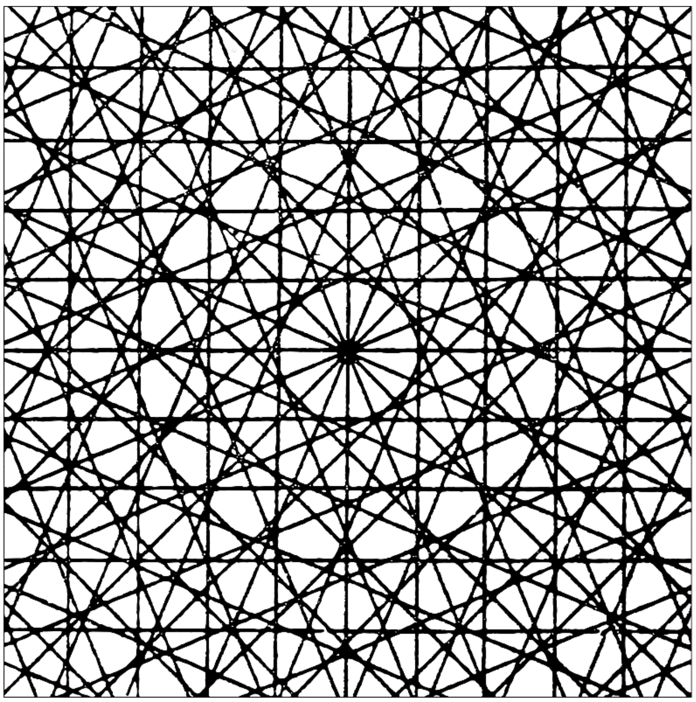

ABSTRACTS

16th InterRad

September 11th—15th

Ljubljana 2022

NEWSLETTER

THE INTERNATIONAL ASSOCIATION OF RADIOLARISTS

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16th InterRad
Ljubljana 2022

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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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Editors: Tim Cifer, Špela Goričan, Aleksander Horvat

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Program & Abstracts

THE ORGANIZING COMMITTEE FOR INTERRAD XVI IN LJUBLJANA 2022

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HOSTS

International Association of Radiolarists

Research Centre of the Slovenian Academy of Sciences and Arts

Slovenian Academy of Sciences and Arts

ORAL SESSIONS AND CONVENERS

TAXONOMY, BIOSTRATIGRAPHY AND PALEOECOLOGY OF PALEOZOIC RADIOLARIANS

SPECIAL SESSION IN MEMORY OF MARTIAL CARIDROIT (1957-2019)

Conveners: **Taniel DANELIAN & Paula NOBLE**

TAXONOMY, BIOSTRATIGRAPHY AND PALEOECOLOGY OF MESOZOIC RADIOLARIANS

SPECIAL SESSION IN MEMORY OF ELSPETH URQUHART (1949-2019)

Convener: **Rie S. HORI**

TAXONOMY, BIOSTRATIGRAPHY AND PALEOECOLOGY OF CENOZOIC RADIOLARIANS

SPECIAL SESSION IN MEMORY OF WILLIAM R. RIEDEL (1927-2020)

Convener: **David LAZARUS**

RADIOLARIANS FROM MOUNTAIN BELTS AND PAST OCEANS – RECORDS OF CLIMATE HISTORY

JOINT SESSION WITH IGCP 710: WESTERN TETHYS MEETS EASTERN TETHYS

Conveners: **Peter O. BAUMGARTNER & Nevenka DJERIĆ**

RADIOLARIANS IN CONTEMPORARY ECOSYSTEMS

Conveners: **Tristan BIARD & Fabrice NOT**

GEOMETRY OF RADIOLARIAN SKELETONS

Convener: **Atsushi MATSUOKA**

SESSION PLACES

All oral and poster presentations take place at the same location:

Research Centre of the Slovenian Academy of Sciences and Arts (https://www.zrc-sazu.si/en)

Slovenian Academy of Sciences and Arts (https://www.sazu.si/en/about-sasa)

- Oral presentations: Main Hall SAZU (SAZU, Novi trg 3, SI-1000 Ljubljana)
- Poster presentations: ZRC Atrium (ZRC SAZU, Novi trg 2, SI-1000 Ljubljana, Slovenia)

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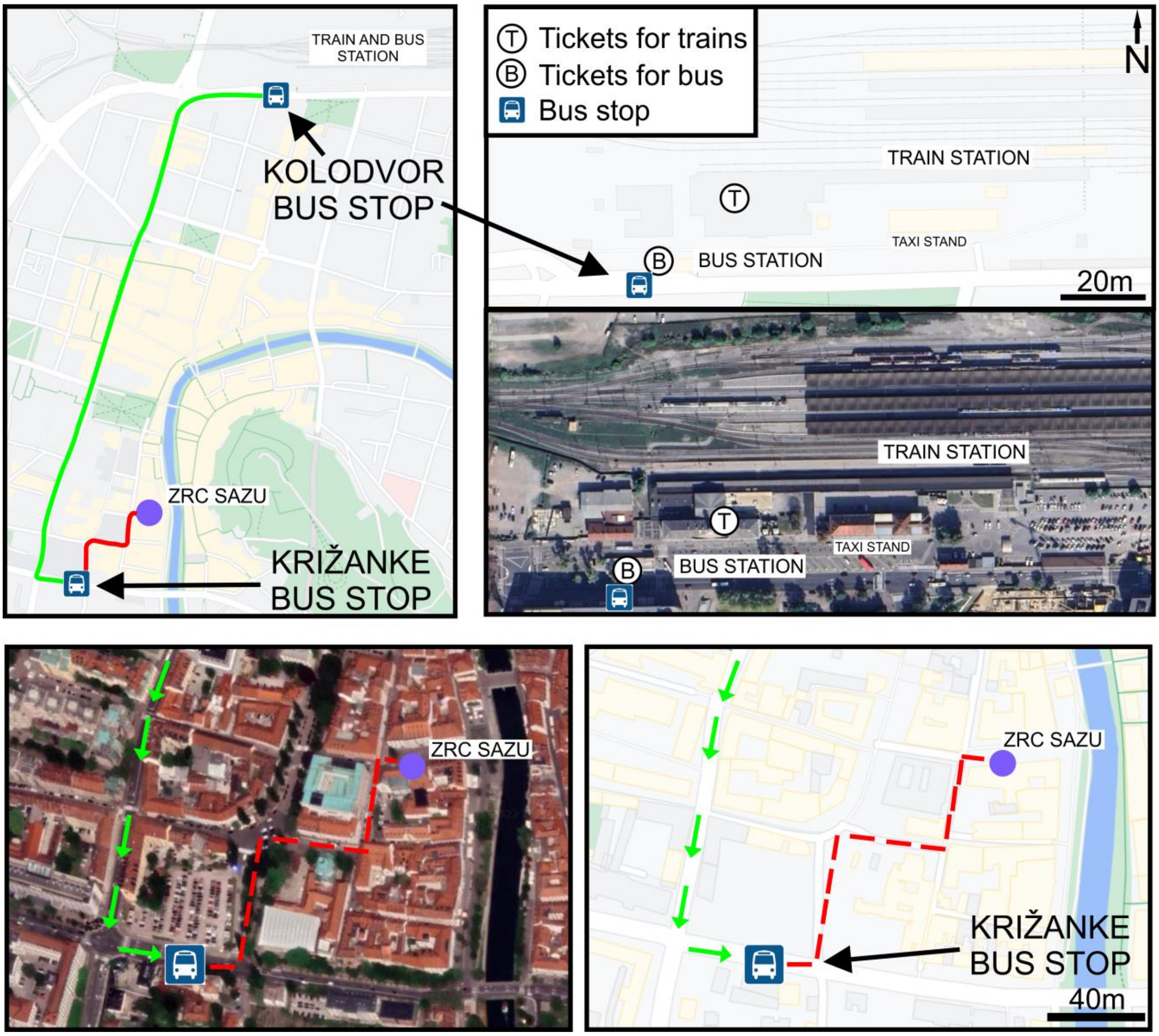

TRANSPORTATION FROM THE TRAIN/BUS STATION TO THE VENUE (ZRC SAZU).

1: ROUTE BUS (10-20 MINUTES, 1,3€/ONE WAY)

LINE 2 direction **NOVE JARŠE** or **LINE 27** direction **NS RUDNIK**

Before using the route bus go to the Bus Station and acquire the URBANA CITY CARD (https://www.lpp.si/en/single-city-card-urbana). At the bus station you have to upload money on the URBANA CITY CARD, which is used to pay the bus ticket directly at the route bus.

ENTER route bus at bus stop KOLODVOR

EXIT route bus at bus stop KRIŽANE

WALK from bus stop KRIŽANKE to the VENUE (indicated with red line)

2: TAXI (10-15 MINUTES, 5-8€/ONE WAY)

THE VENUE (ZRC SAZU)

ZRC ATRIUM

- September 11th, Sunday (evening): arrival; registration and Ice Breaker Party
- September 12th, Monday (morning and afternoon): poster session
- September 13th, Tuesday (morning and afternoon; evening): poster session and Conference Dinner
- September 15th, Thursday (morning and afternoon): poster session, business meeting and farewell coffee

MAIN HALL SAZU

- September 12th, Monday (morning and afternoon): Opening ceremony and oral presentations
- September 13th, Tuesday (morning and afternoon): oral presentations
- September 15th, Thursday (morning and afternoon; evening): oral presentations and closing ceremony

PROGRAM OVERVIEW

SUNDAY 11 September	MONDAY 12 September	TUESDAY 13 September	WEDNESDAY 14 September	THURSDAY 15 September	FRIDAY 16 September
Northern Calcareous Alps (pre-conference excursion A)	Registration (from 08:00 ZRC Atrium) Hall SAZU 9:00 Opening S7 Geometry	Hall SAZU S3 Cenozoic	mid-conference excursions: B1 Kras B2 Julian Alps	Hall SAZU S4 Mountain belts and past oceans	Montenegro (post-conference excursion C)
	Coffee Break	Coffee Break		Coffee Break	
	S1 Paleozoic	S3 Cenozoic		S4 Mountain belts and past oceans	
	Lunch Break	Lunch Break		Lunch Break	
	S2 Mesozoic	S6 Recent		Business Meeting & Closing ZRC Atrium	
	Coffee Break	Coffee Break			
	S2 Mesozoic	S6 Recent			
Registration ZRC Atrium from 17:30	poster session & Pz and Mz working groups ZRC Atrium	poster session & Cenozoic/ Recent WG ZRC Atrium			
Icebreaker Party ZRC Atrium from 18:00		Dinner at 19:00 ZRC Atrium			

PRELIMINARY PROGRAM

Monday 12. 9.	
9:00 – 9:30	Opening ceremony
	S7 - Geometry of radiolarian skeletons Convener Atsushi MATSUOKA
9:30 – 10:00 key note	Atsushi Matsuoka, Takashi Yoshino, Katsunori Kimoto & Naoko Kishimoto EVOLUTION OF THE MESOZOIC FAMILY PANTANELLIIDAE AND ITS MORPHOLOGICAL FEATURES
10:00 – 10:20	Takashi Yoshino, Atsushi Matsuoka, Katsunori Kimoto & Naoko Kishimoto GEOMETRICAL VARIATIONS OF SKELETAL STRUCTURES OF GENUS *PANTANELLIUM*
10:20 – 10:45	Coffee Break
10:45 – 11:00	**S1 – Taxonomy, biostratigraphy and evolution of Paleozoic radiolarians.** **In memory of Martial CARIDROIT (1957–2019)** Conveners Taniel DANELIAN and Paula NOBLE
11:00 – 11:30 key note	Taniel Danelian & Claude Monnet MACROEVOLUTIONARY DYNAMICS IN EARLY PALEOZOIC RADIOLARIA
11:30 – 11:50	Jiani Sheng & Jonathan C. Aitchison MIDDLE AND UPPER CAMBRIAN RADIOLARIAN ASSEMBLAGES FROM THE GEORGINA BASIN, AUSTRALIA
11:50 – 12:10	Rie S. Hori, Junpei Kawamura & Teppei Tamura SILURIAN RADIOLARIAN FOSSILS FROM THE TYPE AREA OF KUROSEGAWA TECTONIC ZONE, SHIKOKU-SEIYO GEOPARK, JAPAN
12:10 – 12:30	Galina P. Nestell & Merlynd K. Nestell RADIOLARIANS FROM AN UPPER KASIMOVIAN (PENNSYLVANIAN) LAKE BRIDGEPORT SHALE REGRESSIVE SEQUENCE (GRAFORD FORMATION, CANYON GROUP), NORTH-CENTRAL TEXAS, USA
12:30 – 14:30	Lunch Break
14:30 – 14:40	**S2 – Taxonomy, biostratigraphy and paleoecology of Mesozoic radiolarians.** **In memory of Elspeth URQUHART (1949–2019)** Convener Rie S. HORI
14:40 – 15:00	Peter O. Baumgartner, Xin Li & Atsushi Matsuoka MORPHOLOGIC FEATURES AND EVOLUTION OF JURASSIC-CRETACEOUS AUSTRAL RADIOLARIA
15:00 – 15:20	Péter Ozsvárt LATE ANISIAN (ILLYRIAN) RADIOLARIANS FROM THE DOLOMITES, SOUTHERN ALPS, ITALY
15:20 – 15:40	Yuki Tomimatsu, Tetsuji Onoue & Manuel Rigo HIGH-RESOLUTION RADIOLARIAN AND CONODONT BIOSTRATIGRAPHY OF THE UPPER TRIASSIC AND ACROSS THE TRIASSIC-JURASSIC BOUNDARY IN THE INUYAMA AREA, CENTRAL JAPAN
15:40 – 16:10	Coffee Break

16:10 – 16:30	Tetsuji Onoue, Yuki Tomimatsu, Honami Sato & Manuel Rigo RADIOLARIAN RESPONSES TO THE NORIAN "CHAOTIC CARBON EPISODE" IN THE PANTHALASSA
16:30 – 16:50	Tim Cifer, Špela Goričan & Hans-Jürgen Gawlick RADIOLARIAN PALEOECOLOGY ACROSS THE SINEMURIAN–PLIENSBACHIAN TRANSITION AT MT. RETTENSTEIN (NORTHERN CALCAREOUS ALPS, AUSTRIA)
16:50 – 18:00	poster session
18:00 –	sessions of Paleozoic and Mesozoic working groups

Tuesday 13. 9.	
9:00 – 9:10	**S3 - Taxonomy, biostratigraphy and paleoecology of Cenozoic radiolarians** **Special session in memory of William R. RIEDEL (1927–2020)** convener David LAZARUS
9:10 – 9:30	Peter O. Baumgartner, Claudia Baumgartner-Mora, Daniel Rincón Martínez & Sandra M. Restrepo Acevedo LATE CRETACEOUS AND PALEOCENE RADIOLARIA FROM THE SAN JACINTO FOLD BELT, NORTHEAST COLOMBIA
9:30 – 9:50	Mathias Meunier & Taniel Danelian PROGRESS IN MIDDLE EOCENE RADIOLARIAN BIOSTRATIGRAPHY AND PALEOBIODIVERSITY; NEW INSIGHTS FROM THE EQUATORIAL ATLANTIC
9:50 – 10:10	Gayane Asatryan, Johan Renaudie & David Lazarus NEW UNDERSTANDING OF THE EOCENE-OLIGOCENE SOUTHERN OCEAN RADIOLARIAN FAUNAL CHANGES
10:10 – 10:30	Akihide Kikukawa, Yoshiaki Aita & Nobuhiro Kotake RADIOLARIAN AND DIATOM FOSSILS FROM INFILL OF TRACE FOSSIL *TASSELIA ORDAMENSIS* FROM THE OLIGOCENE AND MIOCENE DEEP-SEA SEDIMENTARY ROCKS IN JAPAN
10:30 – 11:00	Coffee Break
11:00 – 11:20	Paulian Dumitrica ON THE STATUS OF *SATURNULUS PLANETA* HAECKEL 1879, A *NOMEN OBLITUM* RADIOLARIAN SPECIES ILLEGALLY REINTRODUCED IN LITERATURE BY SUZUKI *IN* SUZUKI ET AL. (2021), AND THE CATASTROPHIC CONSEQUENCES OF THIS ACT FOR THE STABILITY OF THE TAXONOMY OF SATURNALID RADIOLARIA
11:20 – 11:40	Dave Lazarus, Nori Suzuki, Jeremy Young, Jean Pierre Caulet & Johan Renaudie RADIOLARIA@MIKROTAX: A PROGRESS REPORT ON PUTTING A SYNTHESIS OF CENOZOIC RADIOLARIAN TAXONOMIC DATABASES ONLINE
11:40 – 12:00	Veronica Carlsson, Taniel Danelian, Pierre Boulet, Philippe Devienne, Aurelien Laforge & Johan Renaudie A SIMPLE CNN APPROACH FOR AUTOMATIC CLASSIFICATION OF EIGHT CLOSELY RELATED SPECIES OF THE MIDDLE EOCENE GENUS *PODOCYRTIS*
12:00 – 12:20	Martin Tetard, Ross Marchant, Giuseppe Cortese, Yves Gally, Thibault de Garidel-Thoron & Luc Beaufort A NEW AUTOMATED RADIOLARIAN IMAGE ACQUISITION, STACKING, PROCESSING, SEGMENTATION AND IDENTIFICATION WORKFLOW

12:20 – 14:00	Lunch Break
	S6 – Radiolarians in contemporary ecosystems Conveners Tristan BIARD and Fabrice NOT
14:00 – 14:20	Miguel M. Sandin, Johan Renaudie, Noritoshi Suzuki & Fabrice Not RADIOLARIA DIVERSITY, ECOLOGY AND EVOLUTION: AN INTEGRATIVE APPROACH
14:20 – 14:40	Iris Rizos, Sarah Romac, Lucie Bittner & Fabrice Not INSIGHTS INTO THE LIFE CYCLE OF EXTANT RADIOLARIA
14:40 – 15:00	Manon Laget, Natalia Llopis-Monferrer, Jean-François Maguer, Aude Leynaert & Tristan Biard ELEMENTAL MASS OF MODERN RHIZARIA: FROM CELLULAR SCALE TO GLOBAL BIOGEOCHEMICAL CYCLES
15:00 – 15:20	Joost Samir Mansour, Johan Decelle, Charlotte Lekieffre, Benoit Gallet, Sophie Le Panse & Fabrice Not CARBON AND NITROGEN UPTAKE AND TRANSLOCATION BETWEEN THE SINGLE CELL MARINE PROTIST ACANTHARIA AND THEIR SYMBIONTS
15:20 – 15:50	Coffee Break
15:50 – 16:10	Natalia Llopis Monferrer, Colleen Durkin, Steven Haddock & Fabrice Not Si-ORHIGENS Project: Unravelling the Silicification prOcess in RHIzaria through GENetics and Skeletal growth
16:10 – 16:30	Marie Cueille, Taniel Danelian, Koen Sabbe, Elisavet Skampa, Maria Triantaphyllou & Alexandra Gogou POLYCYSTINE RADIOLARIANS OFF SOUTH-WESTERN CRETE (EASTERN MEDITERRANEAN) AND THEIR SEASONAL FLUXES DURING 2005-06: ENVIRONMENTAL DRIVERS AND COMPARISON WITH COCCOLITHOPHORE EXPORT
16:30 – 16:50	Johan Renaudie, David Lazarus, Volkan Özen, Gabrielle Rodrigues De Faria & Sarah Trubovitz A 'BIG DATA' LOOK AT THE IMPACT OF CLIMATE ON FOSSIL PLANKTON BIODIVERSITY, WITH A PROJECTION FOR FUTURE CLIMATE CHANGE
16:50 – 17:10	Rie S. Hori and Teams of Living Radiolarian study at Ehime University A MOVIE OF LIVING RADIOLARIA FROM SURFACE SEAWATER OF THE KUROSHIO CURRENT NEAR JAPAN FOR EDUCATION AND FUTURE STUDY VER. 2
17:10 –	poster session and Cenozoic/Recent Working Group session
19:00 –	Dinner

Wednesday 14. 9.	**Fieldtrips B1 (Classical Karst) and B2 (Julian Alps)**

Thursday 15. 9.	
	S4 - Radiolarians from mountain belts and past oceans – records of climate history **Joint session with IGCP 710: Western Tethys meets Eastern Tethys** Conveners Peter O. BAUMGARTNER and NEVENKA ĐERIĆ
9:00 – 9:30 key note	Peter O. Baumgartner, Xin Li, Christian Vérard & Atsushi Matsuoka NEOTETHYAN, SUBTROPICAL GYRE AND AUSTRAL RADIOLARIA – TRACERS FOR PANGEA BREAKUP AND CLIMATE CHANGE OF THE JURASSIC-CRETACEOUS TRANSITION
9:30 – 9:50	Hans-Jürgen Gawlick TRIASSIC-JURASSIC RADIOLARITE EVENTS IN THE WESTERN TETHYS REALM – REASONS?, CONTROLLING FACTORS?
9:50 – 10:10	Nevenka Djerić, Hans-Jürgen Gawlick & Špela Goričan NEW AGE DATA ON THE OPHIOLITES FROM THE CENTRAL SERBIA: IMPLICATION FOR THE JURASSIC EVOLUTION OF THE VARDAR OCEAN
10:10 – 10:40	Coffee Break
10:40 – 11:00	Duje Kukoč, Damir Slovenec, Matija Vukovski, Duje Smirčić, Mirko Belak, Tonći Grgasović & Dražen Japundžić RADIOLARIAN DATING OF THE EVOLUTION OF THE NEOTETHYS OCEAN AT THE JUNCTION OF THE SOUTHERN ALPS AND THE DINARIDES (NW CROATIA)
11:00 – 11:20	Marco Chiari, Emilio Saccani, Špela Goričan, Michele Marroni, Luca Pandolfi, Morteza Delavari, Asghar Dolati, Tahmineh Pirnia, Godhrat Torabi & Edoardo Barbero RADIOLARIAN BIOSTRATIGRAPHY AND GEOCHEMISTRY OF THE OPHIOLITES FROM MAKRAN AND NAIN-ASHIN (IRAN): A SYNTHESIS
11:20 – 11:40	Goran Andjić, Renjie Zhou[2], David M. Buchs, Jonathan Aitchison & Jianxin Zhao DETERMINING THE AGE AND TECTONIC EVOLUTION OF THE OCEANIC CRUST USING CALCITE U-PB GEOCHRONOLOGY AND RADIOLARIAN BIOSTRATIGRAPHY
11:40 – 14:00	Lunch Break
14:00 –	Business meeting
	Closing ceremony

LIST OF POSTERS

Session	Authors	Title
S1	Tea Kolar-Jurkovšek, Marina S. Afanasieva, Aleksander S. Alekseev, Yury A. Gatovsky, Carlos Martínez-Pêrez & Bogdan Jurkovšek	A recovery of the oldest Albaillellaria finding in Central Europe
S2	Marta Bąk & Krzysztof Bąk	Correlation of Albian-Cenomanian radiolarian and foraminiferal datum events with new chemostratigraphic ($\delta^{13}C_{org}$) data from a reference section in the Outer Carpathians
S2	Dario Ferrari, Marco Chiari, Luca Bachechi & Enrico Pandeli	Radiolarian dating of the chert used in lithic tools assemblages from "Artofago cave" (Italy)
S2	Paulian Dumitrica	New Middle Triassic bell-shaped Nassellaria
S2	Konan Suwazono, Yuki Tomimatsu, Shun Muto & Tetsuji Onoue	Radiolarian biostratigraphy and recovery from ocean anoxic event during Early-Middle Triassic: Chichibu Belt, Japan
S2	Qiangwang Wu, Angela Bertinelli, Alda Nicora, Umberto Susta, Manuel Altieri & Manuel Rigo	Biostratigraphic record of the upper Carnian radiolarians from the Pizzo Mondello section (western Sicily, Italy)
S3	Sarah Trubovitz, David Lazarus, Johan Renaudie & Paula J. Noble	Radiolarians show threshold extinction response to late Neogene climate change
S3	Sarah Trubovitz, Johan Renaudie, David Lazarus & Paula J. Noble	New species of late Neogene Lophophaenidae (Nassellaria, Radiolaria) from the eastern equatorial Pacific
S3	Johan Renaudie, Nichole A. Anest & David Lazarus	The Lamont radiolarian and diatom slides collection
S4	Marta Bąk & Krzysztof Bąk	Radiolarian and foraminiferal response on environmental perturbation induced by climate change recorded in uppermost Albian to upper Cenomanian Oceanic Anoxic Events
S4	Marco Chiari, Luca Mordini, Adonis Photiades & Emilio Saccani	Radiolarian biostratigraphy and geochemistry of basalt-chert associations in the ophiolites of the Ypaton area (Greece)
S4	Nevenka Djerić, Hans-Jürgen Gawlick & Špela Goričan	Radiolarian biostratigraphy and microfacies of Upper Triassic radiolarites from central and western Serbia
S4	Marína Molčan Matejová	Triassic and Jurassic radiolarians from the Meliata Ocean – preliminary results
S7	Atsushi Matsuoka, Yuta Tomita, Hayato Yokoyama &Tsuyoshi Ito	Radiolarians and related items for outreach activities

ABSTRACTS

Determining the age and tectonic evolution of the oceanic crust using calcite U-Pb geochronology and radiolarian biostratigraphy

Goran ANDJIĆ[1], Renjie ZHOU[2], David M. BUCHS[3], Jonathan C. AITCHISON[2] & Jianxin ZHAO[2]

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2) School of Earth and Environmental Sciences, The University of Queensland, 4072 St Lucia, Australia
3) School of Earth and Environmental Sciences, Cardiff University, United Kingdom

Active accretionary wedges result from the convergence between a downgoing oceanic plate and an overriding plate. There, loose sediment and rock material sourced from both plates is stacked into fault-bounded, deformed packages that are incorporated into the overriding plate. In modern settings, both accretionary complexes and downgoing plates lay far below sea level, making methods of getting first-hand observations complex and costly (such as drilling/dredging/seismic reflection). In contrast, exhumed ancient accretionary complexes provide a more accessible way to study the tectonic evolution of subduction zones and oceanic plates partly or completely lost to subduction.

Documenting the history of ancient oceanic plates from accretionary complexes is faced with the challenge of dealing with dismembered pieces of oceanic crust, whereby the original succession of lithologies − called ocean plate stratigraphy (Isozaki et al. 1990) − was partly or entirely lost. Establishing the timing of formation and subduction of oceanic plates hence implies determining the age of meter- to kilometer-sized blocks of oceanic crust and the sedimentary matrix in which they are embedded. Dating ocean plate stratigraphy in accretionary complexes has classically relied on paleontology rather than on geochronology because processing and identifying fossils, such as radiolarians, are well practiced by the community. In contrast, mafic igneous rocks from the oceanic crust generally lack minerals commonly used in geochronological studies (such as zircon), and are often subject to strong alteration. Therefore, if a block of mafic igneous rock is not in stratigraphic contact with a datable sedimentary rock, its age is very likely to remain unknown.

We studied the accretionary complex represented by the Carboniferous Texas Beds in the southern segment of the New England Orogen, which is the youngest belt of a collage of Paleozoic subduction-related orogens occupying the eastern third of the Australian continent. Altered ocean island basalt (OIB)-like rocks, cherts and shallow-marine carbonates are embedded throughout the complex. Although these rock associations were considered to represent remnants of oceanic islands based on existing biostratigraphic, geochemical and lithological data, their original relationship was obscured by tectonic dismemberment, possibly during accretion and/or gravitational collapse of islands arriving at the subduction zone. Their exact timing of formation and accretion, which is critical to reconstruct the origin and evolution of the dismembered ocean plate stratigraphy, was not known before.

Two distinct types of calcite were formed in the studied OIB-like volcanic rocks. One calcite type precipitated in amygdules (voids representing former gas bubbles in a molten lava), whereas the other type precipitated in orthogonal fractures which are also visible among all the lithologies in the accretionary complex. Beside distinct morphologies, these calcites have distinct U-Pb geochronological ages and geochemical signatures. Calcite precipitation from low-temperature hydrothermal fluids in amygdules occurred at around 378–354 million years ago, whereas calcite precipitation from seawater in fractures occurred at around 331–279 million years ago.

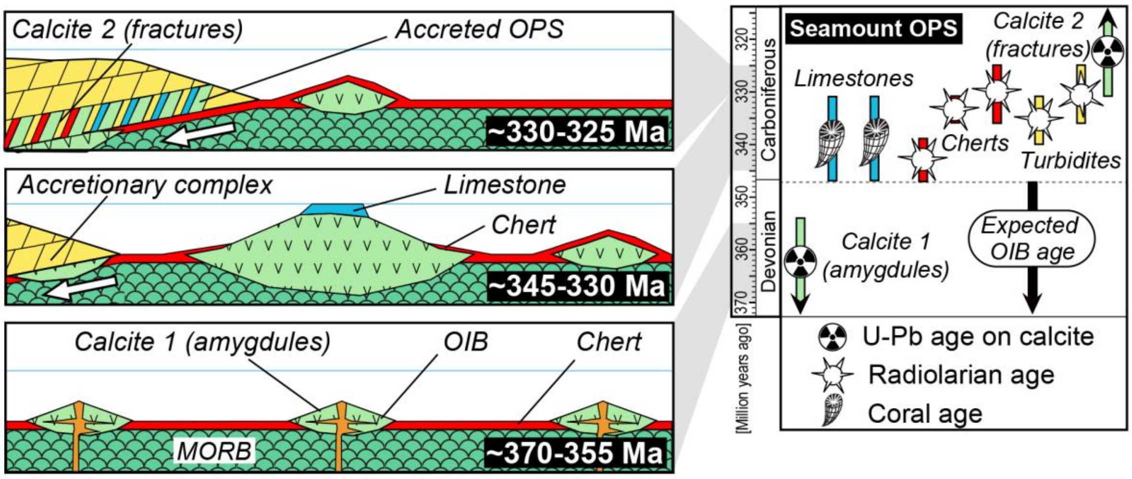

Figure 1. Summary of the age constraints used to establish the timing of formation and accretion of Paleozoic intraplate volcanoes. Modified from Andjić (2022) and Andjić et al. (2022). OPS = Ocean Plate Stratigraphy; OIB = Oceanic Island Basalt; MORB = Mid-Ocean Ridge Basalt.

Taken at face value, the timing of precipitation of the two generations of calcite does not translate into clear geological implications. It is only when combined with new and existing fossil age data that the significance of the geochronological ages becomes meaningful. When integrating data from all the lithologies making up the accretionary complex, it is possible to reconstruct the following sequence of events (Figure 1):

-> no later than 354 million years ago = intraplate volcanic eruptions;
-> 347–330 million years ago = deep to shallow marine sedimentation on intraplate volcanoes;
-> 330–325 million years ago = accretion of intraplate volcanoes to Gondwana;
-> no earlier than 330 million years ago = brittle deformation of intraplate volcanoes within the accretionary complex.

The main conclusion of our work is that a minimum age of formation of altered and weathered, mafic volcanic rocks can be obtained using calcite U-Pb geochronology. In the context of accreted ocean plate stratigraphy, the broader geological implications of the minimum age of formation of volcanic rocks have to be determined in conjunction with fossil, structural, and geochemical data.

References

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Keywords: Calcite U-Pb geochronology, ocean crust history, Late Paleozoic, Australia

New understanding of the Eocene-Oligocene Southern Ocean radiolarian faunal changes

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Polar plankton are responsible, via sequestration in deep ocean water and ocean sediments, for a large fraction of the global carbon cycle's removal mechanism. Future temperature increase scenarios are alarming, in that high polar ocean temperatures risk loss of a significant amount of this plankton. This would decrease pCO_2 removal, and thus intensify climate change. The main goal of our project is to understand this risk by studying how polar plankton and oceans interacted in the past. We focus our study on the Southern Ocean (SO) as a key region for understanding this process. Here we report on the record of radiolarians across the cooling that occurred over the Eocene/Oligocene (E/O) transition. Currently, there is only incomplete published research using quantitative radiolarian data for radiolarian faunal assemblages during the Eocene Oligocene transition, and the only comprehensive study to date (Apel, 2005) is mostly unpublished. The purpose of this study is to reveal quantitative changes in these assemblages, and evolutionary responses to the ca 6° C cooling that occurred in the SO at the E/O.

Our data so far comes from three sites in the Southern Ocean: Site 689 near Antarctica, from Weddell Sea, Site 1090 near the polar front, and Site 511 on the Falkland Plateau. The age model for Site 1090 is based on a robust paleomagnetic stratigraphy, but new age models, including a reinterpretation of the paleomagnetic polarity patterns, were created for the other sites.

Radiolarian abundance varies widely from site to site or even from interval to interval. There are relatively abundant and well-preserved radiolaria from certain intervals but also a lack of enough radiolaria to generate paleoceanographic data in other intervals.

The radiolarian assemblage shows mixed high and low latitude taxa but the dominance of polar species. Radiolarian diversity peaks around the Priabonian Oxygen isotope Maximum (PrOM, ca. 37.3Ma) and after the Eocene-Oligocene Transition (EOT, ca. 33Ma), with a lower diversity between both events, thus showing a somewhat different pattern than that seen in diatoms (Özen, in prep.). The PrOM shows a marked radiolarian origination event, while the period immediately following the EOT is marked by both significant extinction and origination in the region (i. e. an evolutionary turnover).

There are about 200 unidentified species encountered so far in the studied material. The majority of them are thought to be new to science, though some may also have been recorded by Apel (2005). A significant number of these are small artostrobids, well below 100 microns. These may previously have been overlooked, as prior studies (other than Apel) mostly did not use the smaller (45 microns) sieves used in our study.

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Keywords: Paleogene, plankton, radiolaria, water masses.

Correlation of Albian-Cenomanian radiolarian and foraminiferal datum events with new chemostratigraphic ($\delta^{13}C_{org}$) data from a reference section in the Outer Carpathians

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This study reports a high-resolution analysis of a continuous 46.5-m-long sedimentary deep-water succession exposed in the Silesian nappe of the Western Outer Carpathians (Barnasiówka-Jasienica (B-J) section) in relation to biotic (radiolarian and benthic foraminiferal) and chemostratigraphic (carbon isotope) events.

The section studied contains uppermost Albian–middle Cenomanian flysch deposits with biogenic material containing a high admixture of isolated spicules of siliceous sponges, and numerous radiolarians and foraminifers. These biogenic particles, originated mostly from extensive biotic proliferation on the European peri-Tethyan shelves, were transported by gravity currents, admixed into lithologically different types of sediments, and accumulated below the calcium compensation depth on deep seafloor of the Silesian basin.

Organic carbon isotope data ($\delta^{13}C_{org}$) from hemipelagic shales mark carbon isotope excursions that are characteristic of the mid-Cretaceous. These are the Albian–Cenomanian boundary interval (CTBI) containing oceanic anoxic event (OAE)1d, mid-Cenomanian event (MCE) Ia, and MCE Ib (Bąk et al. 2022).

The OAE1d is placed in the lowermost part of the CTBI in the B-J section. The lower boundary of the OAE1d marks a negative shift on $\delta^{13}C$ curve, followed by the first positive peak with an amplitude of 1.1‰ which ends the monotonous upper Albian series of values with very little variation. This $\delta^{13}C_{org}$ excursion occurs within the *H. barbui* radiolarian Zone and it is close to the base of the *Bulbobaculites problematicus* agglutinated foraminiferal Zone.

The mid-Cenomanian event I has been recognized among carbon isotope data as a "twin-peaked" positive $\delta^{13}C_{org}$ excursion, distinguished as the MCE Ia and MCE Ib (after Mitchell et al. 1996). Their calibration with biostratigraphy was based on the correlation of the identified $\delta^{13}C$ curve with two chosen isotopic curves from the Western Interior Seaway (Pueblo) and Anglo-Paris Basin (Folkstone) (Bąk et al. 2022).

Above the deposits corresponding to MCE Ib in the B-J section, the $\delta^{13}C_{org}$ values decrease to a deep trough, then increase again to form a much lower "plateau," and decrease once more to a double negative shift. The second negative shift, which is much deeper, most probably represents the MCE II (Bąk et al. 2022) corresponding to the base of the *Hemicryptocapsa prepolyhedra* radiolarian Zone (Bąk M. 1999, 2011). The FO of this species was observed in various tectonic-facies units of the Outer and Inner Carpathians in the middle Cenomanian *Thalmanninella reicheli* foraminiferal Zone (details in Bąk M. 2011). In similar stratigraphic position was found the FO of *Uvigerinammina praeankoi* Neagu which is a deep-water agglutinated foraminiferal index species known from non-calcareous facies of this region (e.g., Bąk K. 2007). Other radiolarian taxa useful in the stratigraphy of the Middle Cenomanian in the B-J section are represented by *Hemicryptocapsa tuberosa* Dumitrică and *Stichomitra stocki* (Campbell and Clark). The first occurrence of *H. tuberosa* coincides with base of the MCE Ia, while the FO of *S. stocki* corresponds to the end of the MCE Ib.

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Keywords: Cretaceous, bio- and chemostratigraphy, OAE1d and MCE

Radiolarian and foraminiferal response on environmental perturbation induced by climate change recorded in uppermost Albian to upper Cenomanian Oceanic Anoxic Events

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The background of the research presented here is the current fast global warming trend proceeding at a rate that is unprecedented over decades to millennia (e.g., Held et al. 2010). For paleontologists it could be analogous to fast climatic changes that affected marine ecosystems during the Cretaceous. Looking for an analogy between the Cretaceous ocean and the modern ocean, the question arises whether the fossil record of marine microorganisms can identify the same causes of global changes. The modern oceans have absorbed 90% of increased heat in the top 700 meters of the water column while it is heating at an annual rate of 0.4 degrees Fahrenheit (= 0.28 °C) since 1969 (Levitus et al. 2017). Ocean warming causes open-ocean deoxygenation, reduced ventilation of the water column and increases its stratification. All of these factors strongly affect ocean nutrient cycles and influence on marine habitat.

The radiolarian and foraminiferal species from deep-water settings in the Umbria-Marche and the Outer Carpathian basins of the Western Tethys were used for interpretation of environmental changes during the latest Albian through the late Cenomanian time interval.

The frequency of 184 recognized radiolarian species has been processed and analysed. The whole radiolarian set has been subdivided into six supergroups, including 25 groups related to specific water masses (Bąk 2011). The assembled species represented various feeding preferences and ecological strategies. An increase of the total number of radiolarians in the sediments related to the Oceanic Anoxic Event (OAE)1d and OAE2 (Bonarelli Level) displays a positive correlation with an increase of phosphorus (*P*) content, and with a significant decrease in radiolarian diversity. Most of radiolarian species avoided levels with high *P* content, in contrast to some species such as *Holocryptocanium barbui* and *Cryptamphorella conara* which increased significantly in number of specimens. On the contrary, diversified radiolarian assemblages appear at levels directly preceded by a notable *P* increase, marking a period when the water system was saturated in relation to nitrogen.

The radiolarian abundance in the sediments is strongly related to their preservation during sinking in the water column and at the water/sediment interface, increasing significantly at levels marked by eutrophy and high pellet production. Thus, pelletization played an important role in the transport of radiolarian skeletons and their further preservation, irrespective to conditions of their growth.

The record of a slightly enhanced content of small, globular (*Hedbergella*-like) forms in sediments corresponding to the OAE1d in the Carpathian deposits may be result of an increase in sea surface temperature. Many planktonic foraminiferal assemblages show changes in depth preferences during the late Albian and early Cenomanian. This trend concerns a rapid adaptation to living in a surface habitat and the decline of surface-dwelling species (Ando et al. 2010). This vertical migration to greater depths and changes in adaptive strategy may, at least in part, be related to warming of intermediate or cooling of surface water during an interval that started at the Albian–Cenomanian transition (Leckie et al. 2002).

The current microfossil study sheds light on the biological effects of the Cretaceous climate conditions, indicating the role of the mesopelagic zone and oceanic circulation in nutrient exchange, which modulates and controls the OAE's. The mesopelagic zone played an important role in *P* sequestration and was responsible for the release of most of *P*, leading to enhanced eutrophication of water column.

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Keywords: Cretaceous, OAEs, radiolarians and foraminifers, climate changes

Late Cretaceous and Paleocene radiolaria from the San Jacinto Fold Belt, Northeast Colombia

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Here we report on peculiar radiolarian assemblages from the lowest sedimentary formations of the San Jacinto Fold belt (SJFB), along the Caribbean of NW-Colombia. The SJFB is a major Upper Cretaceous to Paleogene sedimentary wedge, originally deposited on a basement of oceanic affinity represented by serpentinites and Upper Cretaceous basalts. The highest part of the wedge, exposed in the San Jacinto Mountains, has been grouped into the following formations (Fm):

1) The **Cansona** Fm, considered to be of Campanian-Maastrichtian age, locally overlies serpentinites or is interbedded with Upper Cretaceous basalts. It consists of cherts, organic-rich shales, siltstones and limestones. The formation has been interpreted on the basis of palynofacies as a shallow marine, low energy, inner to middle shelf paleo-environment, with water depths between 20 and 100 m.

2) The **San Cayetano** Fm, so far dated as Upper Paleocene-Lower Eocene, consists of lithic-arkosic continent-derived sandstone turbidite fans, hemipelagic organic-rich shales and some cherts. This formation unconformably overlies remnants of an accreted Late Cretaceous intra-oceanic arc, which are tectonically intermixed with continental rocks.

Several assemblages extracted by HCl and HF from calcareous and siliceous shales attributed to the **Cansona** Fm yielded Campanian assemblages containing: *Amphipyndax tylotus* Foreman, *Dictyomitra multicostata* Zittel sensu Pessagno, *Foremanina schona* Empson-Morin, *Pseudotheocampe abschnitta* Empson-Morin, *Siphocampe altamontensis* (Campbell & Clark), *D. urna* (Foreman), *D. tina* (Foreman), *D. ruckena* Empson-Morin, *D. sallilum* (Foreman), *Amphipyndax tylotus* Foreman, *A. pseudoconulus* (Pesagno), *Stichomitra cechena* Foreman, *S. carnegiensis* (Campbell and Clark), *Dictyomitra* aff. *D. formosa* Squinabol, *Alievum gallowayi* (White), *Archaeodictyomitra lamellicostata* Foreman, *Theocampsomma comys* Foreman, *Cornutella cretacea*, ?*Calocyclas hispida*, *Mita regina* (Campbell and Clark), *Dictyomitra koslovae* Foreman.

However, one sample (Las Tinas Creek, sample 500267-1) with this assemblage was assigned to the Las Palmas Chert of the upper Paleocene San Cayetano Fm, which poses a stratigraphic problem to be solved: Are these cherts allochthonous slide blocks of exhumed older rocks of the Cansona Fm ?

On the other hand, a sample (CC7-C-12.75) from Cerro Cansona and one sample from El Clan Quarry (CCL-C-90), located about 10 m above the base of the San Cayetano Fm, yielded abundant spherical latticed spumellarians (Actinommids). The age is defined by the presence of *Amphisphaera aotea*, *A. kina*, *Buryella granulata*, and *Lithostrobus longus*, as well as some rare, silicified planktonic foraminifera of *Parvularugoglobigerina eugubina*-type. This assemblage corresponds to the radiolarian Zone RP3 of Hollis (2002), which is equivalent to the upper part of NP2 and the lower part of NP3, in the lower Danian. This suggests that the San Cayetano Fm may include the lowermost Paleocene, which reduces the hiatus inferred by earlier work (Duque-Carobetween the Uuper Cretaceous Cansona Fm and the Paleocene San Cayetao Fm (Duque-Caro, 1979).

In the study area, age and paleo-environments of the sedimentary units have been traditionally determined by foraminifera and palynomorphs. The presence of Radiolaria sheds a new light on these determinations. The documentation of opportunistic radiolarian assemblages in tropical "near-shore" environments of the Late Cretaceous/Paleocene is a challenging objective, but it is difficult to reach, because of the poor recovery of determinable radiolarians. However, these assemblages may become important indicators of high fertility and high production/preservation of organic matter in formations with a high source rock potential.

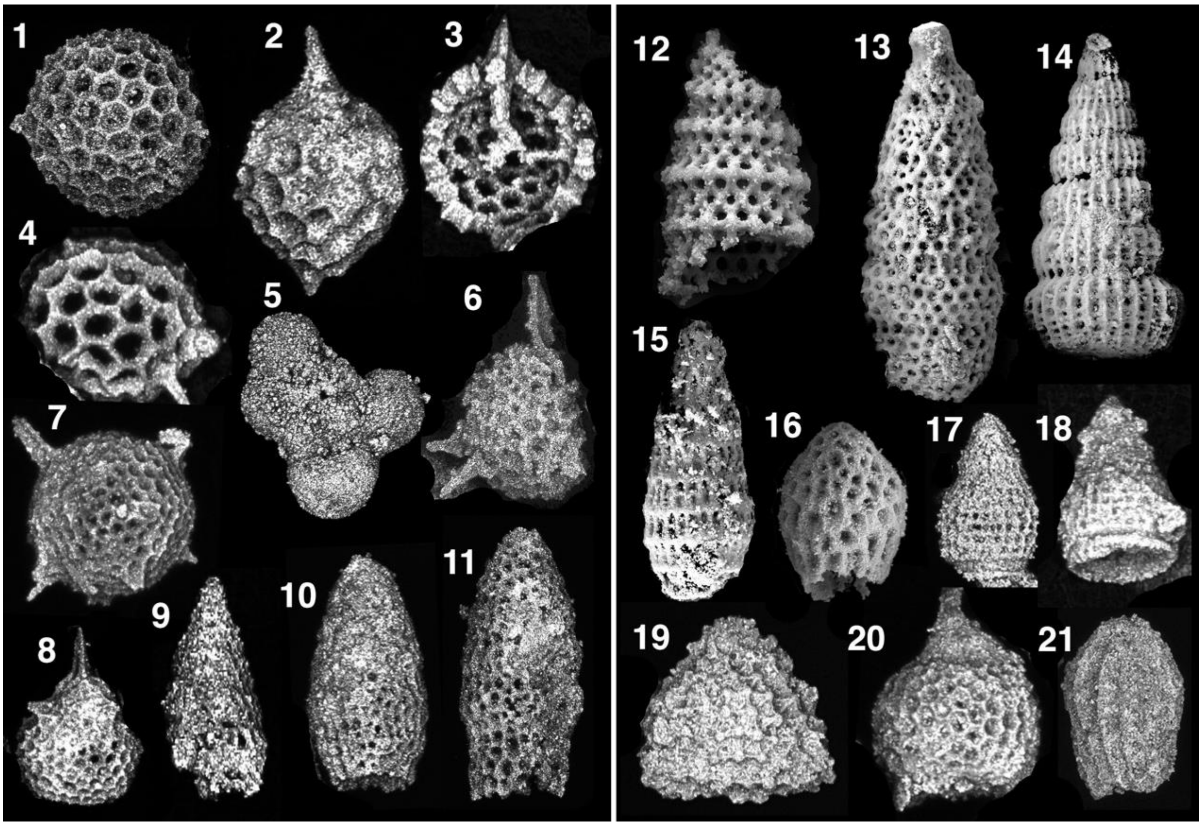

Figure 1. Early Paleocene (1-11) and Campanian 12-21 radiolarians and (5) planktonic foraminifer fom the Cansona Formation, San Jacinto Belt, NE-Colombia 1) *Amphisphaera* sp. 2-4) *Amphisphaera aotea*, 5) *Parvularugoglobigerina eugubina* 6)*Amphisphaera kena*, 7) *Entapium* sp., 8) ?*Clathrocyclas* sp. 9) *Lithostrobus longus, 10-11) Buryella granulata*, 12) *Foremanina schona*, 13) *Amphipyndax tylotus* 14) *Dicyomitra multicostata,* 15) *Siphocampe altamontensis,* 16) *Pseudotheocampe abschnitta,* 17) *Dictyoprora tina,* 18) *Dictyoprora urna,* 19) *Alievum gallowayi,* 20) ? *Calocyclas hispida,* 21) *Theocapsomma comys.*

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Keywords: Late Cretaceous- Paleocene, radiolaria, San Jacinto Fold Belt, Colombia

Morphologic features and evolution of Jurassic-Cretaceous Austral radiolaria

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The systematics and evolution of Austral radiolaria is still in its infancy. Many authors have, mostly informally, described "non-Tehyan" radiolaria that were suspected to represent either high southern and/or high northern paleo-latitude assemblages. Here, we intend to identify some morphological characteristics of Austral radiolaria, which may be common to several taxa, including at family level.

Windalia **Ellis 1993** was probably the first, formally described, Late Jurassic-Cretaceous genus which is today clearly recognized as an Austral taxon group. It has a *Yamatoum*-type cephalic structure and is, for now, classified under the Amphi-pyndacidae. The *Windalia*- group is easily recognized by is external double-layered test composed of: 1.) An outer layer with "windaliid chicken wire structure", i. e. diagonally running, anastomosing costae that form elongated oval or rhomboid pore frames. 2.) and an inner layer with small round pores arranged hexagonally. Septa are not at external strictures (if present), but at lower third of the external bulge.

Thick shelled morphology, was already noted by Aita and Spörli (1992), for "non-Tethyan" forms of the Middle-Late Jurassic matrix of the Waipapa accretionary prism. Undescribed thick-shelled multicyrtid nassellarians attributed by them to *Stichocapsa* and *Spongocapsula* spp. were suspected to belong to high latitude assemblages. Some of these taxa should now be assigned to ***Aitaum*** **Pessagno and Hull (2002)**, also represented by thick shelled forms (e.g. *Aitaum yehae* Pessagno and Hull, 2002, pl. 2, fig. 17, 21). Thick shelled morphologies have a bipolar distribution. We suspect that Austral and high-latitude radiolarians could have a longer life time than closely related low-latitude forms, and therefore attain thicker shells through secondary thickness growth. Similar observations exist for high-latitude planktonic foraminifera.

Cavus, a term introduced by Pessagno and Hull (2002, p. 246), as a character of the genus *Aitaum* Pessagno and Hull, as "circular cavity on surface of post-abdominal chambers" (note: *cavus* is a masculine noun, *cavi* in plural). It has been illustrated and/or mentioned by several authors and represents a morphological feature so far unique to Late Jurassic-Early Cretaceous Austral nassellarian taxa belonging to the Archaeodictyomitridae, Parvicingulidae, Amphipyndaxidae, and several genera of the *Tricolocapsa-Aitaum* group. *Cavi* are probably not a genetically fixed morphological adaptation to a particular environment, but rather the result of an unknown infection or an attached parasite inhibiting or modifying secondary shell growth in a specific place. It has not been reported from outside the Austral Realm.

Spindle-shaped forms accurately drawn already by Tan (1927) from the island of Rote, are included in a new family erected by Baumgartner et al. (2022). Several taxa share some morphological features such as a more or less irregular ornamentation or raised ridges forming polygonal pore frames called "pits" with small pores in the depression. These taxa probably originated along the high paleolatitude Gondwanian margin. 3 genera may have evolved from a common Late Jurassic ancestor, endemic to the earliest Tithonian-Berriasian Austral assemblages recovered from Hole 765C-Cores 62R-58R in the Argo Abyssal Plain (AAP)off the north-western Australian margin.

Parvicingulids with a thick-shelled dome-shaped proximal portion have been reported both from northern and southern mid to high paleolatitudes. Several species suddenly appear in the AAP during the middle-late Berriasian, probably related to the breakthrough of a the circum-S-polar current system. They disappear during the early/middle Barremian. One particular form occurs at the AAP in the Tithonian and Berriasian and has been reported also from the Le May Group of Alexander Island, Antarctica, as well as from the upper Kimmeridgian-middle Tithonian of the Koryak Mountains, Western Pacific Rim of Russian Far East, showing its bi-polar distribution.

The Tithonian to Aptian/early Albian radiolarian record recovered from Hole 765C-Cores 62R-36R in the AAP, unique by its density of well-preserved radiolarian assemblages and by its faunal contents (Baumgartner, 1992) has been integrated by Baumgartner et al. (2022). with published records of southern hemisphere "non-Tethyan" radiolarian assemblages from Timor/Indonesia, Southern Tibet, Antarctica, Patagonia, New Zealand and the Southwest Pacific. Several evolutionary lineages of Austral radiolaria are defined by one new family, one new subfamily, 7 new genera and 30 new species.

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Keywords: Jurassic-Cretaceous, Austral radiolaria, morphologic features

Neotethyan, Subtropical Gyre and Austral Radiolaria – tracers for Pangea Breakup and climate change of the Jurassic-Cretaceous transition

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The Jurassic/Cretaceous (J/K) boundary, unlike other system boundaries, cannot be linked to a catastrophic paleo-environmental crisis, but to a gradual palaeocean-ographic change recorded in the Western Tethyan intra-Pangean basins by a shift from bio-siliceous (radiolarian) to calcareous (nannoplankton) pelagic sedimentation.

The Tithonian to Aptian/early Albian radiolarian record recovered from Hole 765C-Cores 62R-36R in the Argo Abyssal Plain off the Northwestern Australian margin is unique by its density of well-preserved radiolarian assemblages and by its faunal contents (Baumgartner 1992; Baumgartner et al. 2022). The integration with published records of southern hemisphere "non-Tethyan" radiolarian assemblages from Timor/Indonesia, Southern Tibet, Antarctica, Patagonia, New Zealand and the West Pacific allows to define radiolarian paleobiogeography of the southern hemisphere and its implications for the early opening of oceanic gateways within Pangea and global climate change during the J/K transition.

Radiolaria recovered from claystone yielded the low diversity, "Crypto-Archaeo" Assemblage (chiefly cryptocephalic/cryptothoracic nassellarians and *Archeodictyo-mitra* spp.) interpreted as tolerant to oligotrophy, originated in the Subtropical Gyre (STG). In contrast, assemblages extracted from radiolarite layers, interpreted as pelagic turbidites/contourites derived from the deeper W-Australian margin, are dominated by Austral taxa, related to an influx of S-polar cold water into the early Argo Basin since the earliest Cretaceous (Fig. 1). Neotethyan taxa are very rare to absent before the late Hauterivian/Barremian, when they gradually gain in diversity and abundance.

The southern hemisphere Late Jurassic-Early Cretaceous radiolarian biogeography is defined from low- to high latitude: 1. the Neotethyan (NT), 2. the Central Panthalassan (CP), 3. Eastern Boundary Current (EBC), 4. the Subtropical Gyre (STG) and 5. the Austral (A) circum-south-polar realms. Radiolarian biogeography and plate tectonic models support a scenario of palaeoceanographic and global climatic change during the Jurassic-Cretaceous transition related to progressive Pangea break-up: Oceanization between Africa and Madagascar-India-E-Antarctica and the connection of the Proto-Caribbean with S-high latitudes via the S-American Quebrada Grande and Rocas Verdes back-arc basins resulted in: 1. An increased heat transfer to the Southern hemisphere which caused cooling and less nutrient flux in Neotethyan regions during et Late Tithonian dry event. 2. A northward shift of the northern winter Intertropical Convergence Zone reduced the Neotethyan mega-monsoon area and allowed the establishment of a southern Neotethyan subtropical gyre, documented by the "Crypo-Archaeo" Assemblage. 3. The south-polar West Wind Drift may have forced a circum-S-polar cold current through the epicontinental rift between India and Antarctica-Australia, since the Berriasian (140 my) transporting Austral Radiolaria into the Argo Abyssal Plain, where they accumulated in radiolarite layers.

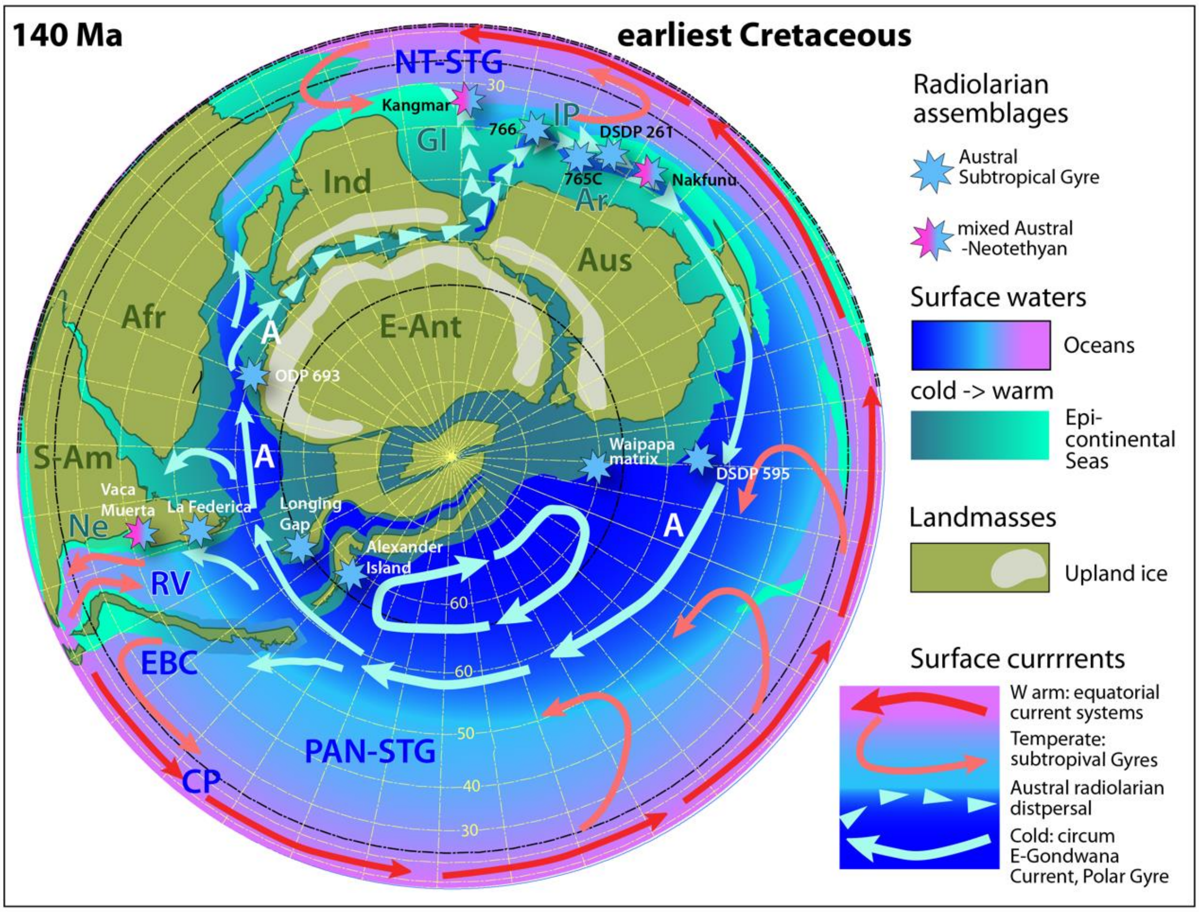

Figure 1. 140 Ma (earliest Cretaceous) Paleogeography of S-Gondwana centred on the South Pole, after Baumgartner et al. (2022), with indications of ocean surface currents, latest Jurassic-Early Cretaceous Austral radiolarian dispersal routes and known localities yielding non-Tethyan, Austral radiolarian taxa. **Ar**: Argo Abyssal Plan, **GI**: Greater India, **IP**: Indian Promontory, **Ne**: Neuquen Basin, **RV**: Rocas Verdes Ocean (Vérard et al. 2012). Circum- East Gondwanian surface ocean current system inspired by Gordon (1972). Dispersal routes of Austral radiolarian adapted from Baumgartner (1992). **A:** Austral, Circum-S-polar current system. **EBC:** Eastern Boundary Current. **CP:** Central Panthalassan Current. **NT-STG:** Neotethyan Subtropical Gyre. **PAN-STG**: Panthalassan Subtropical Gyre. **RV:** Rocas Verdes monsoonal circulation.

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Keywords: S-hemisphere Austral, Subtropical Gyre, Neotethyan Radiolaria, Jurassic-Cretaceous transition

A Simple CNN Approach for Automatic Classification of Eight Closely Related Species of the Middle Eocene Genus *Podocyrtis*

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This study intends to evaluate the application of AI to the automatic classification of radiolarians and uses as an example eight distinct morphospecies of the Eocene radiolarian genus *Podocyrtis*, which are part of three different evolutionary lineages and most of which are useful in biostratigraphy. The samples used in this study come mainly from the equatorial Atlantic (ODP Leg 207) and were supplemented selectively with some samples coming from the North Atlantic and the Indian Oceans. To create an automatic classification tool, numerous images of the various species were needed to be trained in a convolutional neural network (CNN), and the one we will use here is MobileNet (Howard et al., 2017), since it's a simple and lightweight architecture that is simple to replicate and can be used as a starting point for further CNN architecture implementations. Here we will present a short explanation of all the different steps from slide preparation into images that are trained in a CNN.

1. Images were taken with a light microscope and some of the *Podocyrtis* specimens were handpicked direct from loose sediment and attached on a slide and mounted with Norland epoxy, to faster obtain a relatively large dataset.
2. All specimens had been photographed with different focal points at the same field of view (FOV) which later were stacked into completely focused images by using Helicon Focus 7.
3. Thereafter each particle taken on the same FOV were segmented so that each individual object became its own individual image or so called vignette. The images were also transformed into 8-bit grayscale with black background (Tetard et al., 2020). This step is to centralize the objects in the middle and to reduce the image size.
4. The vignettes were then preprocessed with a simple Python script to rotate the small image dataset into the same position and to resize all images into a similar size, 256 x 256 pixels (Fig. 1).
5. The different radiolarians were then classified by one taxonomic expert in discussion with two other experts. Three different datasets were obtained: one consisting of a mixture of broken and complete specimens, some of which appear sometimes blurry; the second and third datasets were levelled down into two further steps which excludes broken and blurry specimens while increasing the quality.
6. These datasets were used to train the CNN and our model randomly selected 85 % of all specimens for training, while the rest 15 % were used for validation.

The CNN had an overall accuracy of about 91 % of all datasets, and the preferred dataset due to F1 score (average between precision and recall) was the dataset which only had a removal of incomplete specimens.

Three predicational models were thereafter created, which had been trained on each dataset and obtained an accuracy of over 90%. These prediction models worked well for classification of *Podocyrtis* coming from the Indian Ocean (Madingley Rise, ODP Leg 115, Hole 711A) and the western North Atlantic Ocean (New Jersey slope, DSDP Leg 95, Hole 612 and Blake Nose, ODP Leg 171B, Hole 1051A). Even if the morphological differences encountered in different parts of the world's oceans, and differences in image quality, most species could be correctly classified or at least be classified with a neighboring species along a lineage.

Classification improved slightly for some species by cropping and/or removing background particles of images which did not segment properly in the image processing. However, depending on cropping or background removal the best result came from the predictive model trained on the dataset consisting of a mixture of broken and complete specimens.

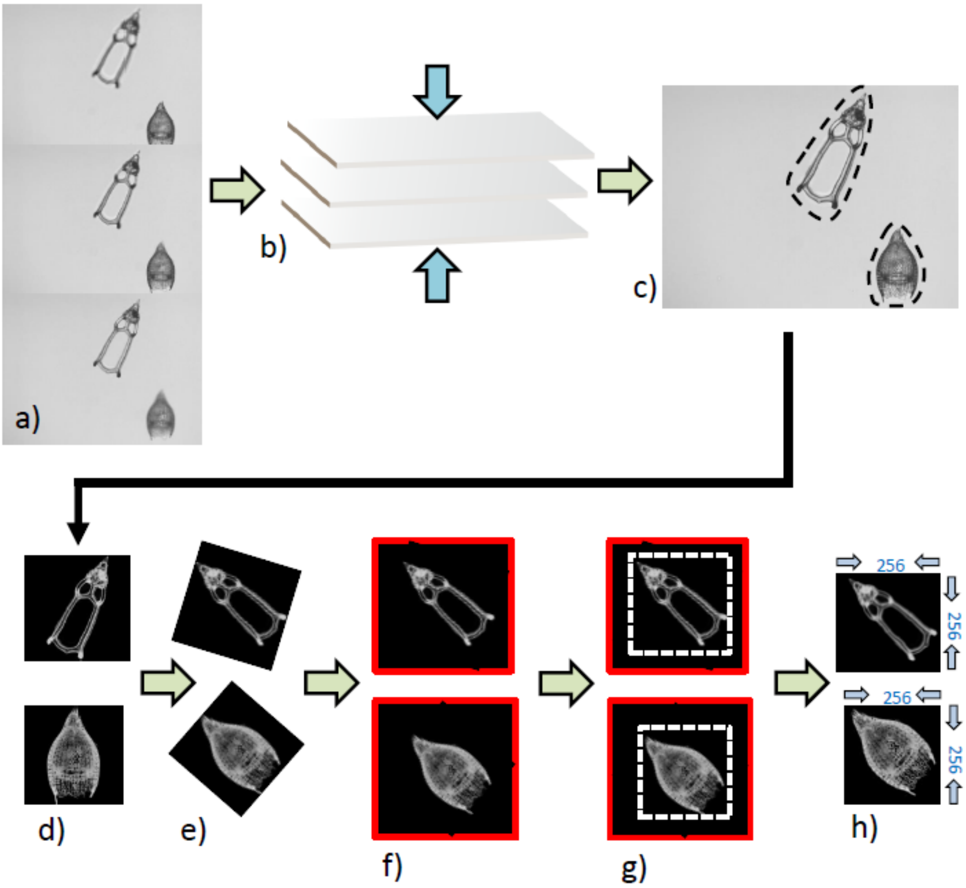

Figure 1. Visual image acquisition and processing.

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Keywords: Automatic classification, Middle Eocene, *Podocyrtis*, Tropical Atlantic

Radiolarian biostratigraphy and geochemistry of the ophiolites from Makran and Nain-Ashin (Iran): A synthesis

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We present a synthesis of the biochronological data on cherts and geochemistry of the associated volcanic rocks in the periphery of the Central Iran Microcontinent (CIM, Iran), that is, in the Makran (Durkan Complex and Coloured Mélange) and Nain-Ashin region.

The Durkan Complex is a key tectonic element of the Makran Accretionary Prism (SE Iran) that was previously interpreted as representing a continental margin succession. Barbero et al. (2021) suggested that this complex consists of distinct tectonic slices representing different parts of a seamount chain. Radiolarian determinations were performed on samples collected from the Cherty-Limestone and Basalt lithostratigraphic unit in the Manujan and Chah Shahi 1 transects. In detail in the Manujan transect the age of sample MK 367 is early Coniacian-late Campanian for the occurrence of *Dictyoprora sallilum* (Foreman) with *Dictyoprora urna* (Foreman), and the age of the samples MK 469 and MK 471 is early Coniacian-late Campanian due to the presence of *Dictyoprora urna* (Foreman). The sample MK 367 is associated with pillow lavas generated in within-plate oceanic settings. In the Chah Shahi 1 transect the sample MK 796 contains radiolarians with poor/moderate preservation and the age is early Coniacian-late Campanian due to the presence of *Dictyoprora urna* (Foreman). This sample is stratigraphically associated again with basalts of within-plate oceanic settings.

In the Makran, the Coloured Mélange consists of volcanic rocks, locally stratigraphically associated with radiolarian cherts. The volcanic rocks include: 1) normal type mid-ocean ridge basalts (N-MORB); 2) oceanic plateau basalts (OPB); 3) alkaline basalts; 4) calc-alkaline basalts, basaltic andesites, andesites, and dacites; 5) volcanic arc tholeiitic basalts and dacites, and metabasalts. The age of the volcanic arc tholeiites ranges from late Hauterivian-early Aptian for the presence of *Pantanellium masirahense* Dumitrica with *Orbiculiformella titirez* (Jud) (sample MK 145) to latest Cenomanian-early late Campanian for the presence of *Acanthocircus hueyi* (Pessagno) (sample MK 152). The age of calc-alkaline rocks is early Coniacian-Santonian for the presence of *Dictyoprora urna* (Foreman) with *Crucella cachensis* Pessagno (sample MK 146) while the age of OPBs is early Turonian-early Campanian for the presence of *Afens liriodes* Riedel and Sanfilippo with *Archaeospongoprunum bipartitum* Pessagno (sample MK63).

The Nain and Ashin ophiolites (Central Iran) consist of Mesozoic mélange units (Coloured Mélange), which include serpentinized peridotite slices, tectonic slices of sheeted dykes, and pillow lavas - locally stratigraphically associated with radiolarian cherts. Based on their whole rock geochemistry and mineral chemistry, these rocks can be divided into two geochemical groups. The sheeted dykes and most of the pillow lavas show island arc tholeiitic (IAT) affinity, whereas a few pillow lavas from the Nain ophiolites show calc-alkaline (CA) affinity. In the Ashin ophiolite the inferred age for the chert sample (AS 1010), stratigraphically associated with the pillow lava of island arc tholeiitic affinity, is early - middle Albian for the presence of *Mita gracilis* (Squinabol) and *Crococapsa asseni* (Tan). In the Nain ophiolite the chert samples (NA 424 and NA 510) associated with pillow lavas of island arc tholeiitic affinity contain poorly preserved radiolarians (e.g. the genus *Dicyomitra*). Therefore is not possible to give a precise age assignment for these samples. In summary, our data indicate that the western and southern rims of the CIM were characterized by volcanic arc activity during the Cretaceous.

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Keywords: Iran, radiolarian cherts, pillow basalts, geochemical data

Radiolarian biostratigraphy and geochemistry of basalt-chert associations in the ophiolites of the Ypaton area (Greece)

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In the NE part of Thebes, the Boeotia region in mainland Greece extends the ophiolite complex of the Ypaton area. This outcrop consists of the southeastward prolongation of the Othris, Kallidromon, and Atalanti ophiolite complexes. The Ypaton ophiolitic complex appears tectonically sandwiched between the Pelagonian-derived platform units of neritic limestone bearing *Cladocoropsis mirabilis* Felix of Malm *s.l.* age at the base, and at the top, overthrust during post-upper Eocene compressive tectonic episodes by neritic limestone bearing *Orbitopsella sp.* of Middle Lias age including the Ktypas Mountain.

In this area we sampled seven sections and we collected seventeen samples (radiolarian cherts, basalt, polygenic and monogenic basalt breccia) for radiolarian biostratigraphy and basalt geochemistry. The sampled successions belong to the Sub-ophiolitic mélange unit which consist of continental- and oceanic-derived slices associated with sheared sedimentary deposits (shales, pebbly mudstones, pebbly sandstones).

The ages of radiolarian cherts are referable to the Middle Triassic and Middle Jurassic, in particular the samples 13GR81 and 13GR83 are referable to the latest Anisian for the presence of *Oertlispongus inaequispinosus* Dumitrica, Kozur & Mostler with *Paroertlispongus mostleri* (Kozur), while the samples 14GR5 and 14GR7 are respectively referable to the latest Bajocian-early Bathonian (UAZ 5) for the presence of *Protunuma ochiensis* Matsuoka with *Hemicryptocapsa tetragona* (Matsuoka) and late Bajocian - middle Bathonian (UAZ 4-6) for the presence of *Unuma gordus* Hull with *Striatojaponocapsa synconexa* O'Dogherty, Goričan & Dumitrica.

Keywords: ophiolites, mélange, Trassic and Middle Jurassic radiolarians, Ypaton, Greece

Radiolarian paleoecology across the Sinemurian–Pliensbachian transition at Mt. Rettenstein (Northern Calcareous Alps, Austria)

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The studied assemblages from Mount Rettenstein span from the Upper Sinemurian (*Canutus rockfishensis–Wrangellium thurstonense* and *Jacus*? *sandspitensis* radiolarian zones) to the Lower Pliensbachian (*Canutus tipperi–Katroma clara* Zone). The age of the assemblages was calibrated with ammonites, calcareous nannofossils, and carbon and strontium isotopes (Cifer et al., 2022). Mount Rettenstein is the first location known to have a continuous record of well-preserved radiolarians across the Sinemurian–Pliensbachian boundary.

Radiolarians were found in a 95 m thick succession of hemipelagic siliceous limestone and marl overlain by red condensed Adnet-type limestone. Mudstone and wackestone microfacies were determined throughout the section, with abundant sponge spicules, radiolarians, and rare echinoderms and foraminifera. Bioturbation is common in the entire section, indicating that bottom waters were not oxygen depleted.

Six radiolarian assemblages were studied in detail, four in the Upper Sinemurian and two in the Lower Pliensbachian part of the section (Fig. 1). In total, the samples yielded 192 species belonging to 70 genera. For taxon-quantitative analysis we determined the proportion of sponge spicules, the spumellarian/nassellarian ratio and relative abundances of radiolarian genera and families.

All samples are dominated by sponge spicules that account for nearly 85 % of the siliceous fauna. The ratio between spumellarians (including entactinarians) and nassellarians is in the Sinemurian 4.5:1 and decreases in the Pliensbachian to 3:1. The predominance of sponge spicules over radiolarians and the predominance of spumellarians over nassellarians indicate a relatively shallow depositional depth. Contrary to these ratios that are relatively stable, the diversity is much higher in the Sinemurian and drops significantly across the Sinemurian–Pliensbachian boundary (Fig. 1) implying an environmental crisis at this level.

The inferred crisis is well reflected in relative abundances of families. The most significant changes in spumellarians occur in Pantanelliidae (*Pantanellium, Gorgansium*), Angulobrachiidae (*Paronaella, Cyclastrum, Loupanus*) and Emiluviidae (*Beatricea, Udalia*?, *Thurstonia*?), whose numbers decrease drastically from the Sinemurian to the Pliensbachian. The opposite trend is observed in Xiphostylidae (*Archaeocenosphaera, Novamuria*) and Conocaryommidae (*Praeconocaryomma*). In nassellarians, the most dramatic drop is observed in mono- and dicyrtid taxa (Poulpidae and Ultranaporidae). In the Sinemurian they account together for up to 50 %, whereas in the Pliensbachian they represent less than 5 % of nassellarians. Multicyrtid nassellarians also experience a drop, which is, however, less significant (from 50 % in the Sinemurian to 30–40 % in the Pliensbachian). Williriedellidae (*Zhamoidellum*), on the other hand, constitute less than 5 % of nassellarians in the Sinemurian, but up to 65 % in the Pliensbachian. A unique pattern is recorded in Saturnalidae: their proportion with respect to all radiolarians is below 5 % in the first three samples, increases to 24 % in the uppermost Sinemurian sample and then drops again to about 8 % in the Pliensbachian (Fig. 1).

Comparison with vertical distribution of morphologically similar taxa in modern oceans suggests that during the environmental crisis surface-dwelling radiolarians suffered greater losses than those living in deeper water. Based on comparisons with Mesozoic taxa that have shown to be related to higher or lower productivity (Pantaneliidae vs. Williriedellidae) we conclude that the environmental deterioration was most probably caused by nutrient depletion. Diminished nutrient supply could be induced by arid climate and thus lowered terrigenous input or by a diminution of the inflow of fertile water from the open sea of the Neotethys Ocean due to low sea-level at the end of the Sinemurian. The uppermost Sinemurian peak proportion of Saturnalidae that characteristically abound in enclosed basins with restricted oceanic circulation could be the first sign of environmental deterioration. We note that other well-preserved earliest Pliensbachian radiolarian faunas, e.g. those from Haida Gwaii, British Columbia, are equally diverse as their Sinemurian counterparts. The described radiolarian crisis was thus not a global phenomenon but was probably limited to the western embayment of the Neotethys.

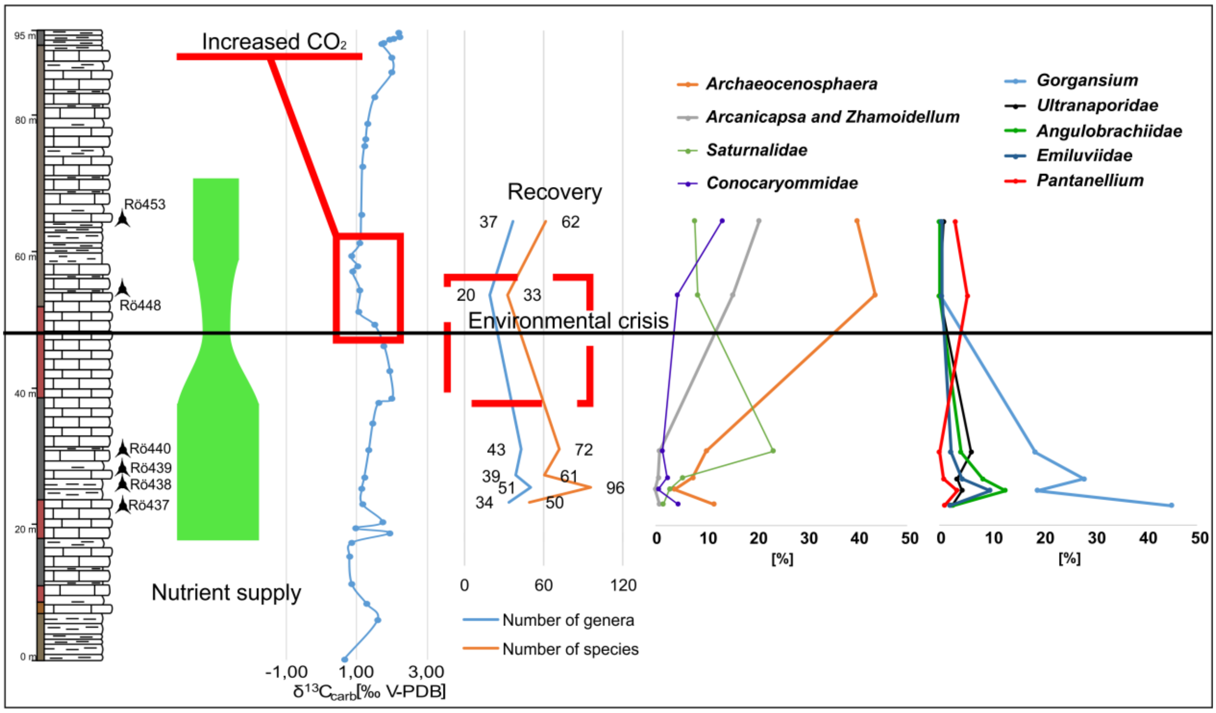

Figure 1. Stratigraphic log of the Rettenstein section with radiolarian samples, a schematic display of nutrient supply, stable carbon isotope curve showing a marked negative excursion at the beginning of the Pliensbachian, diversity of radiolarian species and genera, and relative abundances of selected radiolarian families.

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Keywords: Early Jurassic, Western Tethys, taxonomic diversity, relative abundances

Polycystine radiolarians off South-Western Crete (Eastern Mediterranean) and their seasonal fluxes during 2005-06: environmental drivers and comparison with coccolithophore export

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Global change phenomena are having a strong impact on the structure and functioning of marine ecosystems. Especially enclosed and naturally oligotrophic seas, such as the Eastern Mediterranean (EMed), can be expected to be highly sensitive to these phenomena. Based on time-series data of plankton material collected in sediment traps moored at the south Cretan margin, this study presents for the first time extant Polycystine radiolarian assemblages from the south Cretan margin and changes in their skeleton flux during the period spanning October 2005 – May 2006. The seasonal pattern in radiolarians flux is then compared with the one obtained by Malinverno *et al.* (2009) for coccolithophores from the same sediment trap materials.

The sediment trap samples were collected by the Hellenic Center of Marine Research of Greece at 500m depth. We identified nearly 20 different species/taxa of radiolarians. *Archiperidum* spp. is the most common taxon found, with ca. 50% of total abundance. Other main taxa comprise *Cornutella profunda*, *Didymocyrtis tetrathalamus*, *Phormospyris stabilis*, *Zygocircus* spp. and *Lithomelissa setosa*. Nasselarians are more abundant than spumellarians and we observed a very high proportion of juvenile specimens, especially of *Archiperidum* spp., *Didymocyrtis tetrathalamus* and *Lithomelissa setosa*.

The results of radiolarian vertical export show an interesting seasonal signal that appears to be strongly controlled by important climatic and oceanographic seasonal changes. During late fall-early winter, from a very low flux in October (8 x 10^3 m^{-2} day^{-1}, compared with an average export value of 67×10^3 m^{-2} day^{-1}), the export gradually increases until December, after which it dropped again in January. These changes occurred against a background of a decreasing trend in Sea Surface Temperature (SST) and an increasing trend in surface water mixing during the period September to February. During late February – early March, the radiolarians flux tripled to reach the highest values for the entire studied interval, with a peak of 188×10^3 m^{-2} day^{-1} recorded during the first two weeks of March. This late winter-early spring transitional period is marked by a maximum mixing of the water column coeval with minimal values of SST. As a result, large quantities of nutrients originating from deeper parts of the water column reached the surface waters. It is also noteworthy that the end of February also corresponded to a period of maximum rainfall, which may also have undoubtedly increased nutrient concentrations in the surface waters through both soft water discharges (the studied site is close to the coastline of southern Crete) and precipitation of atmospheric dust that originates from North Africa. The peak flux in radiolarians in late February coincides with a peak in Chl-a. Radiolarian export is then significantly lower during April and May, which correlates well with a drop in Chl-a values and rainfall, and the onset of water column stratification in March. Similar seasonal variations are also portrayed by Malinverno *et al*. (2009) for calcareous nano-phytoplankton, from the same sediment trap collection. Indeed, these authors observed a peak in coccosphere fluxes during the late winter-early spring interval. However, the highest vertical export appears to occur in late March, two weeks after the peak in radiolarian flux. The studied by Malinverno *et al*. (2009) appears then to follow a different trend after March, with the vertical export of coccospheres increasing in April-May, while we note a plateau for radiolarians, with a drop of both fluxes in early April (down to 16×10^3 m^{-2} day^{-1} for radiolarians).

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Keywords: Radiolaria, vertical export, diversity, Mediterranean Sea

Macroevolutionary dynamics in early Paleozoic Radiolaria

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An exhaustive sample-based dataset of middle Cambrian to Silurian radiolarian occurrences is used here to explore the presence of evolutionary faunas (*sensu* Sepkoski, 1981) within early Paleozoic radiolarians. This dataset has already been analysed recently to document the taxonomic diversity through time of early Paleozoic radiolarians, as well as to evaluate biases possibly influencing the observed patterns (Danelian & Monnet, 2021).

A factor analysis of this dataset allowed the detection of several evolutionary faunas composed of specific radiolarian families, which record simultaneous increase and decrease in species richness over geological time.

The oldest evolutionay fauna is composed of middle Cambrian Archaeospicularia assigned to the families Archeoentactiniidae and Palaeospiculidae. However, this fauna may result from the low sample record of radiolarians in this interval. It is followed in the late Cambrian and Early Ordovician (Tremadocian) by an evolutionary fauna dominated by echidninid and protoentactinid archeospicularians, in addition to palaeospiculids.

These three archaeospicularian families are still dominant during the Floian – Dapingian, but a new evolutionary fauna characterized by aspiculid and proventocitid radiolarians diversifies during this interval. It is also dominated heavily by the oldest spumellarian family Antygoporidae, which first appeared in the Floian. During the Darriwilian emerges a new evolutionary fauna that will last until the end of the Ordovician. It is heavily dominated by the spumellarian families Inaniguttidae and Haplotaeniatidae, and to a lesser extent by the entactinarian families Haplentactiniidae and Entactiniidae. The emergence in this fauna of the deep-dwelling albaillellarian family Ceratoiciskidae, but also of the peculiar archaeospicularian family Secuicollactidae, is also noteworthy.

Finally, Silurian radiolarians constitue a separate evolutionary fauna. It is more or less composed of the same families as the previous fauna, but it is heavily dominated by the archaeospicularian family Secuicollactidae, as well as the entactinarian family Paleoscenidiidae. Amongst spumellarians, Haplotaeniatidae appear to characterize the early–mid Silurian, followed by Inaniguttidae in the late Silurian.

Factor analysis of the early Paleozoic dataset of radiolarians provides thus complementary insights:

- It confirms the evolutionary affinity of the Early Ordovician fauna with the one present in the late Cambrian oceans;
- It highlights the dramatic faunal change occurring during the Dapingian–Darriwilian transition, possibly due to the profound climatic and oceanographic changes that took place during this interval;
- The contrast between the Late Ordovician and Silurian radiolarian evolutionary history and dynamics.

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Keywords: Macroevolution, early Paleozoic, evolutionary faunas, paleobiodiversity.

New age data on the ophiolites from Central Serbia: Implication for the Jurassic evolution of the Vardar Ocean

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Middle to Upper Jurassic radiolarites are of special interest for the reconstruction of Neo-Tethys oceanic domain, the Jurassic geodynamic history of the western Tethyan realm and the palaeogeographic evolution of the Inner Dinarides.

An outcrop near Kragujevac (Velike Pčelice section) in the ophiolitic mélange shows a basalt block with its 23 m thick sedimentary cover sequence, mainly composed of claystones and radiolarites. The sediments were studied for their biostratigraphic age and their lithofacies to reconstruct the depositional setting. Directly on top of the basalt predominantly siliceous claystones were deposited. Upsection, follows a more and more radiolaritic succession with 3-5 cm thick radiolarite beds in the lower part and 1-3 cm thick radiolarite beds in the upper part of the section with cm-thick claystone intercalations. The lower part of the section is characterized by quartz-filled hydrothermal veins missing in its upper part. In contrast, the upper part of the section is bioturbated, deformed and with an increasing clay content.

The preservation of the radiolarians in the different parts of the section is poor to moderate but yielded determinable age diagnostic radiolarian assemblages. The lowermost 4.5 m of the section contain *Hemicryptocapsa marcucciae* (Cortese), *Cinguloturris carpatica* Dumitrica and *Williriedellum crystallinum* Dumitrica (sample VP 3), higher up appear *Gongylothorax favosus* Dumitrica (sample VP 5), and in the highest part of the section *Praewilliriedellum robustum* (Matsuoka), *Cinguloturris carpatica* Dumitrica, and *Williriedellum crystallinum* Dumitrica (sample VP 6). In total, the age of the radiolarites is Callovian to lower Oxfordian, indicating a very rapid deposition of this radiolarite succession, different from known Triassic Steinmann Trinities from the Neo-Tethys ocean floor. These are in few cases preserved in the ophiolitic mélanges of the Inner Dinarides, but mostly dismembered into different blocks consisting of Middle and Late Triassic radiolarites and the Neo-Tethys ophiolites.

However, this Callovian block of Neo-Tethys ophiolites (most probably SSZ-ophiolites) with its cover sequence is the first direct proof of Jurassic ophiolites in the Inner Dinarides. Similar Middle Jurassic blocks are known from Albania (e.g., Chiari, Marcucci & Prela, 1994), Greece (Baumgarter, 1984) and the Guevgueli Ophiolite Complex/Axios Zone (Republic of Macedonia, Kukoč et al., 2014). The only Late Jurassic (Early Oxfordian) age date for the siliceous mudstones within the extrusive sequence of the Guevgueli Ophiolite (northern Greece) is given in Danelian et al. (1996).

According to the geological map of Kragujevac the ophiolitic mélange is sealed by the Early Cretaceous paraflysch, which led to following geodynamic reconstruction: Middle to Early Late Jurassic ophiolite obduction on the greater Adria plate was followed by Tithonian-Berriasian mountain uplift and unroofing. During this process the ophiolitic mélange in the Kragujevac area was transported to the east of the metamorphic dome and sealed in its position by the paraflysch (Berriasian to Aptian).

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Keywords: Middle-Late Jurassic, Radiolarians, Neo-Tethys ophiolites.

Radiolarian biostratigraphy and microfacies of Upper Triassic radiolarites from central and western Serbia

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The age and provenance of Triassic radiolarites in Serbia is crucial to the understanding of the Triassic-Jurassic geodynamic history and palaeogeography of the Inner Dinarides. This study focuses on Late Triassic radiolarian assemblages from Rogojevac and Bukovi localities. The sections are located in central Serbia (Rogojevac locality) and western Serbia (Bukovi locality) and represent the easternmost and one of the westernmost sites with Triassic radiolarites in Serbia, respectively.

The studied radiolarites at the Rogojevac locality (open pit mine), about 17 km NW of Kragujevac (44°01’31″N; 20°46’30″E) are considered as part of the Upper Jurassic ophiolitic mélange (former “Diabase-Chert Formation”; Brković et al., 1978). The age of these radiolarites was believed to be Late Jurassic, but direct age data were not available. The folded radiolarite succession from the Rogojevac locality consists of approximately 50 m thick dm-bedded reddish and mostly strongly recrystallized radiolarites with white-yellowish volcanic ash intercalations. We studied radiolarite samples for their microfacies characteristics and their biostratigraphic age. Three radiolarian samples (RG 1, RG 6 and RG 8) yielded determinable and moderately preserved radiolarian assemblages. All samples are dominated by *Capnuchosphaera* and numerous multicyrtid nassellarians. In sample RG 1 rare specimens of *Capnodoce* occur. The examined radiolarian assemblages show that the radiolarite succession in the Rogojevac quarry was formed during the latest Carnian and Early Norian. Pure radiolarites of this age are only known to be formed on the ocean floor; they are part of the sedimentary cover sequence on top of the Neo-Tethys ophiolites. These results confirm that the radiolarites of the Rogojevac locality are part of the Neo-Tethys ophiolites obducted in Middle-Late Jurassic times.

Radiolarian assemblages of the same age were discovered in a block of radiolarites in the ophiolitic mélange on the north-west slopes of Divčibare Mt. (locality Bukovi). Poorly preserved, but relatively rich radiolarian assemblages were extracted from the small, approximately 2 m thick bedded reddish radiolarite block. Four radiolarian samples (SCG 101, SCG 102, SCG 103 and SCG 104) yielded moderately to badly preserved radiolarian assemblages. All samples are dominated by multicyrtid nassellarians. The samples SCG 102 and SCG 103 are characterized by the presence of the *Xiphothecaella rugosa* (Bragin).

Identical Upper Triassic radiolarites are widespread, known as blocks in the ophiolitic mélanges below the Dinaridic ophiolite nappe, they undoubtedly were derived from the sedimentary cover of Neo-Tethys ocean floor (e.g., Gawlick et al., 2016). We attribute the Upper Carnian to Lower Norian radiolarites therefore as part of the overthrust/obducted Neo-Tethys Ocean during Middle to early Late Jurassic times with subsequent eastward gliding during unroofing since the Tithonian.

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Keywords: Late Triassic, Radiolarians, Inner Dinarides.

On the status of *Saturnulus planeta* Haeckel 1879, a *nomen oblitum* radiolarian species illegally reintroduced in literature by Suzuki *in* Suzuki et al. (2021), and the catastrophic consequences of this act for the stability of the taxonomy of saturnalid Radiolaria

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This article represents one of the two main reactions of mine to the Catalogue of Cenozoic Radiolaria by O'Dogherty et al. (2021) and, especially, Suzuki et al. (2021), of which I am one of the co-authors, but to the results of which I do not completely agree. Both papers are the result of four years of exhausting collaborative work of the four co-authors for the revision of the Cenozoic radiolarian genera (see details in the Introduction of O'Dogherty et al., 2021). It is normal that such a critical inventory generated many discussions and conflicting opinions about the validity of species, genera and families; and that the final result will have some great errors that should be corrected in future to preserve the long-accepted genera (ICZN, *Preamble* and *Art. 23.2*) on the basis of more moderate interpretations of the code.

One such error concerns the replacement of the genus *Saturnalis* Haeckel 1882, that is the founding genus of most saturnalid genus names, by the genus *Saturnulus* Haeckel 1882 as a result of the discovery, by N. Suzuki, of a completely forgotten species, *Saturnulus planeta,* described and rudimentarily illustrated by Haeckel in 1879 and never cited since that year, neither by him in his fundamental work on Challenger material from 1887, nor by any other radiolarian researchers. The "resurrection" of this species and its use in the recent literature of saturnalids without having the approval of the Commission of ICZN, Art 23.2 disturbs the stability of the taxonomic names established, especially, during the last 70 years of modern research and deletes the whole history of research of this intensely studied group of Mesozoic radiolarians which are very important for biostratigraphy of the Mesozoic and one of the simplest and best studied group of radiolarians.

This Cenozoic Catalogue should have had as its guide the 4th edition of the ICZN that, in Art. 23.2 (Purpose) and in the **Preamble** writes that "its objects are *to promote* ***stability*** *and* ***universality*** *of the scientific names of animals and to ensure that the name of each taxon is unique and distinct.* ***All its provisions and recommendations are subservient to those ends and none restricts the freedom of taxonomic thought or actions****."* It also specifies that although "***Priority*** *is the basic principle of zoological nomenclature,* ***its application****, however, under conditions specified in the Code,* ***may be moderated to preserve a long-accepted name in its accustomed meaning"***.

We should have also thought of Deflandre (1960) who wrote that the nomenclature and acceptation of the genera erected by Haeckel should be especially based on his work of 1887 that represents the fruit of his reflections and efforts. Only contributions of new important facts could motivate eventual changes and not purely simplistic, retroactive application of narrow rules. In other words, the results of this collaboration have not been exactly those I had hoped.

To understand my opposition to this replacement I shall try to present a very short history of research of the saturnalid radiolarians.

1882. Haeckel describes very shortly the new genera *Saturnalis*, and *Saturnulus.*

1887. Haeckel describes and illustrates several species of the two genera. For him the genus *Saturnalis* has priority because, when he discusses this group of ring-bearing radiolarians, he calls them Saturnalida, not Saturnulida.

1953. Deflandre erects the subfamily Saturnalinae and considers that *Saturnulus* is a synonym of *Saturnalis*.

1954. Campbell designates, among others, the type species of the two genera.

1967. Nigrini revises the genus *Saturnalis,* synonymizing with it the genus *Saturnulus* and illustrates for the first time, with a photo, the recent species *Saturnalis circularis* Haeckel, type species subsequently designated by Campbell, that must be considered *lectotype*.

1972. Kozur & Mostler start their series of publications on Mesozoic saturnalids. For them *Saturnulus* is also a synonym of *Saturnalis*, which belongs to the family Saturnalidae.

2019. About a month before submitting to the editor the manuscript of the Catalogue of Cenozoic radiolarian genera, O'Dogherty informs me that Suzuki found that in 1879 Haeckel published a species named *Saturnulus planeta* that was never mentioned by him after that year and that this means that the genus *Saturnulus* has priority over *Saturnalis*. The result would be that the superfamily Saturnaloidea Deflandre 1953 will be replaced by the superfamily Heliosaturnaloidea Kozur & Mostler 1972. I was against such a change because *Saturnulus planeta* is a *nomen oblitum* according to ICZN and that it cannot be used before having the approval of the Commission of ICZN. Suzuki didn't want to ask permission because he was in a hurry to publish his article which, in his opinion, is "revolutionary" and in which he wanted, among other things, to describe the new family Saturnulidae Suzuki 2021.

2021. In spite of all my protests and all kind of arguments against, Suzuki erects the family Saturnulidae Suzuki 2021. In the same year O'Dogherty et al. 2021 publish the article on Cenozoic radiolarian genera. In it, on p. 842, I remarked that in the upper right corner of the rectangle of *Saturnulus* is written SATURNULIDAE and below it "assigned in Kozur & Mostler 1972: 30". This is a false citation because in Kozur & Mostler 1972, p. 30 one can find that *Saturnulus* is a synonym of *Saturnalis* and the genus is included in the subfam. Saturnalinae Deflandre 1953 of the family Saturnalidae Deflandre 1953.

Conclusions. The genus *Saturnalis* Haeckel 1882, emended by Nigrini 1967, the only living saturnalid radiolarian genus, with type species *Saturnalis circularis* Haeckel 1887, designated by Campbell 1954 and having as lectotype the specimen *Saturnalis circularis* Haeckel illustrated by Nigrini (1967, p. 25, pl. 1, fig. 9), and easily recognized and illustrated by different researchers (Renz 1976, Dumitrica 1985, Takahashi 1991, Paverd 1995, De Wever et. al. 2001) and even by Suzuki in 2015 (Suzuki & Not) and in 2021 (in Lazarus et al., p. 148), the same year as the one in which he replaced it, must be considered valid. Its replacement by the genus *Saturnulus* Haeckel 1882, with its *nomen oblitum* species *Saturnulus planeta* Haeckel 1879, after 142 years of oblivion, a species that was never cited after its description, neither by Haeckel in 1887, nor by any other researcher of radiolarians, is illegal without the approval of the Commission of the ICZN (art. 23i). Its reintroduction destroys the stability of the saturnalid nomenclature, which is the main object of the ICZN. Consequently, the family Saturnulidae Suzuki 2021 created on the basis of this forgotten species is a synonym of the fam. Saturnalidae Deflandre 1953. Suzuki's act is a pure bureaucratic act that has nothing to do with scientific research. With this act, Suzuki sends us back in the XIX century, although he pretended that he did not publish this part of the Catalogue for the present-day radiolarists but for those who will live "100 or 200 years later". Strange idea! I cited his own words relative to his "revolutionary" scheme and the negative reaction of "several talented Cenozoic radiolarian specialists", as he recognised in an e-mail written for our radiolarian community on the occasion of the new year 2022 in which he reviewed his activity. Among such specialists, he included, it seems, the present author, for whom he wrote a special paragraph (see Suzuki et al. 2021, p. 6, par. 3) that refers to the use of the Principle of First Reviser which I cited several times in messages to him, trying to convince him not to introduce this species for not destroying the long-accepted genus *Saturnalis* Haeckel 1887 and its family Saturnalidae Deflandre 1953. In vain.

References of all cited authors are to be found in: Suzuki, N., O'Dogherty, L., Caulet, J.-P. & Dumitrica, P., (2021).

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Excerpt from ICZN:

Article 23. Principle of Priority.

23.2. Purpose. In accordance with the objects of the Code (see Preamble), the Principle of Priority is to be used to promote stability and it is not intended to be used to upset a long-accepted name in its accustomed meaning by the introduction of a name that is its senior synonym or homonym (for certain such cases see Article 23.9), or through an action taken following the discovery of a prior and hitherto unrecognized nomenclatural act (such as a prior type fixation; for such cases see Articles 70.2 and 75.6).

Article 24, Recommendation 24A. Action of First Reviser. In acting as First Reviser in the meaning of this Article, an author should select the name, spelling or nomenclatural act that will best serve stability and universality of nomenclature.

Keywords: taxonomy, Saturnalidae

New Middle Triassic bell-shaped Nassellaria

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The species illustrated in this poster with drawings in China ink come from a series of samples studied 20 to 40 years ago. Since radiolarians are very well preserved, all specimens have been mounted on slides in hyrax provided by W. R. Riedel a long time ago. The use of this method for such radiolarians is better than the use of electroscan microscopy because one can see the morphology of the initial spicule and the hollow structure of spines that is very common in the Middle and Upper Triassic radiolarians.

The species presented come from the following formations:

1. Grey Guttenstein type limestones of Middle Anisian (Pelsonian) from the locality Cristian, Brasov district, Romania, from which I already published a series of new radiolarian taxa.
2. Buchenstein Formation from Recoaro, Vicentinian Alps, North Italy. First considered Fassanian (early Ladinian) in age, now assigned to the uppermost Anisian (uppermost Illyrian).
3. Illyrian sample F7, from Forrashegy section near Felsöörs, Balaton Highland, Hungary, Paraceratites trinodosus Zone and Subzone (see Kozur & Mostler, 1994).
4. Sample BV 85-70, Livinallongo type limestone, from Monte de Saline, SE of Marmolada Massif, northern Italy (see Kellici & De Wever, 1995).
5. Sample R78/1. Grey micritic cherty limestone, eastern end of the Piatra Zimbrului klippe (Dumitrica 1982, p. 62), uppermost Illyrian.

The poster presents 17 new species assigned to probably 4 new genera: *Silicotinntinabulum*, *Gorispela*, *Pozsvartia* and *Humerocyrtis*. Some names are provisional.

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***Keywords**:* Triassic, Nassellaria, new taxa

Radiolarian dating of the chert used in lithic tools assemblages from “Artofago cave” (Italy)

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New perspectives in the archaeometric investigation of the chert used in lithic tools assemblages allow us to learn more about the socio-economic behavior of prehistoric human groups. The case study here presented is the Artofago cave, South Tuscany (Italy), where, among other things, an Aurignacian lithic complex was excavated from a large fireplace located near the entrance.

The aim of this work is to find out data for the determination of the raw material used for these lithic tools production, to enhance the research about its geographic source area. Here we suggest the importance of the rock’s geological age as a datum that allows us to form hypotheses about its geological formation of provenance. We present a successful application of the Radiolarian Biostratigraphy to date cherts from the archaeological record: 67 chert samples from the Aurignacian lithic complex of the Artofago cave were treated with HF to isolate radiolarian assemblages. The samples had been carefully chosen in advance from flakes, since the analysis is partially destructive.

The age of the chert samples are referable to the Middle-Late Jurassic and in particular to UAZs 8–10 for the presence of *Archaeodictyomitra apiarium* (Rüst) with *Paronaella broennimanni* Pessagno (sample 1-2019/D), UAZs 9–10 for the presence of *Emiluvia ordinaria* Ozvoldova, *Podocapsa amphitreptera* Foreman, *Suna echiodes* (Foreman) with *Paronaella mulleri* Pessagno (sample 1-2019/D) and UAZs 10–11 for the presence of *Emiluvia orea ultima* Baumgartner & Dumitrica with *Zhamoidellum ovum* Dumitrica (sample 1-2019/C). These ages are comparable with those of Monte Alpe Cherts of the Northern Apennines.

Keywords: lithic tools, Jurassic cherts, radiolarians, Italy

Triassic-Jurassic radiolarite events in the Western Tethys realm – reasons?, controlling factors?

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Triassic-Jurassic/Lower Cretaceous siliceous sedimentary rocks and radiolarites play a crucial role for palaeogeographic and geodynamic reconstructions of the Western Tethyan realm and occur widespread in the different orogenic belts around the Mediterranean (e.g. Eastern and Southern Alps, Western Carpathians, units in the Pannonian realm, Dinarides). Their deposition is related to two oceanic realms, the Tethyan and the Atlantic oceanic systems and the continental realm in between (greater Adria since Jurassic times).

The deposition of Triassic–Jurassic/Lower Cretaceous siliceous sedimentary rocks and radiolarites is characteristic for specific stratigraphic levels, in which they were deposited. Related to specific events they were formed widespread in open shelf areas and not only in the oceanic domains, but also in deep-water foreland basins. These radiolarite events are discussed on base of the sedimentary evolution and tectonostratigraphy in the Western Tethys realm.

Rifting in the Neo-Tethys Ocean started in the Anisian, while intra-oceanic convergence started around the Early/Middle Jurassic boundary followed by late Middle Jurassic to Oxfordian ophiolite obduction and mountain uplift from the latest Jurassic onwards. Rifting in the Alpine Atlantic started shortly after the Triassic/Jurassic-boundary in the Middle/Late Hettangian, the continental break-up followed in the late Early Jurassic (Toarcian) and closure started in the Late Cretaceous.

The Triassic sedimentation in the eastern Mediterranean mountain ranges was triggered by the evolution of the Neo-Tethys, whereas in Jurassic to Early Cretaceous times sedimentation was controlled by both the evolution of the Neo-Tethys and the Alpine Atlantic. Whereas in the Eastern and Southern Alps, the Western Carpathians, and the units in the Pannonian realm the Alpine Atlantic has a direct influence on the depositional record this influence on deposition in the Dinarides-Albanides-Hellenides is minor because these areas are shielded by the Adriatic Platform.

During the Triassic, radiolarites were deposited on the Neo-Tethys passive margin and as sedimentary cover of the Neo-Tethys oceanic crust, which has developed since the Late Anisian. Radiolarites are typical sedimentary rocks (often accompanied with volcanics) in Late Anisian to Ladinian times widespread formed in the Dinarides-Hellenides mountain chain. In contrast, radiolarites are only rarely reported from the Triassic sedimentary shelf successions of the Alpine–Carpathian mountain belt. In this domain mainly radiolarian-rich cherty limestones were deposited.

A second more short-lasting radiolarite event followed the demise of the Late Ladinian – Early Carnian shallow-water platform cycle (Wetterstein Carbonate Platform) in the Middle Carnian, but was restricted to not filled intra-platform basins formed between the Wetterstein Carbonate Platform pattern before they became filled by siliciclastics, but also in all mountain ranges. The peak of this radiolarite event predates the “Mid Carnian Pluvial Event”. In the Rhaetian in some areas of the distal Neo-Tethys passive margin radiolarian-rich sediments were deposited related to the partial drowning of the Late Triassic platform.

The final drowning of the Late Triassic platform around the Triassic/Jurassic boundary is widespread followed by radiolarite deposition or radiolarian-rich siliceous marly limestones in the earliest Jurassic elsewhere. The Toarcian black shale event, with deposition of radiolarian-rich sediments is contemporaneous with the eruption of two large igneous provinces, the break-up of the Alpine Atlantic, and the onset of intra-oceanic subduction in the

Neo-Tethys Ocean. Strong Middle Jurassic rifting in the Alpine Atlantic and onset of ophiolite obduction in the Neo-Tethys resulted in the Bathonian-Oxfordian radiolarite event with the peak in the Callovian-Oxfordian contemporaneous with the onset of ophiolite obduction in the Neo-Tethys and the formation of trench-like basins in lower plate position.

Keywords: Triassic-Jurassic, radiolarite events, Western Tethys

Silurian radiolarian fossils from the type area of Kurosegawa tectonic zone, Shikoku-Seiyo geopark, Japan

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Shikoku-Seiyo geopark is one of the 46 Japanese geoparks (9 UNESCO global geoparks in Japan and 37 Japanese national geoparks), located in the western Shikoku, which is famous for location of the type area of the Kurosegawa tectonic zone by Ichikawa et al (1956). Radiolarian-bearing Silurian and Devonian sedimentary rocks are widely distributed in the Kurosegawa tectonic zone, and have been studied by several pioneering radiolarian researchers (Furutani, 1983; Ishiga, 1988; Wakamatsu et al., 1990; Aitchison et al., 1991, 1996; Umeda, 1994). The Okanaro Group is one of these Kurosegawa Paleozoic sedimentary rocks, consisting of limestone and siliceous tuff. We studied the classical outcrop of Silurian trilobite-bearing succession in the Okanaro Group reported by Ishii (1952), which is exposed again after disaster of heavy flooding in 2018. This research project has been conducted under a permission of Shikoku-Seiyo geopark. Numerous Silurian radiolarian fossils were obtained from green siliceous tuff beds which conformably overlies a carbonate sequence including Silurian corals (halysitids and favositids), brachiopod and many carbonate bio-clasts.

The rich radiolarian fauna was obtained from the tuff beds, and includes the following species: *Pseudorotasphaera* aff. *hispida*, *Zadrappolus* aff. *hitoeganensis*, and *Secuiollacta itoigawai*. According to the Silurian-Devonian radiolarian zones by Kurihara (2004), these species are considered to be characteristic of the *Zadrappolus pinosus – Praespongo prava* zone to *Fusalfanus osobudaniensis – S. itoigawai* zone, which suggest Silurian (Ludlow) age.

This radiolarian age is consistent with that indicated by the trilobite, corals and brachiopod fossils previously reported from this area, and also supported by the sedimentary structure through our research.

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Keywords: Kurosegawa, Okanaro, Silurian, Radiolaria.

A movie of living Radiolaria from surface seawater of the Kuroshio Current near Japan for Education and future study ver. 2

Rie S. HORI and Teams of Living Radiolarian study at Ehime University

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Since 1998, our laboratory at Ehime University has been conducting research on living radiolarians obtained from the surface waters of the Kuroshio Current near Japan with many students. In the process, we have recorded and preserved many biological images of living radiolarians. At InterRad XI 2006 in Wellington, NZ, we presented "Beautiful Radiolaria" about living radiolarian images as an educational video, which was distributed free of charge to many individual researchers and museums. This time, as the second version of the series, we will present a compilation of images preserved including recent images of living Radiolaria, mostly collected from surface seawater near western Shikoku Island, Japan. In particular, we will show the differences in the ecology of living Radiolaria (Polycystinea and Acantharea), and Phaeodarea. We are planning to provide this movie to researchers who wish to use it for educational purposes.

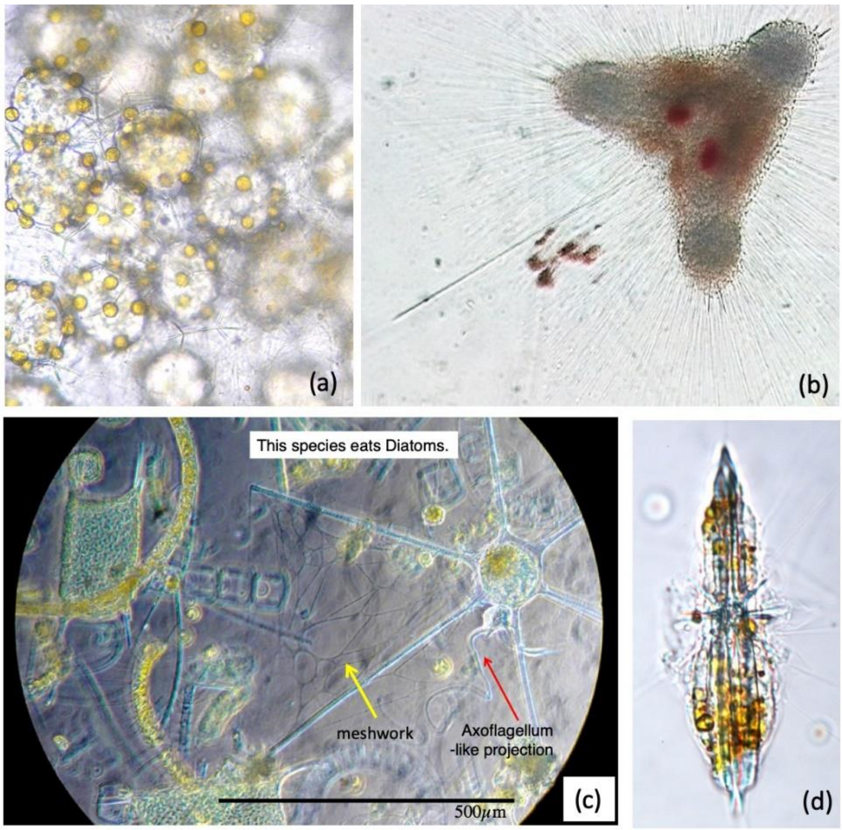

Figure 1. Living Radiolarian cells and Phaeodaria from surface seawater of Kuroshio Current, offshore Kashiwajima, Kochi Prefecture, western Shikoku, Japan. (a) Collodaria, (b) Spumellaria (*Dictyocoryne profunda*), (c) Phaeodaria, and (d) Acantharia.

Keywords: Living Radiolaria, Kuroshio Current, Ecology

Radiolarian and Diatom fossils from infill of trace fossil *Tasselia ordamensis* from the Oligocene and Miocene deep-sea sedimentary rocks in Japan

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Well-preserved microfossils from infill of trace fossils have been reported and used to estimate geological age (e.g., Haga and Kotake, 1996). However, microfossil distribution patterns and details of the mode of occurrence of microfossils within the trace fossils were not revealed in detail. In this study, we observed and described abundant radiolarian and diatom fossils within the trace fossil *Tasselia ordamensis* from the Oligocene Nishinoomote Formation of the Kumage Group, distributed on the Tanegashima Island, and from the Miocene Amatsu Formation of the Awa Group, distributed on the Boso Peninsula, Japan. In addition, we compared the radiolarian fossils recovered from Oligocene *T. ordamensis* to those in the mudstone from the Nishinoomote Formation. As a result, we confirmed that radiolarian and diatom fossils are distributed unevenly in specific locations within *T. ordamensis*. In addition, radiolarian fossils preserved in *T. ordamensis* were better preserved than those in the mudstone matrix. Based on these results, we discussed the possible reasons for the uneven distribution of microfossils within the trace fossils and the different preservation conditions between the interior and exterior of the trace fossils.

Trace fossil *T. ordamensis* consists of a lined inner tube almost perpendicular to a bedding plane and inner and outer fills surrounding the lined inner tube. The outer shape is often pear-shaped or cylindrical. *T. ordamensis* is found in deep-sea sediments and is interpreted as the feeding, excretion, and dwelling trace of polychaetes (Olivero and López Cabrera, 2010). Oligocene and Miocene *T. ordamensis* examined in this study were found from mudstone as a carbonate concretion.

The following procedure was used to process and examine the samples. First, *T. ordamensis* were cut vertically through the lined inner tube. Next, the cut slab with cross-section of the *T. ordamensis* was soaked in diluted hydrofluoric acid and hydrochloric acid solution, then digital images were captured with a scanning electron microscope (SEM), and the internal structures were observed. The number of radiolarian and diatom fossils on the slab surface was counted. Radiolarian fossils were also picked up from residues of Oligocene *T. ordamensis* and four mudstone samples from the Nishinoomote Formation, each with 100 specimens, and observed under a SEM.

The observation results showed that microfossil distribution differed depending on specific locations of the internal structure of *T. ordamensis*. Radiolarian and diatom fossils were abundant in the inner fill and the host rock surrounded by the outer fill, while these microfossils were scarce in the outer fill. In particular, densely packed intact diatom frustules were observed in the host rock surrounded by the outer fill. From the residues of Oligocene *T. ordamensis*, radiolarians of 28 species belonging to 16 genera with well-preserved microstructures were identified. Such radiolarians as *Artophormis gracilis*, *Dorcadospyris ombros*, *Dorcadospyris scambos*, *Lychnocanoma neptunei*, *Stylosphaera minor* and *Theocyrtis setanios* were included. On the other hand, seven species belonging to 7 genera, 12 species belonging to 9 genera, 11 species belonging to 10 genera, and 15 species belonging to 13 genera were identified from four mudstone samples, respectively.

The uneven distribution of siliceous microfossils in *T. ordamensis* should be due to differences in the filling type of the sediments derived from a trace fossil animal. The inner fill, where microfossils were abundant, is thought to have been passively filled with sediments on the seafloor surface (Olivero and López Cabrera, 2010). On the other hand, the outer fill is considered sediment that was actively filled by the excretion of an animal producing *T. ordamensis*. In other words, the inner fill and the host rock surrounded by the outer fill can be interpreted as near-seafloor sediments that were not disturbed by a deposit feeding activity of a *T. ordamensis* animal. These well-preserved microfossil-bearing locations are protected from diagenetic compaction and dissolution by a concretion of the outer fill and likely maintain original species assemblage. Considering the above, we can explain the difference in microfossil preservation between the interior and exterior of *T. ordamensis* in terms of an increase in preservation potential under a concretion process of the trace fossil. In general, the preservation of siliceous microfossils in clastic rocks is considered to be degraded by diagenetic burial, yet it is important to extract well-preserved microfossils as much as possible when examining the geological age and stratigraphy of on-land strata. Therefore, it is preferable to use carbonate concretions of trace fossils, which are less affected by diagenesis than mudstone, as samples for the examination of siliceous microfossils.

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Keywords: Cenozoic, radiolarian preservation, trace fossil, concretion

A recovery of the oldest Albaillellaria finding in Central Europe

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Limestone pebbles from the Paleozoic conglomerate at Podlipoglav locality in Slovenia have been examined micropaleontologically by means of conodonts and radiolarians. The recovered microfaunas are marked by the obvious absence of shallow-water conodont taxa. The Early-Middle Devonian faunas are characterized by relatively abundant polygnathids and the complete absence of shallow-water conodont taxa such as icriodontids that are assigned to the *excavatus-nothperbonus, laticostatus* and *costatus* conodont Zones (Emsian, early Eifelian). The obtained Pennsylvanian conodont faunas are early Bashkirian, and Moscovian in age and they contain deep-water conodont assemblages with obvious absence of shallow-water conodont elements. The original strata of the pebbles containing Late Carboniferous microfaunas have not been known so far from the South Karavanke, as they were probably eroded (Kolar-Jurkovšek et al. 2020).

A single skeleton of an albaillellid Radiolaria was found in a sample together with the conodont *Idiognathoides ouachitensis* indicating a late Bashkirian or early Moscovian age. The featured characters permit to identify this specimen as *Pseudoalbaillella nodosa* Ishiga. This species was first described from Upper Carboniferous chert of the Tamba Belt in Japan (Ishiga, 1982), and is recognized as an index species of the Morrowan-Atokan *Pseudoalbaillella nodosa* Zone (Ishiga, 1990; De Wever et al., 2001). Currently, this zone spans the lower-middle Moscovian interval (Danelian et al., 2017). The joint occurrence of the conodont species *Idiognathoides ouachitensis* (Harlton) and deep-water Albaillellaria (Kozur, 1993; He et al., 2008, 2011), and the finding of the radiolarian species *Pseudoalbaillella nodosa* demonstrates the first evidence of the lower Moscovian deep-water sediments in Central Europe.

Pennsylvanian radiolarians are very rare in Western and Central Europe: only *Albaillella pennata* Holdsworth and *Popofskyellum undulatum* Deflandre have been collected in the Bashkirian strata of England (Holdsworth, 1966, 1969). The blocks of micritic limestone in the Middle Permian (Roadian?) deep-water clastic and turbiditic (?) unit of Gorski Potok, Croatia, contain pyritized Late Pennsylvanian - Early Permian albaillellid radiolarians (Aljinović & Kozur, 2003). Moreover, a late Moscovian *Pseudoalbaillella desmoinesiensis-Pseudoalbaillella annulata* radiolarian assemblage represented by five species was described from Iowa (Nestell et al., 2012), and a fauna with albaillelids was also established from the South Urals in Russia (Afanasieva et al., 2002). The finding of *Pseudoalbaillella nodosa* from Slovenia significantly widens the geographic distribution of Early - Middle Pennsylvanian albaillellid radiolarians and it confirms a deep-water setting of the source basin sedimentation.

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Keywords: Carboniferous, Radiolaria, Conodonts, Dinarides.

Radiolarian dating of the evolution of the Neotethys ocean at the junction of the Southern Alps and the Dinarides (NW Croatia)

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The remnants of Mesozoic oceanic domains, which existed between Adria microplate and Eurasia, are preserved in the Southern Alps and the Dinarides, as well as further south in the Hellenides. These remnants include thick continental margin successions of Adria as well as ophiolites. An ongoing debate exists about some aspects of the evolution of this domain, including the number of oceanic basins and time of their closure, with different interpretations producing different nomenclatures. Most authors, however, now believe a single ocean named Neotethys (*sensu* Schmid et al. 2008) opened in the Middle Triassic and existed until the Late Jurassic/Early Cretaceous. The evolution of the Neotethys in this area includes ocean spreading phase during the Late Triassic and Early Jurassic, Middle Jurassic start of subduction accompanied by formation of supra-subduction crust and ophiolitic mélange and Late Jurassic/Early Cretaceous obduction of ophiolites on the continental margin of Adria.

The westernmost exposures of the Neotethys and continental margin lithologies of Adria can be found in mountains of NW Croatia. These mountains represent uplifted basement units where pre-Tertiary formations, elsewhere covered by thick Neogene and Quaternary sediments, are exposed. Long-lasting and complicated tectonic history of this area where Dinaridic and South-Alpine structures overlap, brought into contact formations of different paleogeographic origin. Consequently, this relatively small area offers a view into different stages of the evolution of the passive margin and oceanic basin, from the initial rifting to ophiolite obduction. Dating pelagic sediments with radiolarians plays a key role in understanding this evolution. Our research focused on the Middle Triassic rift-related volcano-sedimentary successions and fragments of the oceanic crust as well as Jurassic/Lower Cretaceous pelagic successions of the passive continental margin.

Mts. Ivanščica, Strahinjščica and Kuna gora in NW Croatia are considered southernmost part of the Southern Alps. Mts. Strahinjščica and Kuna gora are built predominantly of Middle to Upper Triassic dolomites with limestones, limestone breccias and cherts occurring locally, intercalated with volcanic and volcaniclastic rocks. Younger Mesozoic rocks are found on Mt. Ivanščica where Upper Triassic to Lower Jurassic shallow-marine carbonates are overlain by a Jurassic to Cretaceous pelagic succession. The continental margin succession on Mt. Ivanščica is in a tectonic contact with the Jurassic ophiolitic mélange.

During the Middle Triassic, intensive tectonic movements related to rifting, disintegrated the previously stable shallow marine environment and created number of deep-water basins and submarine highs where pelagic sediments were deposited on top of drowned carbonate platforms. The onset of pelagic sedimentation in NW Croatia is recorded by deposition of pelagic limestones. These limestones were dated with ammonites as Pelsonian to Illyrian (i.e. *Balatonites balatonicus* to *Paraceratites trinodosus* Ammonoid Zones). Resedimented benthic foraminifers, found in these pelagic limestones, indicate the existence of contemporaneous shallow-marine carbonate environment that supplied material to deeper parts of the basin. In places, carbonate breccias were also deposited. Pelagic sedimentation continued in the late Illyrian and early Fassanian with deposition of radiolarian cherts. Radiolarians from cherts are assigned to *Spongosilicarmiger italicus* to *Ladinocampe multiperforata* Radiolarian Zones based on detached spines of Oertlispongidae. Volcaniclastic rocks, produced by intense volcanic activity, are a prominent feature of these successions and are intercalated with pelagic limestones as well as radiolarian cherts. This short-lived basin on the continental margin was filled by eroded volcanic material and prograding carbonate platform in the late Ladinian.

The newly discovered continental margin succession on Mt. Ivanščica indicates the existence of stable shallow-marine carbonate environment in this area from the Late Triassic until the end of the Early Jurassic when re-establishment of pelagic sedimentation took place. Thin bedded marls, shales, marly limestones with intercalated fine-grained calciturbidites were deposited on top of shallow marine carbonates. Higher in the succession radiolarian cherts of Callovian to early Tithonian age (UAZs 7–11) are overlain by calcarenites, upper Tithonian to Lower Cretaceous pelagic limestones and Lower Cretaceous mixed carbonate-siliciclastic turbidites containing ophiolitic detritus. This succession is interpreted as deposited on the distal part of the continental margin in front of advancing ophiolite nappes during the obduction.

New outcrops of the ophiolitic mélange, containing composite blocks of radiolarian cherts and basalts were investigated on Mt. Ivanščica. Formations of the ophiolitic mélange in the northwestern segment of Neotethys started with the change from divergent to convergent regime in the Middle Jurassic. Radiolarian cherts yielded late Illyrian age (i.e. *Spongosilicarmiger italicus* Radiolarian Zone) in contact with E-MORB type basalts. This indicates contemporaneous formation of the oldest oceanic crust of the Neotethys with the deposition of rift-related volcano-sedimentary successions.

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Keywords: Mesozoic, Neotethys, Southern Alps, Dinarides

Elemental mass of modern Rhizaria: from cellular scale to global biogeochemical cycles

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The last two decades have shown the importance of the Rhizaria lineage in the biogeochemical cycles of modern oceans. Siliceous Rhizaria, including Radiolaria and Phaeodaria, could represent an important part of zooplanktonic carbon biomass (Biard et al., 2016) and are associated to large carbon and silica export (e.g. Lampitt et al., 2009; Guidi et al., 2016; Biard et al., 2018). Still, accurate estimations of their carbon biomass are limited by a poor knowledge of their cellular carbon composition (despite recent studies; Mansour et al., 2021), contrasting with well-established allometric carbon to volume relationships for smaller protists (Menden-Deuer and Lessard, 2000).

In this study, we directly measured cellular carbon and nitrogen contents of planktonic siliceous Rhizaria. We present allometric relationships linking these values to cell volume for a broad variety of siliceous Rhizaria, covering most of the size spectrum (i.e. from 200 µm to several mm). These relationships are expressed by the equations $\mathrm{C} = 9.078 \times \mathrm{V}^{0.455}$ for carbon and $\mathrm{N} = 1.435 \times \mathrm{V}^{0.477}$ for nitrogen. Our analysis indicates that the scaling exponent of the carbon to volume allometry is significantly lower than these for smaller protists, highlighting the low carbon strategy of these organisms. Indeed, we show that carbon and nitrogen densities (i.e. in µg $\mathrm{C.mm^{-3}}$ and µg $\mathrm{N.mm^{-3}}$) span over 4 orders of magnitude, possibly accounting for the differences in depth ranges, nutrition modes and colonial or solitary forms.

Finally, using a dataset of ca. 150 000 in situ images of large Rhizaria, covering the top 1 000 m over most oceanic regions (60°N-60°S), we scale these elemental allometries to the global ocean. We present new estimates of Rhizaria global carbon biomass, but also their pool of nitrogen and silica. These new estimations are a first step, not only toward more accurate inclusions of Rhizaria in biogeochemical budgets at global scale, but also allow better understanding of their ecology worldwide.

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Keywords: elemental composition, allometry, biomass, biogeochemical cycles

Radiolaria@mikrotax: A progress report on putting a synthesis of Cenozoic radiolarian taxonomic databases online

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Background - Online, freely accessible taxonomic catalogs are increasingly standard resources in biology and paleontology. Various offline, privately held radiolarian catalogs have long been in development, but prior open, online attempts such as the web version of Radworld, or the current species list at radiolaria.org have stalled, or even ceased to exist. A proposal to use Mikrotax to initiate a new Cenozoic radiolarian taxonomic catalog was accepted at the preceding Interrad in Niigata. Here we report our initial efforts to synthesize existing Cenozoic radiolarian taxonomic data sources and move them into the Mikrotax system.

Mikrotax is an emerging community standard for online marine microfossil taxonomy and is developed and maintained by J. Young at UCL, UK. It currently is the main online taxonomic resource for calcareous nannofossils and planktonic foraminifera, with (in addition to radiolaria) an acritarch section under development. It contains 2 parallel, linkable databases. The Catalog holds original species descriptions. The much richer, main 'Database' part of the system holds current species taxonomic concepts, higher taxa, and many tools, including data syntheses via a link to the NSB (Renaudie and Lazarus) global stratigraphic database of marine microfossil occurrence data. NSB has ca 1.6K valid Cenozoic radiolarian names in its taxonomic tables. The primary source database used in our project is the all-Phanerozoic comprehensive (>15K records) nomenclature and image database of Suzuki, built with the Windows program Paleotax. An early no image version of the MS Access-based Radworld Phanerozoic database of Caulet et al. (ca 10K records) was used to supplement the Suzuki database for missing species descriptions.

Preliminary Results - Most work so far has been in cross-linking data between sources, and in identifying taxonomic names that are Cenozoic in age. Tools used are sql, python; and spreadsheets for pre-upload editing of content. Currently ca 6.5K names (including many synonyms or unillustrated nomina dubia) have been loaded into the original species descriptions part of Mikrotax, and ca 1.7K records have been created in the main 'Database' part of the system. As Cenozoic radiolarian higher level taxonomy is in the middle of a major transformation, a provisional 'hybrid' higher taxa system has been implemented, with relatively coarse top level groupings (mostly equivalent to the old Riedel family names), with finer subdivisions, equal to newer family names. A hybrid system will be needed for many years yet, both while the new taxonomy is far from fully reaching a community consensus, and also as most existing literature is based on the older Riedel system, with published species descriptions often lacking essential detail that would allow them to be assigned to newer family concepts.

The main problems encountered so far are: 1) most records in the source databases are to some degree incomplete, and particularly so for geologic age, where missing and/or conflicting data are extremely common. This has made it difficult to automatically identify Cenozoic taxa for upload; 2) different, and frequently inconsistent use of terms and formats for many fields, requiring a great deal of code-based text string parsing, supplemented by manual editing; 3) conflicting higher level classification(s) in the source databases, which make it difficult to automatically assign many original species descriptions to the appropriate higher level category in the main database. Lastly, the images in the Suzuki database, the main source of imagery so far, are generally rather low resolution (a legacy of Paleotax's early origins) and limited in number for any given species. We have not encountered any real problems with the Mikrotax software itself. The online editing tools occasionally have rough edges, and bulk data uploads are best done by people with significant IT skills, but the system as a whole is very robust. This reflects extensive software development in response to many years of active use by other micropaleontologists.

Given the vast scope of the project, we have decided to concentrate 'new' editing work on a single subgroup, Lophophaenidae, which will serve as a test-bed to better understand the challenges in creating a more complete system. We are using the recent publication of Trubovitz et al. 2022 Zootaxa as the basis for this new editing work.

The current radiolarian content of Mikrotax is viewable at https://www.mikrotax.org/radiolaria/index.php?dir=rads_cenozoic. Despite its current very preliminary state, the system has already seen some use by students and researchers working on Cenozoic forms.

Outlook - A great deal of manual data entry is clearly still going to be needed to fully harmonize even existing data. Further, many data items are missing for many taxa, and must be found, extracted from the primary literature, and (mostly manually) entered into Mikrotax. A much broader range of images, such as often provided by radiolaria.org, will also have to be compiled from literature and other sources. A more formal set of rules are going to be needed to maintain the hybrid higher level taxonomy, and to eventually replace it with a new community consensus nomenclature. The value of Mikrotax would be enhanced by additional content types, or at least new links, to e.g. living biological/molecular data. This would however require additional software development. Here we may benefit from Mikrotax being a resource shared with more influential, resource-rich microfossil researcher communities. Most importantly, to succeed, this new radiolarian catalog must be taken on as a shared effort by the community.

Conclusion - The work done so far has been sufficient to demonstrate the potential of Mikrotax for Cenozoic (and potentially Meso-Paleozoic) radiolarian workers. In comparison to previous platforms, Mikrotax offers much richer information and more flexibility in use, as well as universal access. We therefore recommended it as the platform of choice for future development of a shared community radiolarian taxonomic catalog.

Keywords: radiolarian taxonomic online catalog, Microtax

Si-ORHIGENS Project: Unravelling the Silicification prOcess in RHIzaria through GENetics and Skeletal growth

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Silicon is a major nutrient in the ocean, required for growth by a variety of pelagic and benthic organisms, including microalgae, sponges and rhizarians.

Siliceous rhizarians were among the first protists inhabiting the ocean and, together with sponges, dominated the biogenic silica production during the Cambrian era (Conley et al. 2017), forming an important though poorly understood component of marine ecosystems. In today's oceans, diatoms are thought to dominate the planktonic realm and to be the main contributor to the silicon cycle. However, recent studies have revealed that siliceous Rhizaria have unexpectedly high individual Si production rates and biogenic silica content (Llopis Monferrer et al. 2020).

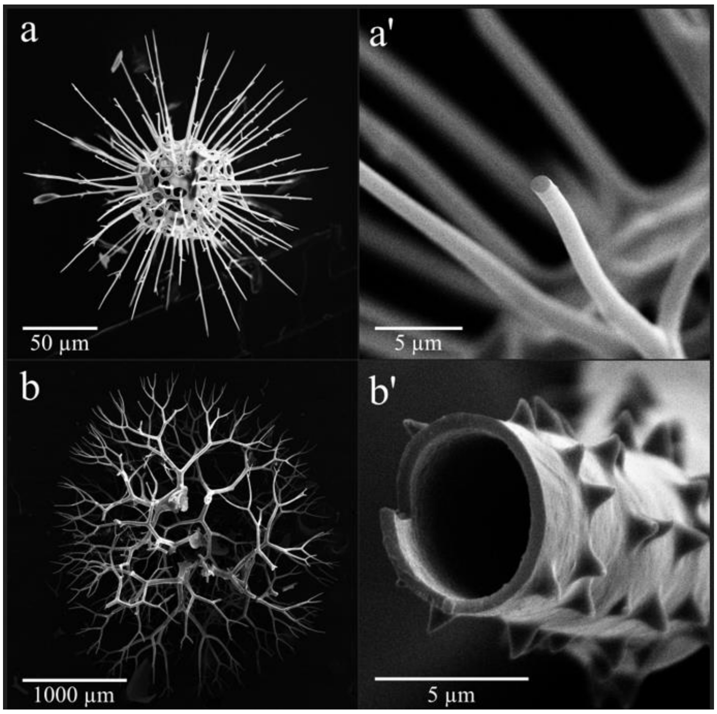

Figure 1. Scanning electron micrograph. (a, a') Polycystine radiolarian (Spumellaria) and its solid skeleton. (b, b') Phaeodaria and its hollow skeleton.

Considering their high dSi uptake rates, it remains a mystery as to why Rhizaria do not outcompete diatoms in the contemporary marine silicon cycle.

Although the presence of SITs genes has been recently reported in Rhizaria (Marron et al. 2016), their activity remains poorly quantified and little understood from a physiological and molecular perspective. The factors regulating rhizarians' skeleton morphogenesis and transporters involved in the process need to be further studied. The Si-ORHIGENS project aims to elucidate the biosilicification process through three tailored work packages: (i) exploration of genomic data to characterize the SITs of Rhizaria at different environmental conditions, (ii) targeted collection and maintenance of these delicate protists using cuttingedge technologies and, (iii) state-of-the-art imaging techniques, based on optical, fluorescent and electron microscopy, to examine silica deposition at a cellular level.

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Keywords: Silicification, living Rhizaria, skeletal growth.

Carbon and nitrogen uptake and translocation between the single cell marine protist Acantharia and their symbionts

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Acantharia (Radiolaria) are ubiquitous, heterotrophic single celled plankton in oceanic waters. Their contribution and roles in ecosystems have previously been underestimated, being elusive due to their broad size range and fragility. Yet, recent studies show that they are major components of the planktic community contributing greatly to, among others, the carbon flux (Michaels, 1991; Gutierrez-Rodriguez et al., 2019). Many of acantharian taxa are known to form a photosymbiosis with the microalgae *Phaeocystis* sp., which is heavily modified inside the acantharian host cell (Decelle et al., 2019). These modifications seem to aim to exploit photosynthetic capabilities (Uwizeye et al., 2021). Whereas observed pseudopodial extensions can suggest an active predation mechanisms (Mars Brisbin et al., 2020; Fig 1A). The mixotrophic mode of nutrient acquisition of the Acantharia allows energy and biomass to go through the food web at varying trophic levels. Thereby, potentially enhancing biomass transfer efficiency to higher trophic levels, and when taken into account would increase carbon export estimates of biogeochemical models by up to 30% (Ward and Follows, 2016). Nutrient uptake rates, indicating dependence on either trophic mode, are therefore crucial in the parametrization of carbon budgets in planktonic ecosystem models.

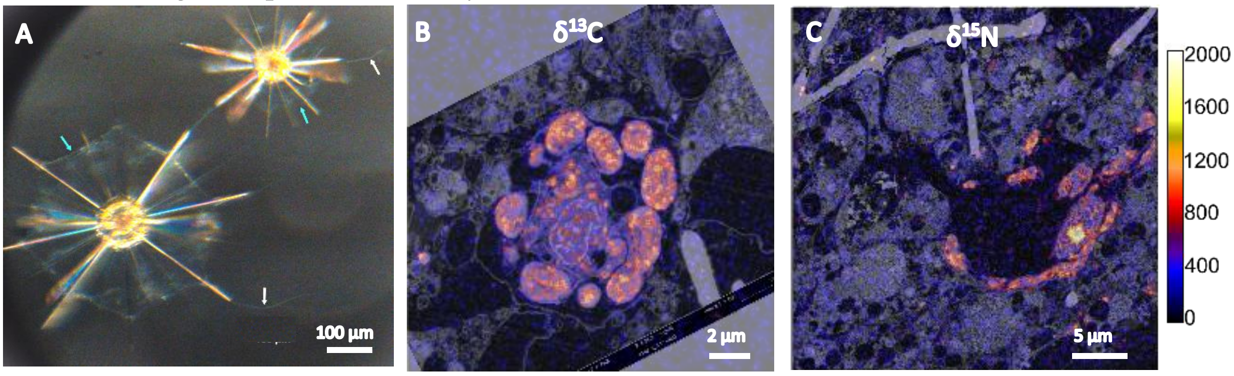

Figure 1. A) Light microscopy photographs showing pseudopodial extensions (white arrows) and the acantharian extended ectoplasm (limits indicated by cyan arrows). **B)** Overlays of Scanning Electron Microscopy and NanoSIMS images for enrichment of ^{13}C and **C)** ^{15}N in the acantharian holobiont. Showing the relative nitrogen and carbon assimilation following incubation. Both carbon and nitrogen (ammonium) enrichment is most clearly observed in the symbiotic microalgae, nitrogen more particularly in the nucleolus (yellow white hotspot). $\delta^{13}C$ enrichment is lost over time.

Yet, the difficulties inherent to the study of live Radiolaria make it that very little is known about their physiology, and thus the metabolic interactions of host and symbiont, or how much Acantharia rely on either photosynthesis or feeding. Here we aimed to elucidate the metabolic dialogue between these symbiotic partners. Therefore, we used single cell isolations of Acantharia incubated with stable isotopes of carbon and nitrogen. This allowed bulk rate measurements of photosynthetic carbon uptake under different conditions of nitrogen availability (nitrate or ammonium) as well as, single-cell chemical imaging to spatially visualize carbon/nitrogen uptake, incorporation, and photosynthate translocation between symbionts and host over time. Results obtained in this study suggest that the uptake of inorganic nutrients in this symbiotic association depends on light, and thus photosynthesis of the symbionts. Our data estimates that photosynthesis would contribute 17.8 ngC on a 16 h light period per day (1112.7 ± 82.1 pgC h^{-1} $Acantharia^{-1}$), thereby constituting 14.5% of total acantharian holobiont's carbon content (122.8 ngC).Survival of Spumellaria (Radiolaria) has been shown to be photosynthesis dependent (Swanberg and Anderson, 1985). Food in absence of light could not extend the survival of the cells. Symbiont photosynthesis thus fulfills an important role in these radiolarians metabolism. Contrastingly, it has also been hypothesized that photosynthesis in other mixotrophic organisms predominately provides energy (Wilken et al., 2014).Whereas, a daily consumption of 14.5% of the holobiont's carbon content might be sufficient for substance and growth, chemical imaging showed no measurable fixation in the host, and thus no carbon transfer from symbionts (Fig 1 B, C).

The usage of recently assimilated photosynthates is implied by a decreasing $\delta^{13}C$ over time. However, the specifics of photosynthate usages cannot yet be ascertained and might be used either directly at the symbionts or at the host cell. We hypothesize photosynthetic carbon uptake would mainly be used for the maintenance and growth of the symbionts (e.g., the plastids). Our results would currently suggest that if the Acantharia cell obtains photosynthetically acquired carbon by translocation it is not assimilated in the host cell, but might still be used for catabolic processes to obtain energy.

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Keywords: carbon; physiology; Acantharia; photosymbiosis

Evolution of the Mesozoic family Pantanelliidae and its morphological features

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The family Pantanelliidae is a Mesozoic radiolarian group with a stratigraphic range of late Triassic to early Cretaceous. Members belonging to this family commonly possess two concentric latticed shells composed of a delicate medullary (inner) shell and a rather robust cortical (outer) one (Figure 1). Most constituents of the family bear primary spine(s). The number of primary spine is used for a diagnose character at generic level. The family includes three subfamilies; Pantanelliinae, Capnodocinae, and Vallupinae. Extensive paleontological research has clarified their evolutionary scenario (Pessagno & Blome, 1980). Detailed morphometric analysis applying X-ray micro-CT and layered manufacturing technology on excellently preserved specimens of earliest Cretaceous (Berriasian) age from the Mariana Trench have made a drastic progress in our understandings of the morphological features of *Pantanellium*. We demonstrate the evolution of the family Pantanelliidae using data from traditional paleontological approach combined with the newly developed techniques.

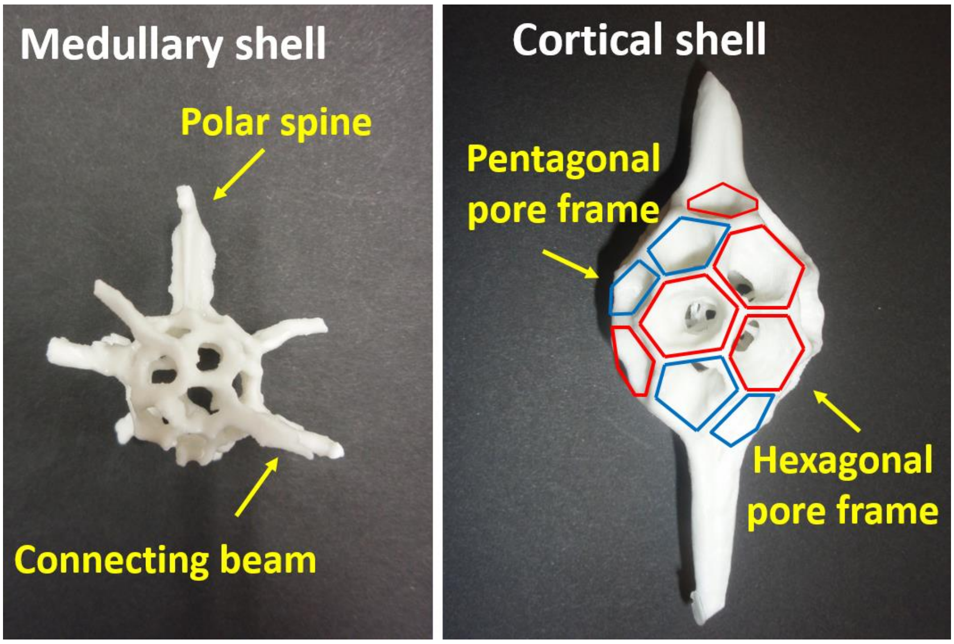

Figure 1. 3D objects of medullary and cortical shells of *Pantanellium*.

Highlights of the Pantanelliidae evolution include late Triassic, early to middle Jurassic and late Jurassic radiation events (Pessagno & Blome, 1980). The first radiation event is characterized by branching of the subfamily Capnodocinae during the late Carnian age in the Late Triassic. The second one produced the genera *Zartus*, *Trillus*, and *Pachyoncus* from *Pantanellium* during the early to middle Jurassic (Pliensbachian to Bajocian). The third one is characterized by branching of the subfamily Vallupinae in the late Jurassic time. Beside these evolutionary events, a minor radiation took place during early Cretaceous when pantanelliids with multi-spines such as the genera *Cecrops* and *Kana* evolved from *Pantanellium*.

Pantanelliid taxa have been utilized for biostrarigraphic zonation of the Mesozoic. Typical examples include evolutionary first appearances of the genera *Trillus* and *Cecrops*. The former defines the base of the *Trillus elkhornensis* Zone (JR2) of early Jurassic (middle Pliensbachian to Toarcian) age. The latter defines the base of the *Cecrops septemporatus* Zone (KR2) of early Cretaceous (middle Valanginian to late Hauterivian) age. Rapid evolution of the subfamily Vallupinae has a potential to produce a fine biostratigraphic framework for the upper Jurassic. The evolutionary trend from *Protovallupus* through *Mesovallupus* to *Vallupus* is a clear morphological change with reduction of the length in primary spines through time. Speciation among the genus *Vallupus* is expected to offer a primary marker defining the Jurassic and Cretaceous boundary. However, the applicability of this marker is limited to the low latitude oceanographic regimes because the *Vallupus* group flourished in tropical and subtropical warm surface waters only.

Morphological analysis of the Berriasian Mariana sample has produced tremendous results. X-ray micro-CT and 3D printing techniques have drastically enhanced our understandings of morphological features of several radiolarian taxa. We have concentrated on pantanelliid specimens since we introduced these new techniques for radiolarian research. Our research started with counting of the exact number of pentagonal-hexagonal pore frames and their configuration on cortical shell surface in a *Pantanellium* specimen (Matsuoka et al., 2012). The next step was to clarify a variation in pore frame number and distribution pattern (Yoshino et al., 2015). This direction in our research is still on-going (Yoshino et al., 2022, this volume). We plan to proceed this approach to different-aged pantanelliid specimens. The family Pantanelliidae can be a model taxon for clarifying morphogenesis and evolutionary history of Radiolaria.

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Keywords: Mesozoic, Pantanelliidae, evolution, morphological analysis

Radiolarians and related items for outreach activities

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Radiolarian-related items have been prepared for enhancing a degree of social recognition of radiolarians. This kind of activities started before the 15th meeting of the International Association of radiolarists (InterRad 15) held in October 2017 in Niigata, Japan in order to advertise the meeting. Our performance has been activated since the InterRad 15. We introduce herein calendars and a set of play cards with radiolarian images. Other outreach items include enlarged 3D models, plastic sleeves, antiviral mask, etc. Radiolarian-inspired art design is also introduced elsewhere (Ito et al., 2020).

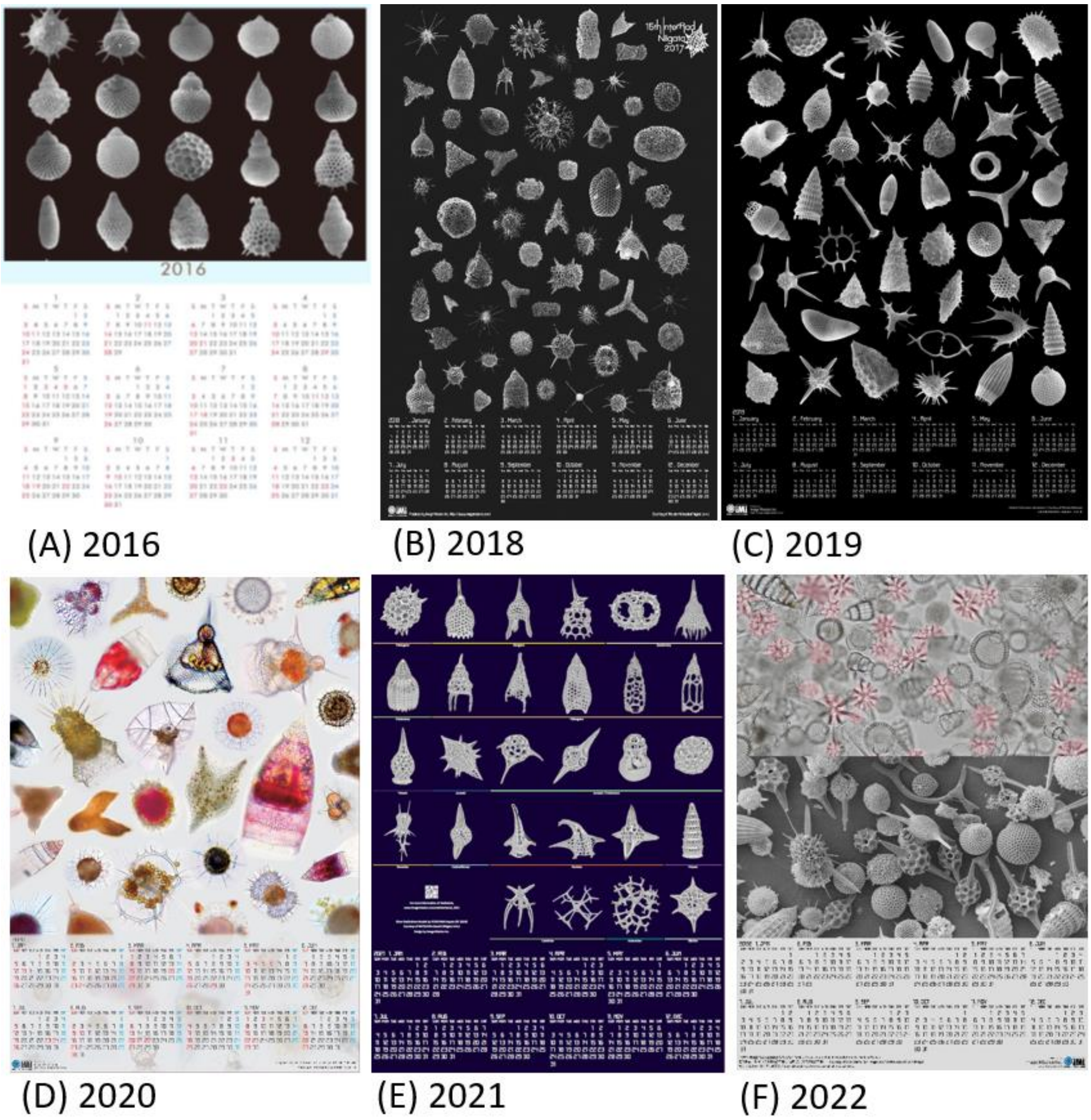

Figure 1. Calendars with radiolarian images.

A radiolarian calendar for the year 2016 (Fig. 1, A) was our first product. A series of radiolarian calendars (Fig. 1, B–F) have been produced constantly since the InterRad 15 in 2017. They are available for sale via the internet at the webpage of Image Mission Inc. They can be purchased at major museums and a few bookshops in Japan. Radiolarian images for each calendar are as follows: scanning electron microscopy (SEM) images of Recent radiolarians obtained from surface waters in the East China Sea for 2018 (Fig. 1, B), SEM images of earliest Cretaceous radiolarians from the Mariana Trench for 2019 (Fig. 1, C), light microscope images of living radiolarians in surface waters in the East China Sea for 2020 (Fig. 1, D), man-made silver models from Cambrian to Recent radiolarians for 2021 (Fig. 1, E) and light microscopy and SEM images of earliest Cretaceous radiolarians from the Mariana Trench for 2022 (Fig. F).

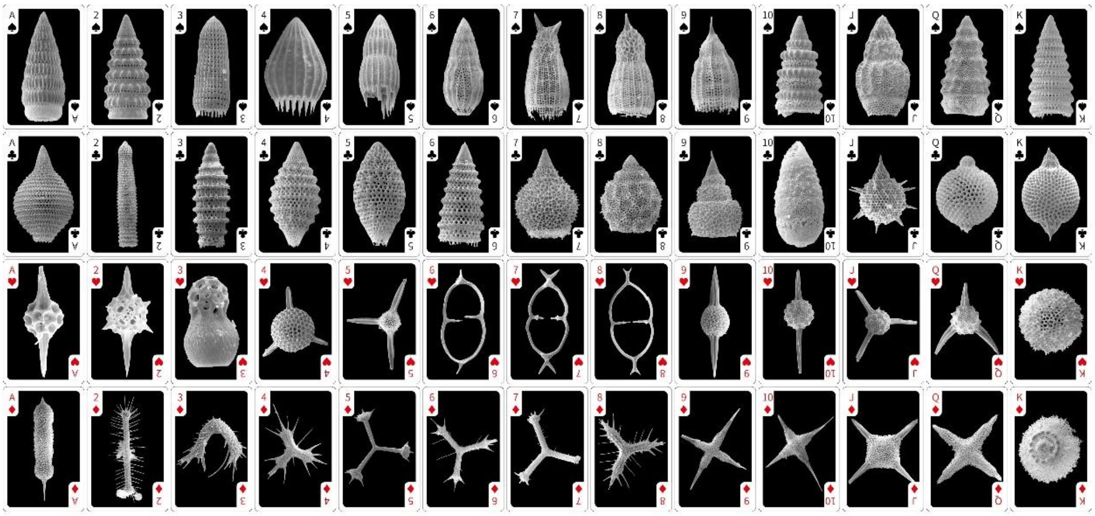

Figure 2. A set of playing cards with SEM images of earliest Cretaceous radiolarians from the Mariana Trench.

A set of playing cards with images of radiolarian skeletons is prepared not only for outreach activities but also for education purposes. The cards are composed of 53 different SEM images of earliest Cretaceous radiolarian species from the Mariana Trench (Matsuoka, 1998). All of them are different species. Specimens on spades and clubs cards are nassellarian species whereas specimens on hearts and diamonds cards are spumellarian species. Diversity and taxonomy of radiolarians are naturally noticed when one uses the playing cards.

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Keywords: Radiolaria, calendar, playing card, InterRad

Progress in middle Eocene radiolarian biostratigraphy and paleobiodiversity; new insights from the equatorial Atlantic

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The middle Eocene deep-sea sedimentary sequences cored at Ocean Drilling Program Site 1260 (Leg 207; equatorial Atlantic Ocean) yielded diverse and abundant radiolarian faunas, which are conducive to improve the middle Eocene biostratigraphic framework, as well as our understanding of radiolarian paleobiodiversity during this interval of profound climate changes. A total of 180 species were identified at this site, in an interval spanning the late Lutetian - early Bartonian. However, many morphotypes found in these samples have not been yet formally described. In an effort to improve the taxonomic resolution of middle Eocene radiolaria, 15 new nassellarian species, belonging to eight families are described for the first time.

The exceptionally expanded and complete sedimentary record of ODP site 1260, as well as the existence of an orbital chronological framework, allowed us to study a number of radiolarian bioevents with a high temporal resolution. We compiled a total of 85 radiolarian bioevents (including 38 first occurrences, 29 last occurrences and four evolutionary transitions), and provided calibrations to the geomagnetic polarity and astronomical timescales. Comparison of the radiolarian successions at ODP Site 1260A with the northwestern Atlantic IODP Site U1403 (Hollis et al., 2020) and the IODP Sites U1331, U1332, and 1333 (Kamikuri et al., 2012) situated in the eastern equatorial Pacific, allowed us to establish the synchroneity of primary radiolarian bioevents that underpin the middle Eocene zonal scheme.

In addition, seven secondary bioevents were found to be synchronous between the equatorial realm of the two oceans, and were therefore used to define seven new subzones for the late middle Eocene low-latitudinal radiolarian biozonation (Figure 1). From oldest to youngest, the new subzones are: *Dictyomitra amygdala* interval subzone (RP13a), *Coccolarnacium periphaenoides* interval subzone (RP13b), *Artostrobus quadriporus* interval subzone (RP14a), *Lithochytris triconiscus* interval subzone (RP14b), *Podocyrtis* (*Podocyrtopsis*) *apeza* interval subzone (RP14c), *Rhopalosyringium* ? *biauritum* interval subzone (RP15a), and *Pentalocorys krooni* interval subzone (RP15b). The refined radiolarian biozonation improves significantly the stratigraphic resolution and age control of the late middle Eocene interval, as biozones/subzones have now an average duration of 525 kyr years, while the average duration of Middle Eocene planktic foraminiferal biozones is ca. 1.28 Ma and 1.27 Ma for calcareous nannofossils.

Nonetheless, a substantial diachronism was also found for 20 secondary radiolarian bioevents, all recorded in both the Atlantic and Pacific oceans. Although a majority of radiolarian species appear to have evolved first in the equatorial Atlantic Ocean and subsequently in the equatorial Pacific, there is no convincing evidence for diachroneity resulting from interoceanic migrations. The reasons for diachroneity remain unclear and it would require additional biostratigraphic investigations in a broader geographic area to elucidate and interpret the observed pattern.

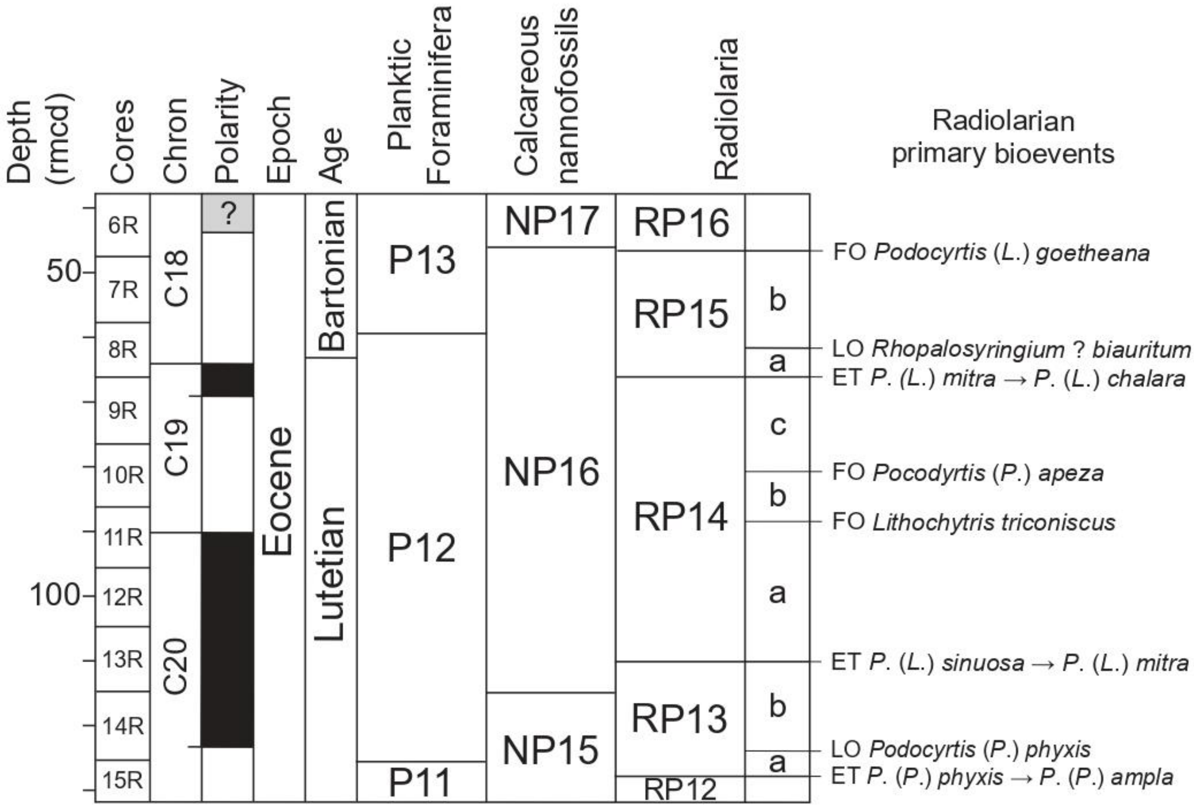

Figure 1. Biostratigraphic summary of calcareous and siliceous microfossils at ODP Site 1260. Modified after Meunier and Danelian, 2022.

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Keywords: biostratigraphy; middle Eocene; equatorial Atlantic; ODP Site 1260.

Triassic and Jurassic radiolarians from the Meliata Ocean – preliminary results

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The basement units of the Western Carpathians are overridden by the Mesozoic superficial nappes, where in the lowermost structural position the remains of the Meliata Ocean suture occur (Meliata Unit). The Meliata Unit is formed by two units differing in deformation and metamorphic degree. The Bôrka Nappe is metamorphosed to blueschist-facies while the Meliata Unit s.s. is a syn-orogenic, very low-grade flysch complex with huge olistostrome bodies of ophiolites, radiolarites and metacarbonates, representing the typical ophiolite-bearing mélange complex. In the past, the age of the sediments of the Meliata Unit was based on the often incorrectly recognised structural position. Therefore, the study of the radiolarian microfauna is essential for providing the stratigraphical data, especially due to the absence of other microfossils. Radiolarians are preserved in: 1) red to green radiolarites, which were formed during the final phase of the Meliata Ocean spreading, and 2) in the flysch sediments of the Meliata mélange matrix. The research was focused on sampling of all known radiolarite occurrences in the Meliata Unit. Only three of 15 localities yielded determinable radiolarians. Radiolarian bearing rocks around the village of Držkovce proved two different ages. The scarce and very poorly preserved radiolarians from red massive radiolarites point to Triassic age, whereas white highly tectonized radiolarites from a nearby old quarry contain poorly preserved, but more diverse radiolarian association of the Middle Jurassic age. At the next locality near the Bohúňovo village, blocks of limestones and limestone breccia embedded in red, occasionally cherty siltstones contain a relatively poor association of Middle Triassic (Upper Ladinian) badly to moderately preserved radiolarians. The third locality is near Čoltovo village, where new outcrops were excavated recently. Here, 2 samples, one from red and white thin-bedded siltstones and one from green and purple radiolarites, yielded moderately preserved radiolarians of Middle Triassic age. In the eastern-most part of the Čoltovo dig-outs, an outcrop of red well-bedded radiolarites yielded poorly to moderately preserved Upper Triassic radiolarians. The rocks determined as both Middle and Upper Triassic in age represent blocks in olistostrome bodies, occasionally even as blocks of older olistostromes (Bohúňovo locality), incorporated in the Jurassic matrix of the mélange complexes of the Meliata Unit s.s. (Držkovce locality).

Acknowledgements

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Keywords: Triassic and Jurassic radiolarians, Meliata Unit, Western Carpathians

Radiolarians from an upper Kasimovian (Pennsylvanian) Lake Bridgeport Shale regressive sequence (Graford Formation, Canyon Group), North-Central Texas, USA

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The presence of Pennsylvanian radiolarians in North-Central Texas was mentioned, but none described, by Boardman et al. (1995) and Nestell and Blome (1996) from two localities in the Bridgeport area of Wise County. One locality, herein named the Acme Brick locality, is in shale considered to be stratigraphically below the Bridgeport Coal (occurs 12 m below the Willow Point Limestone) at the base of a shale pit in the western part of Bridgeport. From this locality, Boardman et al. (1995) illustrated one broken test of a radiolarian identified incorrectly as *Albaillella* sp.

The other locality, not mentioned by Nestell and Blome, herein named the Runaway Bay locality, is situated in the Lake Bridgeport area west of Bridgeport. The Lake Bridgeport Shale exposed at this locality was defined by Scott and Armstrong in 1932, who considered it to be above the Willow Point Limestone and below the Rock Hill Limestone. Radiolarians are found throughout the Lake Bridgeport Shale.

The Lake Bridgeport Shale at the Runaway Bay locality overlies the Willow Point Limestone (thickness about 50 cm) that contains scarce fusulinids of a new species of the genus *Kansanella* (*Iowanella*). Only one species of this genus, *K.* (*I.*) *winterensis* (Thompson, Verville and Lokke), is known from the Upper Pennsylvanian Winterset Limestone Member of the Dennis cyclothem in Iowa (Felton and Heckel, 1996).

The Lake Bridgeport Shale (thickness about 27 m) is considered as the regressive part of a Pennsylvanian sedimentary cycle and begins with a black shale less than one-meter-thick containing conodonts of the *Streptognathodus gracilis* Zone of the upper Kasimovian (Barrick et al., 2021). In this black shale interval, abundant radiolarians of curved forms of the *Pseudoalbaillella u-forma* Group, *P. annulata* Ishiga, *P.* aff. *excella* Nestell, Pope and Nestell, *P.* aff. *boonevillensis* Nestell, Pope and Nestell, *Latentidiota* aff. *medorensis* Nestell, Pope and Nestell, and rare *Latentifistula* sp. are found. Abundant agglutinated foraminifers and rare ostracodes are also found in this interval. The radiolarian tests and the ostracodes are poorly preserved and replaced by probably limonite and pyrite. Such preservation of radiolarians is in all samples of the Lake Bridgeport Shale making precise species identification difficult.

Above the black shale interval there is a sequence of gray silty mudstone weathering brownish gray with three covered intervals: near the base, in the middle part and at the top. Above the first covered interval there is exposure of gray mudstone (House Pad site) with rare conodonts, abundant agglutinated and calcareous foraminifers, well preserved ostracodes, and radiolarians. At the base of the gray mudstone, rare tests of the *Pseudoalbaillella u-forma* Group are still present, but at the top of this interval, the species *Pseudoalbaillella* aff. *protractosegmentata* (Nazarov) appears for the first time.

Above the second covered interval, the same gray mudstone contains conodonts, agglutinated and calcareous foraminifers, radiolarians, and occasionally remains of trilobites and holothurian sclerites. In this interval, radiolarians are represented by the species *Pseudoalbaillella* aff. *protractosegmentata*, and species known from the basal black shale interval excluding tests of *Pseudoalbaillella u-forma* Group. Above the last covered interval and below the Rock Hill Limestone, there is a mostly covered and not fossiliferous thin sandstone interval.

It should be noted that the radiolarian species *Pseudoalbaillella annulata*, *P. excella*, *P. boonevillensis*, and *Latentidiota medorensis* are known from the uppermost Moscovian strata of Iowa (Nestell et al., 2012). Recently, the species *P. annulata* was also found in the lower Kasimovian of North-Central Texas (Williams, 2021), and thus the distribution of this species is from the upper Moscovian to the upper Kasimovian. Some species from the Runaway Bay locality are known from allochthonous Cordilleran sequences in North America, Japan, China, and Chili. But the most similar assemblage of radiolarians is reported from the upper Kasimovian *Haplodiacanthus circinatus – Albaillella protractosegmentata* Ecozone in the Usolka section, southern Urals, Russia (Sungatullina et al., 2019).

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Keywords: Radiolaria, Kasimovian, Pennsylvanian, North-Central Texas

Radiolarian responses to the Norian "chaotic carbon episode" in the Panthalassa

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The Late Triassic is marked by three episodes of organic carbon-isotope perturbations that occurred in the mid Carnian, the late Norian, and the Triassic/Jurassic boundary (TJB) interval. The late Norian "chaotic carbon episode" has recently been reported from North America, Italy, and China (Whiteside and Ward, 2011; Zaffani et al., 2017; Jin et al., 2022), likely reflecting a global carbon isotope signature. Although extinctions within major pelagic groups (e.g., radiolarians and conodonts) have been documented in the mid Carnian and TJB chaotic carbon episodes, the impact of the late Norian episode on the pelagic communities at this time remains unclear. In this study, we examine organic carbon isotope ($\delta^{13}C_{org}$) profile and changes in radiolarian assemblages in a middle to upper Norian bedded chert succession in the Sakahogi section (Onoue et al., 2016), Japan, which was deposited in a low latitudinal zone of the Panthalassa Ocean.

Carbon isotope analysis of the study section reveals a significant negative carbon isotope excursion (NCIE) in the late Norian (Sevatian) *Mockina bidentata* conodont zone. This NCIE can be correlated with the S1-NCIE event of Zaffani et al. (2017). The present biostratigraphic analysis also shows the boundary between radiolarian zones TR7 (*Lysemelas olbia* zone; Sugiyama, 1997) and TR8A (*Praemesosaturnalis multidentatus* zone) at the same time of the NCIE. The lowermost part of the TR8A zone, where $\delta^{13}C_{org}$ decreases, contains predominantly undetermined spherical spumellarians along with a large amount of saturnalids (*Palaeosaturnalis* and *Praemesosaturnalis*). In particular, the first occurrence of the genus *Praemesosaturnalis* coincides with the NCIE. Nassellarians are extremely rare in the NCIE interval.

A saturnalids-dominant assemblage associated with negative excursion of $\delta^{13}C_{org}$ were also found in chaotic carbon episode at the TJB section in Japan (Tomimatsu et al., in this volume). The unusual radiolarian assemblage and the NCIE at the TJB have suggested a link between the radiolarian turnover and the Central Atlantic Magmatic Province (CAMP) volcanic event. The cause of the Norian chaotic carbon episode is debated, and potential triggers include the eruption of Angayucham large igneous province (Zaffani et al., 2017; Rigo et al., 2020; Jin et al., 2022). As with the TJB event, changes in seawater chemistry, temperature, and/or a reduced primary productivity in response to the Angayucham volcanism are possible drivers for the radiolarian faunal change during the Norian chaotic carbon episode.

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Keywords: Norian, C isotopes, bedded chert, Panthalassa

Late Anisian (Illyrian) radiolarians from the Dolomites, Southern Alps, Italy

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A detailed taxonomic and biostratigraphic range of Late Anisian (Illyrian) radiolarians have been studied from the Dolomites, Southern Alps, Italy. The radiolarian fauna was obtained from three continuous pelagic sections: (1) the classical Frötschbach section; (2) the Seceda drill core and the closely tied (3) Seceda outcrop. All sections penetrated the Buchenstein Beds in different thicknesses, all of them crossing the Anisian – Ladinian boundary interval (*R. reitzi* ammonoid zone to *E. curionii* zone), even the topmost part of the Seceda core contains the younger Ladinian levels as well (*Frankites regoledanus* ammonoid zone). **The Frötschbach section** outcrops 35 meters of the Lower Plattenkalk and Knollenkalk part of the Buchenstein Beds and stratigraphically ranges from the *Reitzi* ammonoid zone to the *Gredleri* ammonoid zone. Four samples were collected by Hans Rieber in 1995 from the lowermost part of the section and Kozur and Mostler began the investigations of radiolarian fauna in 1996. They took more than 250 SEM pictures, however, they did not publish any results from these sections and the rich, well-preserved radiolarian fauna. In 2010, Heinz Kozur managed and hand over to Péter Ozsvárt (PO) the complete residuum of the samples from Frötschbach section and the unpublished SEM pictures. After this, PO photographed the residuum material and more than 800 SEM pictures were taken of the extremely well-preserved radiolarians helping to fully process this interesting and rich material. **The Seceda borehole** was drilled through a complete succession of Middle Triassic pelagic Buchenstein Beds in the northwestern Dolomites for pure research purposes in 1998 (Brack et al., 2000). The borehole penetrated 109 m of sediments, of which Buchenstein strata were recovered in 88 m thickness. A total of 98 samples were taken by PO from the borehole in 2009. **The Seceda section** represents one of the most complete sequences of the Buchenstein Beds in the Dolomites. The section exposes 70 meters of Buchenstein units from the Lower Plattenkalke to the topmost breccias. 21 samples were taken by Hans Rieber from the base of the section and additional 9 samples from the upper part.

The classical but informal “Buchenstein Beds” is the characteristic succession of bedded pelagic siliceous carbonates and cherty limestone with greenish volcanic intercalations in the Middle Triassic interplatform basins (Brack & Rieber, 1993) in the entire Southern Aps. The well-bedded, siliceous, black, laminated micritic limestone frequently contains well-preserved radiolarians. Our assemblage contains quite diverse Illyrian fauna, with 180 species and 75 genera including 24 new species and 2 new genera. Our study provides new insights into the stratigraphic ranges of many well-known Middle Triassic species.

The Anisian period was a unique and special moment in the diversification history of radiolarians: In a very short time, a high number of new genera and species appeared at the end of the Anisian. The number of newly appeared radiolarian genera was the highest in the whole Triassic (Fig. 1), while the rate of diversification was the second highest after the Carnian period. This blooming and accelerated evolution can be detected in all main radiolarian groups, however, these unique evolutionary innovations and accelerated rates of evolutionary changes in siliceous microplankton are still unclear.

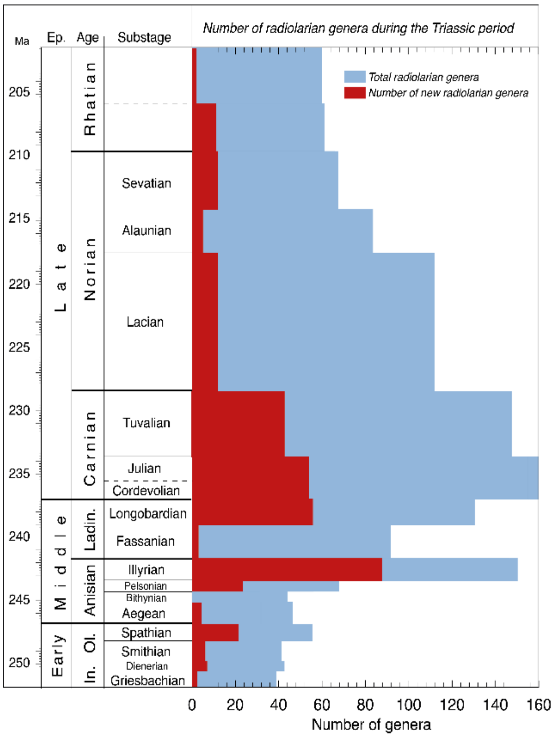

Figure 1. Radiolarian genus diversity through Triassic time

The examination of extinction events in radiolarians has been extensively studied during the past two decades. However, significantly less research has focused on the diversification increasing, radiation and accelerated evolution of silicious microplankton. Three of the presently exciting fundamental question in radiolarian evolutionary history: What has driven these uniquely rapid evolutionary changes? Why did so many new genera and species suddenly appear? What happened at the end of the Anisian? In fact, the Buchenstein beds show characteristically low-oxic or anoxic facies. This laminated facies rich in organic matter yields the richest and perfectly preserved radiolarian fauna. This low-oxic facies may have been caused by the episodic closure of the seaways of the Buchenstein basin bordering the open ocean, later, with the opening the oceanic barriers, these radiolarian communities were able to quickly spread over long distances.

In fact, many new morphological characteristics of radiolarian test and many new morphological shapes appeared in this short period in a more or less isolated, high-organic flux controlled basin associated with an active volcanic environment. Many similar environments from the Mesozoic to the Cenozoic are known in the Neotethys, yet other basins are not characterized by the appearance of such large numbers of new radiolarian species. This suggests that direct environmental influences on the radiolarian genome (e.g. strong cosmic flux) may have played a greater role than changes in conventional environmental parameters (e.g. increasing acidic volcanism, temperature, salinity or sea level changes.

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Keywords: Illyrian, Blooming and accelerated evolution, Buchenstein Basin

A 'big data' look at the impact of climate on fossil plankton biodiversity, with a projection for future climate change

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Phytoplankton as a whole is responsible for half of global productivity and to the bulk of the marine biological carbon pump, while large heterotrophic protists such as polycystine radiolarians also contribute significantly to marine carbon export to the deep sea (see e.g. Guidi et al. 2016). Given the difficulty to monitor marine single-celled eukaryotic populations, our knowledge of their biology and ecology is very limited, and thus it is difficult to estimate their extinction risk in the current context of anthropogenic climate change. Micropaleontology offers an alternative way to understand and estimate their capacity to adapt to climatic fluctuations. We first present updated diversity reconstructions using the Neptune database (NSB; Renaudie et al. 2020). We show how the diversity and abundance history of these groups changed throughout the Cenozoic and what the role of climate/oceanographic changes on their evolution was. We also explicitly examine possible living plankton responses to future climate change. We have compiled the age range of several hundred species of living diatoms, calcareous nannofossils and radiolarians, and translated them, using the benthic oxygen isotope stack of Westerhold et al. (2020), into global mean temperature ranges that each species lived through. It reveals a tipping point around +3.5°C above preindustrial global mean temperature after which a large fraction of the compiled species of radiolarians, diatoms and calcareous nannofossils will enter a climatic *terra incognita*, i. e. a temperature range that they never encountered before in their individual species evolutionary history, and to which they are thus likely not adapted for. Using current estimates of global mean temperatures projected for 2300 under various RCP scenarios (IPCC Representative Concentration Pathways) locates this tipping point as occurring within the range of RCP4.5 and RCP6.0. Although based on warming to date, future warming may follow, or be below the RCP 4.5 projection (Pielke et al., 2022), our sensitivity projections are only rough approximations using global mean climate states. Due to polar amplification of temperature change, tipping points for plankton may be reached in polar regions much more rapidly than in our estimates.

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Keywords: Diversity, Cenozoic, Climate Change, Neptune Database.

The Lamont radiolarian and diatom slides collection

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In June 2021, the Museum für Naturkunde in Berlin, Germany, acquired the radiolarian and diatom slides collection from the Lamont-Doherty Earth Observatory in Palisades, USA. It consists of ca 40,000 radiolarian and 30,000 diatom slides prepared between the 1960s and ca 2000 by many scientists and technicians, under the leadership of James D. Hays (for the radiolarians) and Lloyd Burckle (for the diatoms). The coverage is global (see Figure 1), but with a focus on the late Neogene to Quaternary, and includes many slides made from surface sediments and piston cores mostly recovered from the various Lamont research vessels (R/Vs Robert Conrad, Vema, Eltanin, etc.), in addition to some made from deep-sea drilling samples. Many of these slides were used in the seminal CLIMAP studies of Quaternary climate change (e.g. CLIMAP project members, 1976) which also demonstrated the validity of the Milankovitch orbital variations theory of the earth's ice ages (Hays et al., 1976). This finding in turn laid the foundation for high resolution age dating of sedimentary sections, a fundamental part of modern paleoceanography and climate change research. The slides are currently documented by a card index library that accompanied the collection when acquired. A cross-referenced database documenting them and incorporating core repository metadata is in progress. Complete and thorough reevaluation of these now publicly accessible slides may provide an improved baseline for global studies of modern radiolarian and marine diatom diversity and for the establishment of new radiolarian and diatom-based oceanographical proxies.

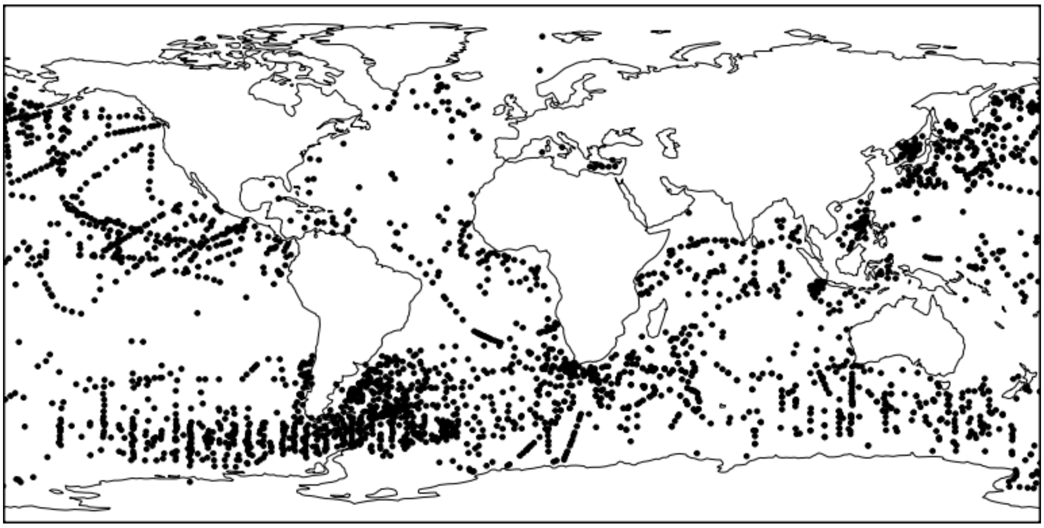

Figure 1. Map showing the geographic extent of the Lamont collection's content. Each dot corresponds to the provenance of at least one sample.

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Keywords: Cenozoic, Collection, History.

Insights into the life cycle of extant Radiolaria

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During the last decade, research on extant Radiolaria has brought a revised perspective on their classification and distribution at a global scale, has revealed their impact on biogeochemical cycles and has approached the nutrient dialog between host and microalgae in photosymbiotic species. Still, comprehension of radiolarian life cycles is poor and is essentially based on knowledge from the 80's–90's. The maintenance of Radiolaria in laboratory is tedious and the transition from one generation to another has never been witnessed. Accumulating observations on the field has led to the suggestion of diverse reproductive strategies for the 4 extant radiolarian groups (Acantharia, Spumellaria, Nassellaria, Collodaria), including the formation of cysts, transition from solitary to colonial stages and the production of flagellated swarmers. The environmental triggers of life cycle stages transition are currently unknown. By combining *in situ* observations to single-cell DNA and RNA analysis through transcriptomic and digital droplet quantitative PCR analyses, we aim at investigating radiolarian reproductive processes. Searching for conserved protist genes governing life cycle transitions, like genes involved in meiosis and gamete fusion will contribute to reveal how radiolarian life cycles can be influenced by the biotic and abiotic environment and pave the way for developing targeted cultivation methods.

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Keywords: extant Radiolaria, life cycle, swarmers, single-cell transcriptomics

Radiolaria diversity, ecology and evolution: an integrative approach

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Radiolaria are holoplanktonic amoeboid protists mostly known for their elaborate skeletons as the “stars” of the oceans. The opaline silica skeleton of some species preserves well in sediments, showing an extensive and continuous fossil record since the Cambrian. In modern oceans, Radiolaria contribute significantly to plankton communities, both at surface where they establish symbiotic relationships with photosynthetic microalgae and at depth such as in the mesopelagic waters. Despite their importance in both modern and past ecosystems, radiolarian evolutionary history and ecology remains elusive, and mostly inferred from the fossil record and sediment samples.

Recent studies on single cell radiolarian specimens have integrated molecular (rDNA) with optical and electronic microscopy approaches establishing robust morpho-molecular frameworks for main groups of Radiolaria (Biard et al., 2015; Decelle et al., 2012b; Sandin et al., 2019, 2021). Here we integrated the most extensive, non-redundant rDNA dataset of Radiolaria to date through a detailed curation of all available molecular barcodes and environmental markers. Phylogenetic analyses revealed six major groups within Radiolaria: Acantharia, Spumellaria, Nassellaria (including the colonial Collodaria) and three diverse environmental clades so-called RAD-A, RAD-B (with *Sticholonche zanclea* and *S. ventricosa* as the only two species described) and RAD-C. The fossil calibration of the molecular clock coupled with metabarcoding analysis allowed reconstructing their eco-evolutionary history since they first diversified in the Early Neoproterozoic. Two major events characterized their diversification; the development of the skeleton in the Early Paleozoic and the establishment of the symbiosis in the Jurassic, when oligotrophy (Decelle et al., 2012a) and anoxia governed the oceans. A large undescribed environmental diversity was found associated with early diverging nodes showing a preference towards deep environments. Such patterns led us to hypothesize a large skeleton-less diversity of radiolarian specimens yet to be explored. Our comprehensive and contextualized morpho-molecular framework contributes to improve the understanding of the evolutionary history of Radiolaria and brings a standpoint for a detailed exploration of their diversity and distribution in contemporary oceans.

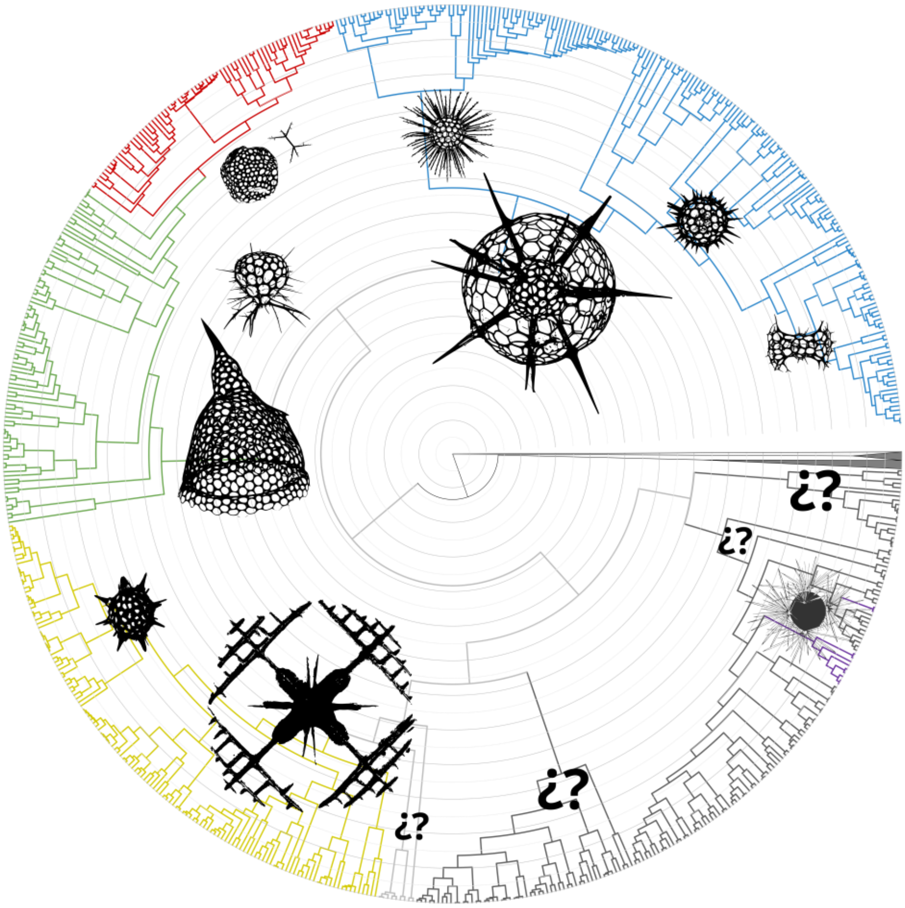

Figure 1. Schematic phylogenetic tree of Radiolaria. Described groups are highlighted in different colours: Acantharia (yellow), Nassellaria (green, with Collodaria in red), Spumellaria (blue) and Taxopodida (purple). Taxopodida silhouette was rendered from Borgen A (1897) Z wiss. Zoot., 63, 141–186.

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Keywords: rDNA, molecular clock, environmental diversity, diversification

Middle and upper Cambrian radiolarian assemblages from the Georgina Basin, Australia

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Radiolarian assemblages ranging from middle to upper Cambrian with exceptional preservation were recovered from three localities of the Georgina Basin, far north-west Queensland, Australia. With these new data added to knowledge of scarce Cambrian radiolarian occurrences globally, a revision of Cambrian radiolarian biostratigraphy with higher resolution became possible (Aitchison et al., 2017). Micro-CT studies were conducted on several species including *Fungomacula barbatula* whose family and order level classifications were undecided, and *Parechidnina aspinosus* whose structure has been long debated, resulting in placement of the genus *Parechidnina* under families Echidninidae and Aspiculidae with contradictory diagnoses (Kozur et al., 1996, Won et al., 2005, Noble et al., 2017).

Detailed structural analyses revealed that *F. barbatula* has an eccentrically placed initial spicule and a thick shell exclusively constructed of spicules and straight rays (Figure 1). Based on its spicular composition, *Fungomacula* is placed within Archaeospicularia. Therefore, the earliest occurrence of an internal spicule, which marks one of the most important evolutionary developments in radiolarians, occurred within the order Archaeospicularia. Its unique skeletal structure differs from other genera placed in spicule-constructed families suggesting establishment of a new family Fungomaculidae is necessary.

Complete digital dissections of two *P. aspinosus* specimens reveals that this species is constructed exclusively by fused rods, which nullifies the hypothesis that this genus is composed of modified point-centered spicules (Kozur et al., 1996). However, to support its placement under Aspiculidae (Won et al., 2005), discussion of whether the rod structure should be defined as a type of spicule is critical.

Scanning electron microscopy studies of specimens belonging to genera *Palaeospiculum, Archeoentactinia and Parechidnina* from the middle and upper Cambrian assemblages reveal structures resembling axial canals of sponge spicules. These structures are preserved as both hollow centers within a solid spicule, and solid thin rods within hollow spicules, which suggest that these structures are not likely to be results of taphonomic processes.

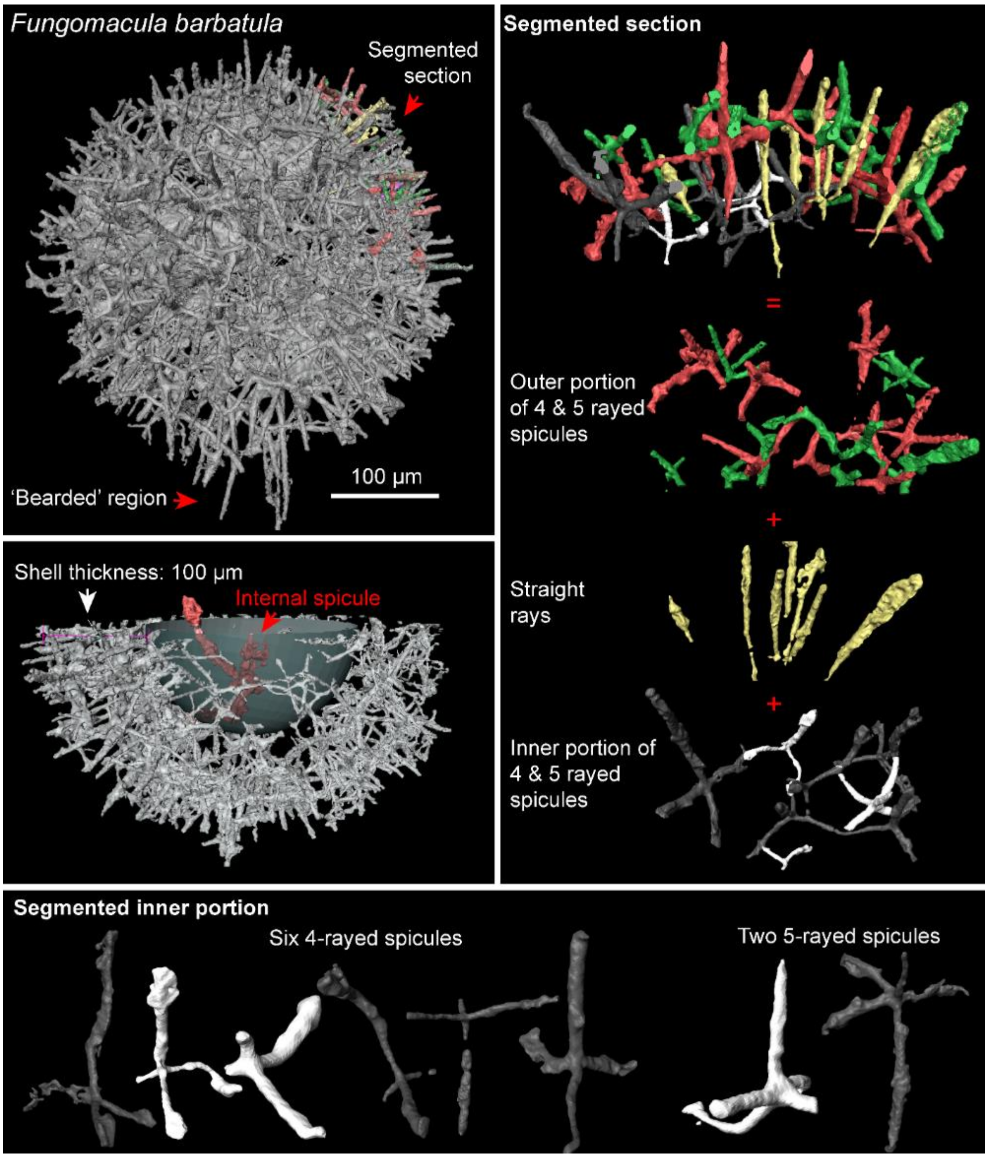

Figure 1. Results of micro-CT analysis of a *Fungomacula barbatula* specimen from the middle Cambrian Inca Formation displaying its spicular composition revealed by digital dissection.

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Keywords: Cambrian, Micro-CT, Taxonomy, Australia

Radiolarian biostratigraphy and recovery from ocean anoxic event during Early-Middle Triassic: Chichibu Belt, Japan

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The globally recognized ocean anoxic event (OAE) at the Permian/Triassic boundary (PTB) resulted in the extinctions of Paleozoic-type radiolarians. Previous studies of Upper Permian to Lower Triassic pelagic sedimentary rocks in Japan (i.e., bedded cherts) showed high concentrations of redox-sensitive trace-elements (e.g., vanadium, uranium, and molybdenum), which indicate anoxic to euxinic condition in the pelagic deep-water environments in the Panthalassa. Although the OAE in the pelagic Panthalassa may have delayed the recovery of radiolarian productivity in the Triassic and caused the “chert gap”, the total duration of this oxygen-depleted condition remains unclear. To document the recovery from PTB anoxia and “chert gap” in the Panthalassa, here we show the results of litho- and bio-stratigraphy (radiolarians and conodonts) and chemostratigraphy of redox-sensitive trace elements from the upper Olenekian (Lower Triassic) to upper Carnian (Upper Triassic) bedded chert successions in Ajiro and Fukura islands in the Chichibu Belt, eastern Kyushu, Japan.

Two bedded chert sections were identified in Ajiro Island: AJ and AJR sections (Onoue et al., 2011; Muto et al., 2019; Muto, 2021). AJ section is approximately 20 m thick and mainly consists of alternating beds of white shale and black chert. Previous study has recognized four conodont biozones in this section, from the upper Olenekian *Triassospathodus brevissimus* Zone to the middle Anisian *Paragondolella bulgarica* Zone (Muto et al., 2019). AJR section is approximately 20 m thick and consists of greenish gray, purple, and red bedded chert with thin intercalations of siliceous shales. The present biostratigraphic analysis recognizes the middle Anisian to the lowermost Ladinian conodont and radiolarian biozones in the AJR section, from *Paragondolella bulgarica* to *Paragondolella trammeri* conodont zones, and from TR2B to TR4A radiolarian zones of Sugiyama (1997). Fukura Island section is approximately 10 m thick and consists of greenish gray bedded chert with the intercalations of thick white chert beds. Our biostratigraphic analysis reveals that uppermost AJR section and Fukura Island section are correlated to the Ladinian TR3B to the Carnian TR5B radiolarian zones.

We investigated the sedimentary redox changes through the study sections using redox sensitive elements such as manganese (Mn) and iron (Fe). Our data show low concentrations of Fe and Mn in the upper Olenekian to the middle Anisian. Enrichment of Mn rapidly increase across the *P. bulgarica* and *P. excelsa* conodont zones, suggesting the deep-water environments changed from suboxic to oxic conditions in the middle (Pelsonian) to late (Illyrian) Anisian. PTB anoxia recorded in the Upper Permian bedded chert successions in Japan is thought to have started at ca. 252 Ma. Since the deep-ocean environments changed from suboxic to oxic conditions near the middle/late Anisian boundary (ca. 243 Ma) in the study sections, the total duration of this episode of oxygen depletion was likely up to 9 million years until its recovery in the Anisian. Furthermore, our litho- and bio-stratigraphic examinations reveal that the recovery of radiolarian productivity and diversity preceded the change to an oxic environment in the deep-sea Panthalassa by about 3 million years.

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Keywords: Chichibu Belt, ocean anoxic event, Triassic

A new automated radiolarian image acquisition, stacking, processing, segmentation and identification workflow.

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Identification of microfossils is usually done by expert taxonomists and requires time and a significant amount of systematic knowledge developed over many years. These studies require manual identification of numerous specimens in many samples under a microscope, which is very tedious and time-consuming. Furthermore, identification may differ between operators, biasing reproducibility. Recent technological advances in image acquisition, processing and recognition now enable automated procedures for this process, from microscope image acquisition to taxonomic identification.

A new workflow has been developed for automated radiolarian image acquisition, stacking, processing, segmentation and identification (Fig. 1). The protocol includes a newly proposed methodology for preparing radiolarian microscopic slides. We mount eight samples per slide, using a recently developed 3D-printed decanter that enables the random and uniform settling of particles and minimizes the loss of material. Once ready, slides are automatically imaged using a transmitted light microscope. About 4000 specimens per slide (500 per sample) are captured in digital images that include stacking techniques to improve their focus and sharpness. Automated image processing and segmentation is then performed using a custom plug-in developed for the ImageJ software. Each individual radiolarian image is automatically classified by a convolutional neural network (CNN) trained on a Neogene to Quaternary radiolarian database (currently 24.603 images, corresponding to 149 classes) using the ParticleTrieur software.

The trained CNN has an overall accuracy of about 90 %. The whole procedure, including the image acquisition, stacking, processing, segmentation and recognition, is entirely automated via a LabVIEW interface, and it takes approximately 1 h per sample. Census data count and classified radiolarian images are then automatically exported and saved. This new workflow paves the way for the analysis of long-term, radiolarian-based palaeoclimatic records from siliceous-remnant-bearing samples.

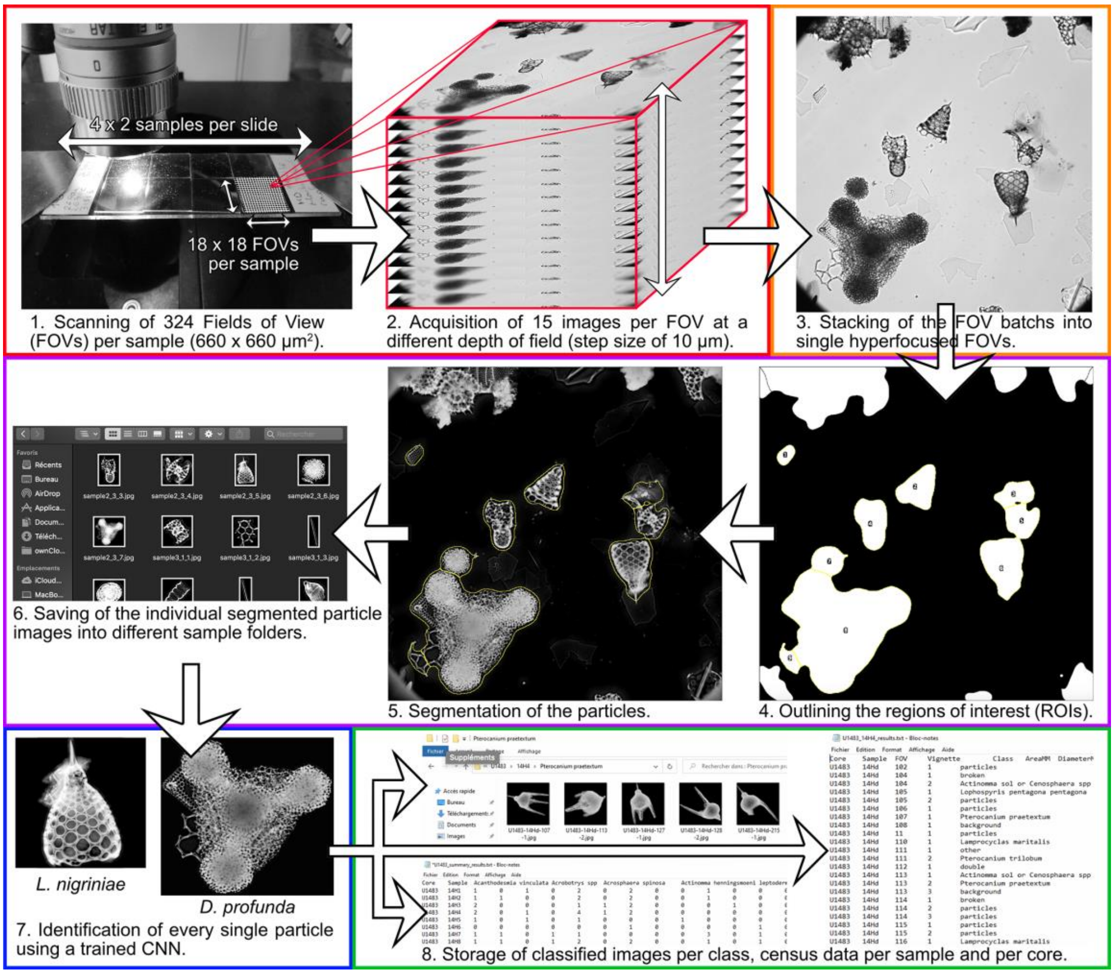

Figure 1. Automated radiolarian image acquisition, processing and identification workflow. Panels 1 and 2 (red rectangle) show the automated acquisition steps. Panel 3 (orange rectangle) shows the automated FOV image stacking step. Panels 4, 5 and 6 (purple rectangle) show the automated FOV image processing and segmentation steps. Panel 7 (blue rectangle) shows the automated recognition step. Panel 8 (green rectangle) shows the automated export of classified images, census counts and morphometric measurements.

Keywords: Radiolaria, automated microscopy, image processing, neural networks.

High-resolution radiolarian and conodont biostratigraphy of the Upper Triassic and across the Triassic-Jurassic boundary in the Inuyama area, central Japan

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The Triassic/Jurassic boundary (TJB: ~201.36 Ma) interval records one of the five largest mass extinctions during Phanerozoic Earth history. The release of volcanic and contact metamorphic carbon and sulfur gases from the Central Atlantic Magmatic Province (CAMP) is commonly invoked as the trigger for climatic perturbations during the last 300 kyrs of the Triassic, which leads to the end-Triassic mass extinction (ETE). Although previous studies have noted significant extinction of major pelagic groups (e.g. radiolarians and conodonts) during the ETE, a limited number of studies have reported on integrated biostratigraphic research of radiolarians and conodonts in the Panthalassa Ocean (e.g., Tipper et al., 1994; Carter and Hori, 2005). Here, we undertook a high-resolution radiolarian-conodont stratigraphic distribution of an upper Norian to lowest Hettangian bedded chert succession, including the TJB interval in the Katsuyama-B section, Japan (c.a. 12.6 m in thickness). This section is inferred to be a lateral extension of the Katsuyama (section UF: Hori, 1990) section, which accumulated in a pelagic deep-sea environment in a low to middle latitudinal zone of the Panthalassa Ocean.

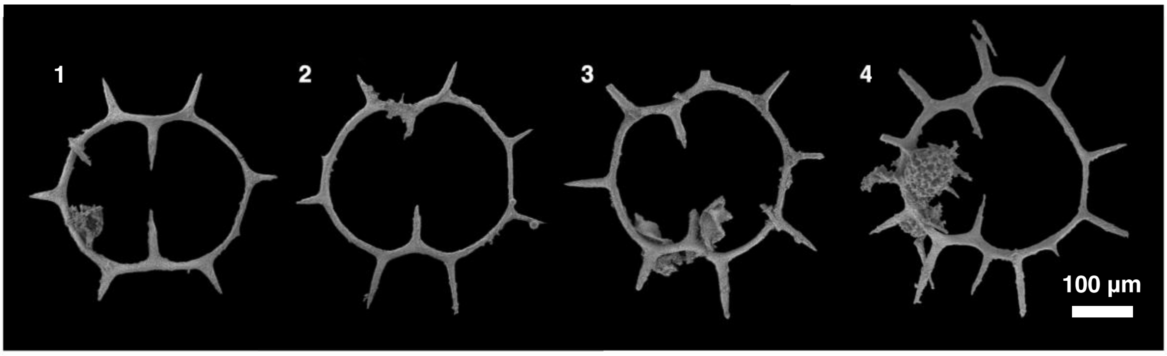

Figure 1. Scanning electron micrographs of *Mesosaturnalis* species in a very short interval across the Triassic/Jurassic boundary from the Katsuyama-B section, Japan. Scale bar = 100 µm.

The biostratigraphic analysis confirmed that the radiolarian species in this section characterize from the TR8B (*Praemesosaturnalis pseudokahleri*) Zone to the JR0B (*Bipedis horiae*) Zone established by Sugiyama (1997), and include *Lysemelas olbia*, *Betraccium deweveri*, *Haeckelicyrtium takemurai*, *Livarella valida*, *Deflandrecyrtium ithacathum*, *Risella tledoensis*, *Tricornicyrtium dikmetasensis*, *Globolaxtrum tozeri*, *Pantanellium tanuense*, *Praehexasaturnalis tetraradiatus*, and *Bipedis horiae*. We also recognized three conodont zones proposed by Rigo et al. (2018) in the studied section: the upper Norian *Misikella hernsteini* zone, the lower Rhaetian *Misikella posthernsteini* zone, and the upper Rhaetian *Misikella ultima* zone. Our biostratigraphic studies revealed that some Rhaetian radiolarian and conodont fauna occurred in the earliest Jurassic. Furthermore, our biostratigraphic analysis revealed an unusually abundant occurrence of a previously unidentified *Mesosaturnalis* species with a thickness 0.6 m across the TJB in the studied section. They have generally 6 to 10 narrow tapering spines (rarely up to 12) surrounding outer part of the ring, and the number of spines seems to increase in the growth process of their ring sizes (Figure 1). This finding suggests that this *Mesosaturnalis* species, which occurs highly abundant in a short interval across the Triassic–Jurassic boundary, is likely to be an excellent indicator for the TJB.

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Keywords: Triassic/Jurassic Boundary, Radiolarian, Conodont, Panthalassa

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Radiolarians show threshold extinction response to late Neogene climate change

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According to numerous ecological models (i.e., Beaugrand et al. 2015; Thomas et al. 2012; Jensen et al. 2017), global cooling over the last 10 million years (Ma) would have caused polar plankton species to move equatorward to conserve their preferred habitat. These models, assume that plankton species can successfully track preferred habitat conditions on a global scale and do not address species' risk of extinction. Previous work has found major changes in community structure and species richness decline (~35% of species) among high-latitude polycystine radiolarians (Renaudie & Lazarus 2013), but without a comparable low-latitude dataset, it has been unclear whether these species were only locally extirpated from the high latitudes or went globally extinct. The goal of this study was to document tropical radiolarian biodiversity dynamics over the last 10 Ma, then compare species richness and taxon occurrence histories between the low and high latitudes to characterize the response of radiolarians to late Neogene climate change. Assemblage comparisons between the Southern Ocean (SO) and eastern equatorial Pacific (EEP) allow us to estimate how many of the species that disappeared from high latitudes ultimately survived global cooling by contracting or shifting their ranges to low latitudes, possibly via isothermal submergence pathways (Casey et al. 1982), or instead went globally extinct. Both high and low-latitude datasets were also compared to regional temperature proxy records (Herbert et al. 2016; Liu et al. 2019; Zhang et al. 2014) to evaluate radiolarian responses under different magnitudes of climate change. While the EEP experienced changes in temperature, productivity, weathering rates, and tectonic configuration over the last 10 million years (Tian et al. 2018), the magnitude of these changes were relatively minor compared to the amplified climate change and variability experienced in the higher latitudes (Herbert et al. 2016). To investigate the differential impacts of these changes, we constructed a comprehensive polycystine radiolarian species richness curve for the low latitudes using tropical and isothermal submergence faunas from International Ocean Discovery Program (IODP) Site U1337 in the EEP. Approximately 5000 specimens were counted from each of 14 samples spanning 10.3 Ma – Recent, to ensure adequate documentation of rare species. These data were used to extrapolate total species richness based on sample coverage metrics, and describe paleocommunity structural dynamics through time. Our results indicate that tropical radiolarian diversity and community structure were remarkably high and stable throughout the study interval (average species richness = 485 ± 36; average evenness (Pielou equitability index) = 0.84 ± 0.02). This stability was observed despite a gradual ~3°C decrease in sea surface temperature (SST) over the last 10 Ma, indicating that this change was below tropical radiolarians' ecologic-evolutionary sensitivity threshold. By contrast, the profound loss of ~35% of SO species richness, and establishment of a single dominant genus (*Antarctissa*), correlates with ~7°C regional SST drop from 5 Ma–Recent at high latitudes. The majority of species lost from the SO were not observed in younger low latitude samples, suggesting that these species went extinct, rather than migrate to track their preferred temperature conditions as anticipated by ecological models. Thus, we interpret the severe decline in SO species richness, preceded by ecological restructuring, as a threshold response to relatively high-magnitude temperature change. Furthermore, we find that the tropics did not serve as a habitat refuge for 71% of species extirpated from the SO, indicating that marine plankton species cannot always track preferred habitats on a global scale and are instead acutely vulnerable to extinction during intervals of considerable climate change. With projected climate change similar in scale to that of the Late Neogene, we anticipate elevated extinction risk for high latitude radiolarians in the imminent future. Additional information on this study can be found in Trubovitz et al. 2020.

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Keywords: Extinction, Diversity, Climate Change, Neogene

New species of late Neogene Lophophaenidae (Nassellaria, Radiolaria) from the eastern equatorial Pacific

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Lophophaenids are a group of nassellarians in the superfamily Plagiacanthoidea, which have two skeletal segments: a cephalis and a thorax, as well as an internal structure of spines and arches. In the eastern equatorial Pacific (EEP), taxa belonging to the family Lophophaenidae have been among the most abundant and species-rich radiolarians in plankton fossil assemblages since the Late Miocene (Trubovitz et al. 2020). However, due to their relatively small size compared to other nassellarians, high morphological diversity, and rare use in biostratigraphy, the lophophaenids have been notoriously overlooked in radiolarian literature, leaving many taxa in open nomenclature or entirely undocumented. In the Neptune Sandbox Berlin (NSB) Database (Renaudie et al. 2020), there are only three valid lophophaenid species reported, typically as rare, from the equatorial Pacific (within 20 degrees of the equator) over the last 10 million years (*Lophophaena cylindrica*, *Lophophaena hispida*, and *Lithomelissa ultima*). By contrast, Trubovitz et al. (2020) found an average of 60 lophophaenid taxa and hundreds of lophophaenid specimens per sample, comprising approximately 10–15% of the total radiolarian assemblages observed in the EEP (Figure 1). Lophophaenids make up the majority of Plagiacanthoidea specimens observed in every sample, and approximately half of the Plagiacanthoidea species in each sample are classified as lophophaenids. Renaudie and Lazarus (2016) also found that lophophaenids are abundant and comprise approximately half of the Plagiacanthoidea species richness in the Late Neogene Southern Ocean assemblages; many of these species had not previously been documented nor described. Thus, lophophaenids are very important in terms of both abundance and taxonomic diversity in both low and high latitude oceans, but regrettably have been historically underreported. In this study (Trubovitz et al. in press) we aim to address this problem by comprehensively documenting the lophophaenids from the Middle Miocene–Recent at IODP Site U1337 in the EEP. We also provide concise discussions of the common lophophaenid genera present during this interval: *Amphiplecta, Arachnocorallium, Arachnocorys, Botryopera, Ceratocyrtis, Lithomelissa, Lophophaena,* and *Peromelissa*. In total, we discuss and illustrate our observations of 101 lophophaenid taxa from the Middle Miocene – Recent in the EEP. We describe 1 new genus, *Pelagomanes* n. gen., which unites several taxa that were questionably assigned to other genera in previous literature. We also describe 23 new species: *Amphiplecta kikimorae* n. sp., *Arachnocorys jorogumoae* n. sp., *Botryopera amabie* n. sp., *Botryopera babayagae* n. sp., *Botryopera bolotniki* n. sp., *Ceratocyrtis? chimii* n. sp., *Ceratocyrtis vila* n. sp., *Lithomelissa alkonost* n. sp., *Lithomelissa babai* n. sp., *Lithomelissa dybbuki* n. sp., *Lithomelissa sirin* n. sp., *Lophophaena arie* n. sp., *Lophophaena casperi* n. sp., *Lophophaena domovoi* n. sp., *Lophophaena gozui* n. sp., *Lophophaena ikiryo* n. sp., *Lophophaena ikota* n. sp., *Lophophaena kaonashii* n. sp., *Lophophaena leshii* n. sp., *Lophophaena rusalkae* n. sp., *Lophophaena shishigae* n. sp., *Lophophaena ushionii* n. sp., and *Pelagomanes ibburi* n. sp., and one new subspecies, *Arachnocorys pentacantha wanii* n. subsp. Sandin et al. (2019)'s recent revision of nassellarian classification based on an integrated genetic-morphologic approach found that both internal and external skeletal morphology should be considered when developing nassellarian taxonomy, so our species and generic concepts follow this principle. In addition to previously described and newly described taxa, we photo-document 35 taxa in open nomenclature, and revise generic assignments of 10 species. This work is designed to be a practical framework for identifying tropical Late Neogene–Recent lophophaenid taxa, and demonstrates their rich morphological diversity.

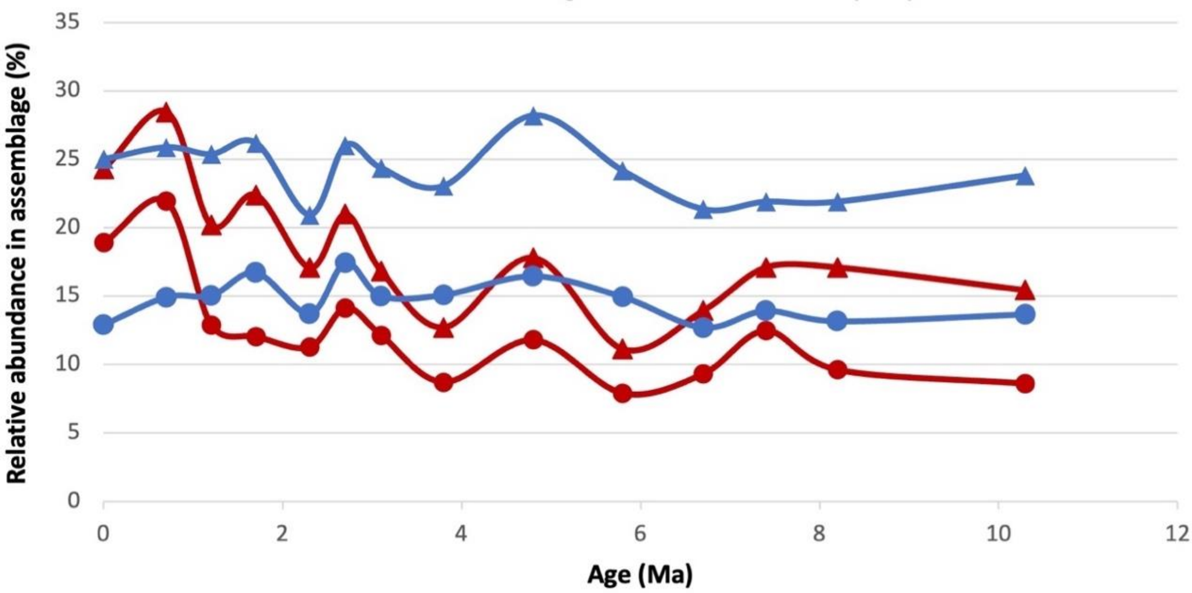

Figure 1. Relative abundance of specimens and taxa belonging to Plagiacanthoidea and Lophophaenidae per sample, from IODP Site U1337 in the EEP over the last ~10 Ma. The relative percentages of total taxa are represented by the blue lines and the red lines represent the percentages of total specimens (triangles = Plagiacanthoidea; circles = Lophophaenidae). The Plagiacanthoidea was among the most abundant and speciose of radiolarian groups encountered in Trubovitz et al. (2020), with at least 10% of the specimens and 20% of the taxonomic richness in every sample. Within the Plagiacanthoidea, lophophaenids consistently made up the majority of specimens (~67%) and taxa (~61%). Figure is from Trubovitz et al., in press.

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Keywords: Lophophaenidae, Neogene, new species, new genus

Biostratigraphic record of the upper Carnian radiolarians from the Pizzo Mondello section (western Sicily, Italy)

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Pizzo Mondello in the Sicani Mountains (western Sicily, Italy) is one of the best localities for the study of the Carnian/Norian boundary. At this site, a 450-m thick continuous succession of upper Carnian to upper Norian marine limestones is well exposed and very easily accessible. The succession belongs to the Scillato Formation (Halobia Limestone auctorum*)* and it shows high sedimentation rates, almost uniform facies, and a rich paleontological record combined with paleomagnetic and stable isotope records. For these features, the Pizzo Mondello section has recently been selected as the GSSP of the Norian stage (Hounslow et al., 2021). In particular, the bivalve *Halobia austriaca* has been voted as the first biomarker to identify the base of the Norian stage (Hounslow et al., 2021).

During the last two decades, several researchers have studied in detail the Pizzo Mondello section in order to better define the bio-, chemo- and magnetostratigraphic events around the Carian/Norian boundary (e.g., Muttoni et al., 2001, 2004; Nicora et al., 2007; Balini et al., 2010; Levera, 2012; Mazza et al., 2010, 2018; Rigo et al., 2018; Hounslow et al., 2021).

Radiolarians are very useful for the calibration of the bio-, chemo- and magnetostratigraphic events, however, they are currently not well studied at the Carnian/Norian boundary of the Pizzo Mondello section (Nicora et al., 2007; Balini et al., 2010; Hounslow et al., 2021). Most of the species in this section were previously regarded as early Norian and actually occur in the latest Carnian of Haida Gwaii (British Columbia) (Carter &Orchard, 2013; Hounslow et al., 2021). Therefore, it is necessary to sample bed by bed around the Carnian/Norian boundary at the Pizzo Mondello section and study its radiolarian biostratigraphy in detail.

As a result, we collected a large number of radiolarians from the upper Carnian portion of the Pizzo Mondello section, such as *Capnuchosphaera crassa* Yeh, *Sepsagon asymmetricus* (Bragin), *Xiphothecaella munda* (Tekin), and *Xiphosphaera*? *fistulata* Carter, which first appears in Ass. 4 to Ass. 5 at Haida Gwaii (British Columbia), uppermost Carnian to early Norian in age (Carter & Orchard, 2013). These associations can be useful tools in the biostratigraphic correlation between North America and Tethyan successions. The radiolarian investigation at the Pizzo Mondello section is still in progress. Further studies will better understand the correlations between conodonts, bivalves, and ammonoids and thus better characterize the base of the Norian stage.

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Keywords: radiolarians, Carnian/Norian boundary, Pizzo Mondello section

Geometrical Variations of Skeletal Structures of Genus *Pantanellium*

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We consider the polyhedral variations of the skeletal structures of the genus *Pantanellium* by using the representation method which we propose here. As we reported previously (Matsuoka et al., 2012; Yoshino et al., 2015), drawing planar graphs well represents the skeletal structures; however, we have not mentioned the effective representation yet. For this reason, we propose a new method for the graph drawing. We approximate the skeletal structures to the edges of polyhedrons with the locations of primary spines by using the method described by Yoshino et al. (2015), and draw the planar graphs of the polyhedron structures by using the following procedure.

The drawing method for the planar graphs is defined strictly in order to compare the skeletal structures. The graphs are drawn based on the diagram illustrated in Fig. 1a. Only the intersections are used for the vertices. The shapes of the polygons, the elements of the planar graphs, must be convex. The following is an outline of the procedure. We focus on the arrangements of polyhedrons around the primary spines first. One of the vertices representing the spines is chosen. The vertex is located at the center of the diagram, and another vertex is located at three intersections on the outermost circle; the vertex opposite to the vertex at the center is represented by the three vertices. The three intersections are chosen to reflect the geometrical relation of the primary spines. The three polygons around the center of the diagram are drawn based on the constraint shown in Fig. 1b. And the rest polygons are drawn in accordance with the locations of the vertices representing the primary spines.

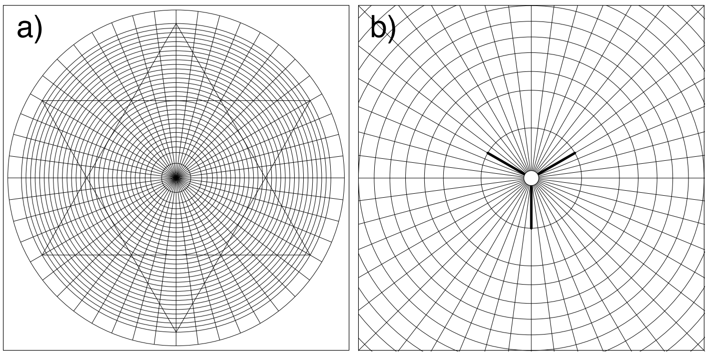

Figure 1. A diagram for drawing planar graphs. A) the whole image and B) the central part.

Figure 2 shows the planar graphs drawn using the three-dimensional data of actual specimens based on the proposed method. The data was obtained by using Micro X-ray CT. Although specimens with more than 26 pores were found, we listed only the graphs for the specimens having less than or equal to 26 pores due to the page number restriction. As shown in the figure, most specimens had different structures according to our criterion. We conclude that the proposed method is too sensitive to consider the skeletal structures of the genus *Pantanellium,* although it works well.

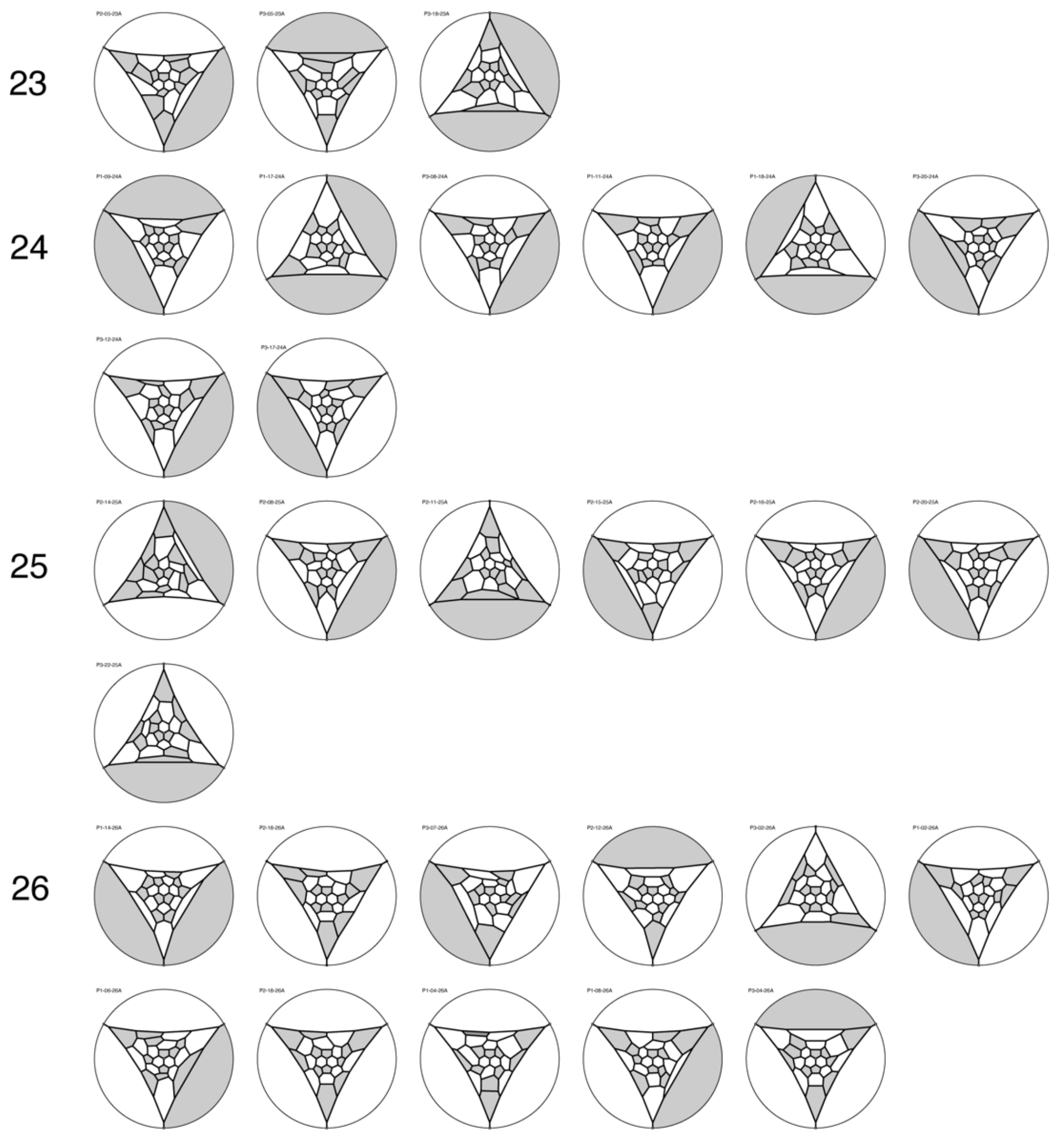

Figure 2. The list of the planer graphs for specimens having the number of pores from 23 to 26. Pentagons are colored in Gray.

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