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Lille 2021: Ordovician of the World
Programme with Abstracts

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LILLE 2021:
ORDOVICIAN OF THE WORLD

PROGRAMME WITH ABSTRACTS

2021 Virtual Annual Meeting of IGCP 653

International Geoscience Programme Project 653
The Onset of the Great Ordovician Biodiversification Event

2021 Virtual Annual Meeting of IGCP 735

International Geoscience Programme Project 735
Rocks and the Rise of Ordovician Life – Filling knowledge gaps in the Early Palaeozoic Biodiversification

Meeting of the Subcommission on Ordovician Stratigraphy

Lille University, Villeneuve d'Ascq, France
September 13–16, 2021

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Before and during the meeting, if you have any questions, concerns or technical problems please contact the organizing team at:

igcp653.735.lille2021@gmail.com

CONTENTS

LILLE 2021:
ORDOVICIAN OF THE WORLD

Lille University, Villeneuve d'Ascq, France
September 13–16, 2021

PRESENTER GUIDELINES

General information

Please be advised that the meeting will be organized with the Zoom platform.

To avoid speakers being interrupted during their talks, we therefore note that all microphones will be muted upon entering the virtual conference. Should you have a question, use either the chat function, or the 'Raise hand' function. The session moderator will then call out those who have questions (depending on what time permits). You can ask your question by pressing down the 'Space bar' on your keyboard.

Presentation Preparation:

Regular Oral Presentation slots are a total of 20 minutes each. Your presentation should not exceed 15 minutes in length. We will have 5 minutes for questions and transitioning to the next speaker. Please keep your presentation to 15 minutes. For keynote talks, the length is of 30 (25 + 5) or 40 (35 + 5) minutes.

Presentation format:
Speakers may choose to (1) present live via-screen share from their own computer during their assigned time slot or (2) submit a pre-recorded presentation to be shared by the session convener during their assigned time slot.

Live presentations can be developed using the preferred presentation mode of the presenter (PowerPoint, Google Slides, Adobe PDF). During the presentation, the presenter should click in Zoom to share that screen with their slides and then implement presentation mode for their slides on their computer.

Pre-recorded presentations should be saved as MP4. Please keep file sizes as small as possible. If you are pre-recording presentations, please use a headset with microphone for best quality audio.

Pre-recorded presentations must be sent to the organisers.

Please, note that all Lightning Talks must be pre-recorded. The length is of 5 minutes, 3 minutes for the presentation, and 2 for questions and discussion.

Session Logistics

Every session will have a session chair, an IGCP 653/735 meeting organizer, and helper present to assist if you need anything. The speaker lineup and moderators/helpers for each session, including times, for each day can be found on the meeting website: https://lille2021.wordpress.com. The IGCP 653/735 meeting organizer or helper will assist you with enabling screen share and ensuring your audio is working. For pre-recorded talks, the moderator or helper will play these during your time slot. We recommend that you use a headset for your audio if you are presenting live.

Please try to join your session 10 mins prior to the start for a sound check. The moderator/helper will turn on your camera and give you the ability to use your microphone when it is your turn to present. You will be given 15 minutes (or 25 to 35 for keynote talks) for your presentation and then 5 additional minutes will be allotted for any questions from the audience. Attendees will ask the questions via chat or by raising their hands but the moderator/helper will choose which questions to ask of you and will ask you orally. You do not need to monitor the Chat or hands raised during your presentation.

Zoom Security: Distribution of the Zoom meeting links are restricted to those who have registered for the conference and agreed to abide by the Code of Conduct, but it for any reason you feel uncomfortable by actions of any of the room attendees via Chat, contact the moderator/helper or IGCP 653/735 representative for your session. They can immediately remove this person from the room.

Technical recommendations for Zoom:

- We suggest the desktop client or mobile app, which use less bandwidth than Zoom in your browser. See Zoom help for more: https://bit.ly/2RM0rzQ.
- Hardwire internet connection to computer to avoid possible wifi interruptions.
- The best way for people to hear you clearly is through a wired or wireless headset with a microphone. Even the old white iPhone headphones are better than speaking into the computer mic. Do not use phone speaker mode.
- If on laptop, have it plugged into the power adaptor and not running on battery.
- When presenting, please close out all other programs on the computer except for Zoom and your presentation (if sharing your screen) to prevent any background noise, notification popups, etc.
- If you get disconnected – Don't panic! and return to the room as soon as possible.
- We encourage you to upload a picture to your Zoom Profile. This will show in case your camera is off.
- You can edit your name and affiliation and add pronouns to your Zoom name.
- Make sure your Zoom computer client is up to date. Zoom regularly introduced updates which sometimes require you to update before logging in if you are using an older version of the software (https://support.zoom.us/hc/en-us/articles/201362233-Upgrade-update-to-the-latest-version)
- Keep your computer on a solid surface to avoid camera movement.
- Dress and act professionally as though it were an in person meeting.

Video recommendations if you'll be on camera:

- For the practice run-through, set up in the same location where you'll be doing the session from so you can see what the video will look like and can make adjustments if needed.
- The light in the room should be shining towards your face and not coming from behind you. Try to face a window or light so your face is well lit.
- People generally look better on screen when the camera is eye level or slightly above - if you're on a laptop this may mean putting the laptop on a box or a stack of large books.
- Be aware that both you and anything in your background will be visible to the public!!!
- Mute your microphone when you are not speaking.

Practice:

- Try out every feature that you will be using and make sure you're comfortable with it. Practice what you'll be doing in the meeting to make sure transitions are smooth.
- Please use the same phone, computer and internet connection that you will for the actual event when you are testing.

Additional misc. recommendations for speakers:

- Verbally describe important images or figures.
- Avoid overuse of pronouns such as this/that/here, use descriptive language instead.
- Take your time speaking, don't rush through your slides.
- Consider adding closed captions to your presentation. Google Slides can produce automatic captions: https://support.google.com/docs/answer/9109474?hl=en as can PowerPoint: https://support.microsoft.com/en-us/office/present-with-real-time-automatic-captions-or-subtitles-in-powerpoint-68d20e49-aec3-456a-939d-34a79e8ddd5f

CODE OF CONDUCT

(in accord with the Paleontological Society's Code of Conduct and adopted from guidelines for a Paleontological Society workshop at GSA, 2019)

This meeting follows the Policy on Non-Discrimination and Member Code of Conduct adopted by the Paleontological Society (PS). In accordance with this program, here at the Lille IGCP 653 and 735 annual meeting, we are committed to the following guidelines.

Examples of Good Behavior:
• Use welcoming and inclusive language
• Be respectful of different viewpoints and experiences
• Gracefully accept constructive criticism
• Focus on what is best for the community
• Show courtesy and respect towards other meeting/workshop attendants, irrespective of seniority or background

Example of Unacceptable Behavior:
• Written (e.g., in the Zoom chat) or verbal comments which have the effect of excluding people on the basis of membership of any specific group
• Causing someone to fear for their safety, such as through stalking, following, or intimidation
• Violent threats or language directed against another person
• The display of sexual or violent images
• Unwelcome sexual attention
• Sustained disruption of talks, events or communications
• Insults or put downs, overly aggressive questioning
• Sexist, racist, homophobic, transphobic, ableist, or exclusionary jokes or comments
• Excessive swearing
• Incitement to violence, suicide, or self-harm
• Continuing to initiate interaction (including photography or recording) with someone after being asked to stop
• Publication of private communication without consent
• Sharing of conference videos or pictures of conference videos without the consent of the presenter

Consequences of Unacceptable Behavior: Participants who are asked to stop any inappropriate behavior are expected to comply immediately. If a participant engages in behavior that violates this meeting Code of Conduct, the organizers may intervene by:
• Skipping ahead or interrupting broadcasting of a presentation video
• Interrupt a question or answer and move to the next question or speaker
• Warn the offender
• Ask the offender to leave Zoom
• Engage the Paleontological Society Ethics Committee to investigate the Code of Conduct violation and impose appropriate sanctions

[Some text based on the *The Carpentries Code of Conduct (CC-BY)*, found at (https://docs.carpentries.org/topic_folders/policies/code-of-conduct.html

GUIDE TO TIME CONVERSIONS

Lille, Berlin, Brussels, Cape Town, Copenhagen, Madrid, Paris, Prague, Roma	**(+1h00)** Beirut, Moscow, St Petersburg, Tallinn	**(+2h30)** Tehran	**(+3h30)** New Dehli	**(+5h00)** Bangkok, Novosibirs k	**(+6h00)** Beijing, Kuala Lumpur, Nanjing, Perth	**(+7h00)** Seoul, Tokyo	**(+8h00)** Sidney
8h00	9h00	10h30	11h30	13h00	14h00	15h00	16h00
9h00	10h00	11h30	12h30	14h00	15h00	16h00	17h00
10h00	11h00	12h30	13h30	15h00	16h00	17h00	18h00
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Lille, Berlin, Brussels, Cape Town, Copenhagen, Madrid, Paris, Prague, Roma	**(-1h00)** Lisbon, London, Marrakesh	**(-5h00)** Buenos Aires, Rio de Janeiro	**(-6h00)** Montreal, New York, Ottawa	**(-7h00)** Bogotá, Chicago, Dallas, Mexico	**(-9h00)** Phoenix, San Francisco
8h00	7h00	3h00	2h00	1h00	23h00
9h00	8h00	4h00	3h00	2h00	00h00
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19h00	18h00	14h00	13h00	12h00	10h00
20h00	19h00	15h00	14h00	13h00	11h00
21h00	20h00	16h00	15h00	14h00	12h00

PROGRAMME

Monday, September 13th

Session 1	Chair : Thomas SERVAIS	
Time (Paris)	Speaker	Title
12h00	**Welcome and Opening Ceremony**	
12h30	**Keynote**: **Farid Saleh**	Fossil preservation in the Fezouata Shale with implications in understanding the early stages of the Ordovician Radiation
13h00	**Lukáš Laibl**, Cécile Bourquin & Francesc Pérez-Peris	Babies from the Fezouata Shale: insight into trilobite development during Ordovician Radiation
13h20	**Lucy A. Muir**, Joseph P. Botting, Sebastian Willman & Yuandong Zhang	Soft tissue in Ordovician graptolites
13h40	**David A.T. Harper**, Borja Cascales-Miñana & Thomas Servais	Biodiversity of marine faunas during the Ordovician radiations: a critical assessment of the data sources
14h00	Break	

Session 2	Chair : Yuandong ZHANG	
Time (Paris)	Speaker	Title
14h30	**Keynote**: **Junxuan Fan** & Yiying Deng	The rising and falling of the Ordovician marine life: a high-resolution perspective from South China
15h10	**Taniel Danelian** & Claude Monnet	Early Paleozoic radiolarian microzooplankton diversity dynamics with special focus on Ordovician events: patterns, significance and limitations
15h30	**Lars E. Holmer**, Zhifei Zhang & Yue Liang	Life habits of Ordovician infaunal lingulids – A Baltic perspective
15h50	**Ana Mestre** & Susana Heredia	Relation between the *Periodon-Paroistodus* biofacies and change in redox conditions: a case of study in Darriwilian uppermost beds of the San Juan Formation, Precordillera Argentina
15h55	**Jessica C. Gómez**, Mercedes Di Pasquo & Silvio H. Peralta	Late Ordovician palynomorphs from the basal strata of the La Chilca Formation, Central Precordillera, Argentina
16h00	**G. Susana De La Puente**, Ricardo A. Astini	New Ordovician chitinozoans from the Central Andean Basin, Argentina
16h05	**E. Kristal Rueda** & Guillermo L. Albanesi	Diversity analysis of middle Floian conodonts from Precordillera and Cordillera Oriental, Argentina
16h10	**Business Meeting of IGCP 653**	
16h30	break	

Session 3	Chair : Olga OBUT	
Time (Paris)	Speaker	Title
17h00	**Keynote**: **Andrei V. Dronov**	Ordovician of Russia
17h40	**Sergei V. Rozhnov**	Morphological background of the Ordovician radiation in pelmatozoan echinoderms
18h00	**Miloš Radonjić**	The Ordovician of Serbia
18h20	**Aija V. Zāns** & Andrej Spiridonov	Evolution and diversity of Late Ordovician brachiopods in the Latvian shallow sea shelf
18h40	**Olle Hints**, Leho Ainsaar, Aivo Lepland, Peep Männik, Tõnu Meidla, Jaak Nõlvak & Sigitas Radzevičius	Latest Ordovician to early Silurian integrated bio- and chemostratigraphy in northern Lithuania, central East Baltic

Tuesday, September 14th

Session 4	Chair : Alycia STIGALL	
Time (Paris)	Speaker	Title
14h00	**Opening**	
14h10	**Keynote**: **Daniel Goldman**, Peter M. Sadler & Stephen A. Leslie	The Ordovician timescale, 2020
14h40	**Alycia L. Stigall**	A review of the Late Ordovician (Katian) Richmondian Invasion of eastern Laurentia
15h00	**Nevin P. Kozik**, Mu Liu, Emma U. Hammarlund, David P.G. Bond, Theodore R. Them II, Sean M. Newby, Jeremy D. Owens & Seth A. Young	High frequency fluctuations in marine oxygen associated with the Late Ordovician mass extinction
15h20	**Achim D. Herrmann**, John T. Haynes, Juan Carlos Guerrero, Peter D. Clift, Keith E. Goggin & Richard Robinet	Testing tectonic hypotheses of the southern part of the Taconic Orogen through a provenance study of Upper Ordovician sandstones
15h40	**Business Meeting of ISOS**	
16h00	Break	

Session 5	Chair : Mansoureh GHOBADIPOUR	
Time (Paris)	Speaker	Title
16h30	**Keynote**: **Luis A. Buatois** & M. Gabriela Mángano	Early Paleozoic biogenic reworking: Assessing infaunal ecospace colonization, ecosystem engineering and environmental expansion
17h10	**Ursula Toom**, Mare Isakar, Olev Vinn & Olle Hints	Links between bioerosion and oversized benthic fossils: insights from the Upper Ordovician of Estonia, Baltica
17h30	**Ian J. Forsythe** & Alycia L. Stigall	Quantifying community ecological change during the Clarksville Phase of the Richmondian Invasion
17h50	**Ceara K.Q. Purcell** & Alycia L. Stigall	Exploring feedback loops among ecological niche evolution, dispersal, and speciation using Late Ordovician brachiopods of eastern Laurentia

18h10	**Cintia Kaufmann** & Laura Inés León	The ichnogenus *Balanoglossites* Mägdefrau 1932 from San Juan Formation (Middle Ordovician), Central Precordillera, Argentina
18h15	**Olev Vinn**, Andrej Ernst, Mark A. Wilson & Ursula Toom	New bioclaustration in trepostome bryozoans from the Late Ordovician (Sandbian) of Estonia
18h20	**Nexxys C. Herrera Sánchez** & Blanca A. Toro	Updated biostratigraphic approach based on key graptolites from the Huancar section, eastern Puna of Argentina
18h25	**Ana Mestre**, Florencia Moreno & Susana Heredia	The GOBE record in the Ordovician San Juan Formation: a new perspective of this global event in the Precordillera
18h30	Break	

Session 6	**Chair : Oive TINN**	
Time (Paris)	Speaker	Title
19h00	**Keynote**: **Beatriz Waisfeld**	The Ordovician of Argentina
19h40	**Jessica C. Gómez**, Jaime Reyes-Abril, Juan Carlos Gutiérrez-Marco & Jean-François Buoncristiani	First possible record of the Hirnantian glaciation in the Caparo region, Venezuelan Andes
20h00	**Carolina Zabini**, Matheus Denezine, Lívia Cardoso da Silva Rodrigues, Lívio Reily de Oliveira Goncalves, Rodrigo R. Adôrno, Dermeval Do Carmo, Mário L. Assine	Taphonomy and record of Ordovician invertebrates in Paraná Basin, Brazil: new findings
20h20	**Christian M. Ø. Rasmussen**, Nicolas Thibault, Svend Stouge, Mikael Calner, Jan A. Rasmussen, Anders Lindskog, Heikki Bauert, Matthias Sinnesael, Oluwaseun Edward, Gabriella Bagnoli, Marie-Louise Siggaard-Andersen, Rongchang Wu, Garmen Bauert, Clemens V. Ullmann, Christoph Korte, Niels Schovsbo & Arne T. Nielsen	A temporal framework for the Mid–early Late Ordovician of Baltica
20h40	**Colin D. Sproat** & Jessica S.A. McLeod	The evolution of early *Zygospira,* one of the earliest spire-bearing brachiopods in North America

Wednesday, September 15th

Session 7	Chair : Wenhui WANG	
Time (Paris)	Speaker	Title
10h00	**Opening**	
10h10	**Keynote**: **Matthias Sinnesael**	Ordovician cyclostratigraphy and astrochronology: a synthesis
10h40	**Petra Tonarová**, Stanislava Vodrážková, Pavel Čáp, Olle Hints, Jaak Nõlvak & Michal Kubajko	Discovery of rich Katian-Hirnantian jawed polychaete fauna from the Prague Basin, Czech Republic
11h00	**Ravi S. Chaubey**, Birendra P. Singh, O.N. Bhargava, S.K. Prasad	Takche Formation (Ordovician-Early Silurian) of Spiti region: litho-microfacies and sequence stratigraphic framework
11h20	**Juwan Jeon**, Kun Liang, Stephen Kershaw, Guangxu Wang, Shenyang Yu, Yue Li & Yuandong Zhang	Stromatoporoids from the uppermost Hirnantian Shiqian Formation of South China and their implications for stromatoporoid faunal recovery
11h40	**Se Hyun Cho**, Byung-Su Lee & Suk-Joo Choh	Pattern and timing of Middle Ordovician re-inundation of North China Platform: integration of facies analysis and conodont biostratigraphy
12h00	Break	

Session 8	Chair : David A.T. HARPER	
Time (Paris)	Speaker	Title
12h30	**Emma M. Dunne**, Nussaïbah B. Raja, Aviwe Matiwane, Tasnuva Ming Khan, Paulina S. Nätscher, Aline M. Ghilardi & Devapriya Chattopadhyay	Colonial history and global economics distort our understanding of deep-time biodiversity
13h10	**Minghao Du**, Haifeng Li & Wenhui Wang	Early part of Paleozoic biodiversity — bias or signal?
13h30	**Qi-jian Li**, Lin Na, Yan-sen Chen & Ming-hang Zhu	The Geobiodiversity Database: a new tech team and novel perspectives
13h50	**Pénélope Claisse** & Allison C. Daley	Diversity of radiodont frontal appendages from the Fezouata Shale
13h55	**Sofia Pereira**, Juan Carlos Gutiérrez-Marco & Isabel Rábano	The first Iberian cyclopygid trilobites: an unexpected record from the 'shallow' peri-Gondwana
14h00	**Maria Gabriela Suarez** & Jorge Esteve	Trilobite enrollment evolution and morphological diversification as a GOBE consequence
14h05	**James R. Thomka** & Parker J. Leclair	Rhythmic bedding and potential parasequences in peritidal-shallow subtidal facies of the Ordovician (Sandbian) Crown Point Formation of northeastern New York state, USA
14h10	**Business Meeting of IGCP 735**	
14h30	Break	

Session 9	**Chair : Khadija EL HARIRI**	
Time (Paris)	Speaker	Title
15h00	**Keynote**: **Mansoureh Ghobadi Pour**	Advances in the Ordovician studies of the Middle East and Central Asia
15h40	**Mohammad Ghavidel-Syooki**	Peri-Gondwanan acritarchs and chitinozoans, from Ordovician succession in the Alborz Mountain Ranges, northern Iran: Regional stratigraphic significance and paleogeographic implications
16h00	**Berkin Oktay** & Işıl Akyûz	Preliminary palynofacies analysis results of two boreholes drilled through the Upper Ordovician (potentially Hirnantian) sequences, southeastern Turkey
16h20	**Navid Navidi-Izad** & Hossein Hashemi	Revision of selected morphotypes of Ordovician acritarchs from northeastern Iran
16h25	**Narima K. Ospanova**	Brief information about the Ordovician deposits of Tajikistan
16h30	**Gustavo G. Voldman**, Farzad Poursalehi, Ali Bahrami, María J. Salas & Hamed Ameri	Ordovician conodonts and ostracods from the Katkoyeh Formation at the Banestan Section, Kerman Province of East-Central Iran
16h35	**J. Carlorosi**, A. Mestre & S. Heredia	Dispersal pattern of the genus *Condorodus* in the Lower and Middle Ordovician of the Western of Gondwana
16h40	**Lívia C. S. Rodrigues**, Dermeval Do Carmo, Mário L. Assine & Philippe Steemans	Palynology of the Ordovician-Silurian boundary, Paraná Basin: glacial / post-glacial transition
16h45	**Presentation of IGCP 668**	

Thursday, September 16th

Session 10	**Chair : Lena RAEVSKAYA**	
Time (Paris)	Speaker	Title
08h00	**Keynote**: **Ian Percival**, Yong-Yi Zhen & Leon Normore	The Ordovician System in Australia – an overview of scientific research over the past decade
08h40	**Kyi Pyar Aung**	Occurrence of the *Hirnantia* Fauna from Shan Plateau, Sibumasu Block and its paleogeographic implication
09h00	**Xiang Fang**, Yong Yi Zhen, Clive Burrett, Wenjie Li, Shenyang Yu, Zhongyang Chen, Xuejin Wu, Chao Li & Yuandong Zhang	Ordovician palaeontology and stratigraphy of Xizang (Tibet): recent expeditions and preliminary results
09h20	**Jeong-Hyun Lee,** Se Hyun Cho, Suk-Joo Choh, Jongsun Hong, Byung-Su Lee, Dong-Chan Lee, Dong-Jin Lee, Seung-bae Lee, Jino Park & Jusun Woo	The Ordovician of the Korean Peninsula: A synthesis
09h40	**Ming Li**, Pengju Liu & Petr Kraft	New isolated specimens of *Psigraptus* from Northeast China illustrating the proximal development

09h45	**Shijia Gao** & Wenhui Wang	*Jiangxigraptus* Yu and Fang 1966 from the Upper Ordovician of South China
09h50	**Mo Huang**, Ming Li & Liting Deng	Hirnantian and Rhuddanian graptolite fauna from Yiyang, Hunan, South China
09h55	**Hadi Jahangir** & Mansoureh Ghobadi Pour	First report on the presence of the *Baltoniodus triangularis* Conodont Zone and position of the lower Dapingian Stage boundary in Iran
10h00	Break	

Session 11	**Chair : Yves CANDELA**	
Time (Paris)	Speaker	Title
10h30	**Keynote**: **Alexandre Pohl**, Elise Nardin, Thijs R.A. Vandenbroucke & Yannick Donnadieu	The Ordovician ocean circulation: a modern synthesis based on data and models
11h10	**J. Javier Álvaro**, Lars E. Holmer, Yanan Shen, Leonid E. Popov, Mansoureh Ghobadi Pour, Zhifei Zhang, Zhiliang Zhang, Per Ahlberg, Heikki Bauert & Laura González-Acebrón	Hydrothermal and fracturing processes associated with the Miaolingian/Furongian and Furongian/Tremadocian contact unconformities in the island of Öland, Sweden
11h30	Sofia Pereira, **Jorge Colmenar**, Jan Mortier, Jan Vanmeirhaeghe, Jacques Verniers, Petr Štorch, David A.T. Harper & Juan Carlos Gutiérrez-Marco	*Hirnantia* Fauna from the Condroz Inlier, Belgium: another case of a relict Ordovician shelly fauna in the Silurian?
11h50	**Petr Kraft** & Jaroslav Kraft	Dendroid graptolites of the Prague Basin during the GOBE
12h10	**Hadi Jahangir**, Abbas Ghaderi, Bahareh Shekofteh & Mohammad Nejad-Abbas	The first record of the Floian (Early Ordovician) conodonts in the East-Central Iran (Kalmard Block)
12h15	**Yong Wang**, Jingqiang Tan & Wenhui Wang	Short- and long-term climate change driven by volcanism at the end-Ordovician in South China
12h20	**Andrei V. Dronov**, Alexander V. Timokhin, Taras Gonta, Tatiana Tolmacheva & Olga Maslova	New data on the Ordovician succession at Moyero River, Siberia
12h25	**Olga T. Obut** & Dmitry A. Pecherichenko	Progress in study of Upper Ordovician radiolarians from the western part of the Altai-Sayan Folded Area
12h30	Break	

Session 12	Chair : Bertrand LEFEBVRE	
Time (Paris)	Speaker	Title
13h00	**Martina Nohejlová** & Aaron W. Hunter	Exceptional preserved starfish bed from the Upper Ordovician of the Barrandian area
13h20	**Benjamin F. Dattilo**, Rebecca L. Freeman, Michael Harrison, David L. Meyer & James Thomka	Overlooked exceptional crinoid preservation: "Phosphatized" Ordovician versus modern stereom microstructure
13h40	Marco Vecoli, **Paul Strother**, Christian Cesari & Charles Wellman	Hirnantian freshwater palynomorphs from Saudi Arabia: phylogenetics and paleoecology
14h00	**Keynote**: **Christopher R. Scotese**	Atlas of the Ordovician World
14h40	**Closing ceremony** **Presentation of workshop, Lyon 2021** **Presentation of IGCP regional meeting, Lille 2022**	

ABSTRACTS

Hydrothermal and fracturing processes associated with the Miaolingian/Furongian and Furongian/Tremadocian contact unconformities in the island of Öland, Sweden

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Abstract

In the island of Öland, the Miaolingian-Tremadocian Alum Shale Formation shows a south-north-trending thinning from 24 m at the southern edge to its complete disappearance at the northern edge of the island. The formation contains several significant episodes of erosion, condensation and non-deposition marked by limestone and conglomeratic interbeds. Two distinct paraconformities are recognized, marking the Miaolingian/Furongian (close to Äleklinta and Bruddesta towns) and Furongian/Tremadocian (Degerhamn town) contacts, and involving gaps that include the whole Paibian Stage and the upper part of Cambrian Stage 10, respectively. They represent synsedimentary extensional fault pulses, which favoured the episodic development of basement reworking (Exporrecta Conglomerate Bed) and shelly carbonate production on palaeohighs (Kakeled Limestone Bed), surrounded by deposition of kerogenous black shales. Both events also point to episodes of active hydrothermal vents in the semi-enclosed Baltoscandian Basin, whose polymetallic (Fe-Pb-Cu) exhalites are sealed by decimetre- to metre-scale ikaite-aragonite mounds, now recrystallized to calcite and vaterite. The mounds include phosphatized arthropod and microbial remains (Örsten Lagerstätte) that reflect the contemporaneous record of hydrothermally related cyanobacterial blooms. Boreholes drilled on Öland have reached the Precambrian Transscandinavian Igneous Belt (TIB) basement (*c.* 1.85 to 1.67 Ga) at depths ranging from 160 to 200 m, so the fracturing and fissuring processes associated with the Miaolingian/Furongian and Furongian/Tremadocian contact unconformities would have involved serpentinization and metallic removal from the TIB. The association of polymetallic ore deposits encrusted by hydrothermally induced carbonate precipitates reflects extremely hot (black) to warm (white smokers) gradations, as a result of chemical-rich clear vent fluids coming into contact with cold seawater.

Keywords: paraconformity, stratigraphic gap, hydrothermal activity, fissuring, Early Palaeozoic, Baltoscandian Basin

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Occurrence of the *Hirnantia* fauna from Shan Plateau, Sibumasu Block and its paleogeographic implication

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Abstract

Ordovician rocks are widely distributed throughout the eastern Myanmar (Shan Plateau). Among them, the latest Ordovician *Hirnantia* fauna is widespread and well documented in Shan-Kayah Region, part of Sibumasu. The *Hirnantia* fauna comprises nineteen genera from three localities including all assignable to Craniopsida (*Pseudopholidops*), Craniida (*Xenocrania*), Orthotetida (*Fardenia*), Orthida (*Giraldibella, Toxorthis, Dalmanella, Mirorthis, Trucizetina, Kinnella, Hirnantia, Draborthis*), Strophomenida (*Minutomena, Leptaena, Paromalomena, Eostropheodonta, Palaeoleptostrophia, Aegiromena*), Rhynchonellida (*Plectothyrella*), and Athyridida (*Hindella*). This is the third reported occurrence of *Hirnantia* in Myanmar. Referring to Ordovician brachiopod workers, these fauna contrasts with the typical *Hirnantia* fauna and that Sibumasu (Thailand, Shan Plateau-Myanmar, and Western Yunnan) was nearby peri-Gondwanan site during Middle and Late Ordovician.

Keywords: *Hirnantia* fauna, Myanmar, Shan-Kayah Region, Sibumasu

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Early Paleozoic biogenic reworking: Assessing infaunal ecospace colonization, ecosystem engineering and environmental expansion

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Abstract

The role of bioturbation as an evolutionary driver is becoming increasingly recognized. Recent research is providing valuable information on animal-substrate interactions during the Cambrian Explosion and the Great Ordovician Biodiversification Event. In addition to evaluating changes in ichnodiversity and ichnodisparity, part of these efforts are focused on

quantifying ecospace colonization and ecosystem engineering along the depositional profile. An increase in ichnodiversity, ichnodisparity, as well as numbers of modes of life and styles of ecosystem engineering took place during the early Cambrian. This increase is regarded as reflecting the evolutionary breakthroughs associated with the Cambrian Explosion. In comparison, a decrease in most metrics is apparent during the middle to late Cambrian. A more modest increase took place during the Ordovician, reflecting the Great Ordovician Biodiversification Event. Whereas the increase in ichnodiversity and ichnodisparity during the Cambrian Explosion is expressed by bioturbation structures, a wide variety of bioerosion structures were added during the Great Ordovician Biodiversification Event. The trace-fossil record suggests that evolutionary innovations took place first in offshore settings and later expanded landwards into marginal-marine environments and seawards into deep-water environments both during the Great Ordovician Biodiversification Event. An example of the former is illustrated by the progressive colonization of brackish-water estuaries by trilobites, whereas an example of the latter is shown by the establishment of deep-marine trace-fossil assemblages of modern aspect. Innovations in carbonate settings seem to have lagged behind those in siliciclastics, but trace-fossil preservational aspects should be considered. Systematic evaluation of the trace-fossil record within a paleoenvironmental framework indicates that intense reworking of the sediment was attained in fully marine environments during the early Cambrian. Ongoing work suggests that bioturbation was impacted by the Late Ordovician Mass Extinction and that the effects show a latitudinal pattern.

Keywords: Cambrian Explosion, Great Ordovician Biodiversification Event, trace fossils, bioturbation, bioerosion

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Dispersal pattern of the genus *Condorodus* in the Lower and Middle Ordovician of the Western of Gondwana

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Abstract

The genus *Condorodus* was recently erected for the geological provinces of the Eastern Cordillera, Famatina and Precordillera of Argentina (Carlorosi *et al*., 2021). The species of this genus have an apparatus composed by six elements locations identified so far: two carminate P elements, two different tertiopedate Sb elements, one dolabrate Sc and one digyrate Sd. No M or Sa were recovered yet. The differences mainly between the P elements support the recognition of three species: *C. diablensis,* the oldest one, that appear in the upper Floian of Eastern Cordillera*,* *C. gracielae* present in the Eastern Cordillera and Famatina of Lower Dapingian age and the youngest species *C. chilcaensis* occurring in the Darriwilian of the Precordillera. The evolutionary characteristics and the distribution pattern of these species would indicate that *Condorodu*s is originated in the Andean Basin (upper Floian) and that through the Famatina System (Dapingian) it would have migrated to the Precordillera region

(early Darriwilian) suggesting further that there were connections between these three basins through these time intervals. Dispersal data from other fossil groups also show this possible connection between these three basins for the mentioned time interval (Gutierrez Marco and Villas, 2007; Benedetto, 2018).

Besides, the morphological features and environmental preferences suggest that late representatives of this genus may have dispersed from western Gondwana to other regions of Gondwana, Perigondwana and Laurentia during the late Darriwilian, and probably they gave rise to conodont apparatuses of similar morphology in the Middle–Upper Ordovician such as *Plectodina, Bryantodina,* and *Yaoxianognathus.*

Keywords: *Condorodus*, Ordovician, dispersal, Gondwana

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Takche Formation (Ordovician–Early Silurian) of Spiti region: litho-microfacies and sequence stratigraphic framework

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Abstract

Litho-microfacies and sequence stratigraphic analysis of the Takche Formation (Ordovician–Silurian) in the Pin valley, Spiti region, Himalaya, leads to the identification of ten lithofacies i.e. siltstone-sandstone facies, sandy-limestone Facies A, sandy-limestone Facies B, sandy-limestone Facies C, sandy-limestone Facies D, calcareous shale-siltstone facies, fossiliferous limestone facies, nodular/ribbon mudstone facies, bedded sandstone facies and silicified sandstone-siltstone facies. The nine identified microfacies include peloidal grainstone, bioclastic wackestone, bioclastic grain-packstone, argillaceous wackestone, bioclastic packstone, wackestone-packstone, densely packed reef rudstone, bioclastic grainstone, and calcimudstone. Five upward shoaling cycles and three sequences (S1-S3), separated by disconformity surfaces (U1-U3), developed due to submarine erosion or rapid fall in relative sea-levels. The distribution patterns of microfacies of the Takche Formation show that the rocks deposited in shallow marine carbonate ramp setting.

Keywords: Takche Formation, Ordovician–Silurian, Litho-microfacies, Sequence stratigraphy, Pin Valley, Spiti

Pattern and timing of Middle Ordovician re-inundation of North China Platform: integration of facies analysis and conodont biostratigraphy

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Abstract

Ordovician strata of North China Platform contain late Floian–early Darriwilian platform wide hiatus. Even though conodont biostratigraphy established the *Histiodella holodentata-Tangshanodus tangshanensis* Biozone above the hiatus in all regions of North China Platform, it is difficult to precisely constrain the timing of epeiric platform inundation following the platform wide hiatus, because a barren zone up to several tens of meters thick is present between the hiatus and the early Darriwilian biozone. The study of the basal and lower members of Makgol Formation, Taebaeksan Basin, Korea, located at the eastern margin of North China Platform highlights the relationship between the barren zone and sedimentology and the need for interdisciplinary approach to resolve the issue.

The conodont biozonation of the Makgol Formation is very similar to other regions of North China Platform. Below the hiatus, the 54 m thick basal member contains *Serratognathus bilobatus*, *S. extensus*, and *Paraserratognathus obesus* biozones, indicating early to middle Floian. The lowermost 17 m interval of the lower member above the hiatus do not yield virtually any conodont and designated as the barren zone, followed by *Tangshanodus tangshanensis* Biozone in the middle to upper part of the lower member.

The lower member is comprised of six facies including laminite, caliche, carbonate breccia, massive to bioturbated lime mudstone, bioclastic wackestone, and peloid-bioclast packstone to grainstone. Their vertical superposition constitutes peritidal and subtidal meter-scale cycles. The lower part of the lower member designated as the barren zone consists only of the peritidal cycles, whereas the subtidal cycles mainly occur in middle to upper part of the member, defined by *T. tangshanensis* Biozone, indicating that conodont distributions are directly related to the depositional environment.

It is suggested that in order to fully resolve the temporal constraint of the re-inundation of North China Platform, integrated approach of the barren zone by facies analysis and conodont biostratigraphy as well as chemostratigraphic method such as Sr stable isotope is needed across the platform because the timing and depositional conditions might vary region by region.

Keywords: Early-Middle Ordovician hiatus, conodont barren zone, facies analysis

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Diversity of radiodont frontal appendages from the Fezouata Shale

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Abstract

Radiodonta is an extinct group of Paleozoic stem-euarthropods, with a body composed of pairs of swimming flaps, and a head bearing an oral cone and a pair of frontal appendages. These animals are distributed globally, from North America, to Eurasia, and Australia. Specimens from all these deposits represent a big diversity of ecologies comprising apex predators, suspension feeders and sediment sifters. The most diverse and abundant radiodont fossils are Cambrian in age. In 2015, the first Ordovician radiodont was described: the two-meter-long suspension feeder *Aegirocassis benmoulai*. This species is known from the Early Ordovician, Fezouata Shale. It is currently the only radiodont from the Fezouata Shale, although other material was mentioned. This work focused on new radiodont remains from this deposit. A total of 8 individuals from the Yale Peabody Museum and the Musée cantonal de Géologie de Lausanne collections were considered. The description is based on frontal appendages only, as it is the most sclerotized body part, and thus, the best preserved part. This study led to a distinction into two genera: *Peytoia* and *Hurdia*. The *Peytoia* morph is unique, and differs from previously described species. Within *Hurdia*, one specimen can be attributed to *H. victoria* or *H. triangulata*, while the other is a new species.

This work thus increases the temporal and geographical range of these genera, previously known mainly in the Laurasian Cambrian.

Keywords: Fezouata, Radiodonta, taxonomy

Early Paleozoic radiolarian microzooplankton diversity dynamics with special focus on Ordovician events: patterns, significance and limitations

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Abstract

We have produced a new and exhaustive sample-based dataset of middle Cambrian to Silurian radiolarian occurrences in order to investigate the diversity patterns of all Early Paleozoic radiolarian species, to find out trends in their taxonomic evolution and to evaluate possible biases influencing these patterns. We have also reviewed the long term radiolarian biotic changes in the context of the Great Ordovician Biodiversification Event (GOBE) and all associated global changes that affected the Earth system at the time.

The Cambrian–Ordovician interval is characterized by a protracted trend of radiolarian diversification peaking in the Darriwilian. This rising trend is produced initially, during the Tremadocian, by Archaeospicularian radiolarians; it may be partly correlated with the basal Ordovician "plankton revolution". The subsequent radiolarian diversity increase during the Early-Middle Ordovician is mainly due to Spumellarian and Entactinarian radiolarians; the Darriwilian peak is the highest for the entire studied interval; it reflects a profound turnover in Ordovician radiolarian plankton assemblages. The Darriwilian appears thus to be a "game changing" interval for radiolarians; it may be explained by the profound oceanographic changes that followed the early Darriwilian cooling trend of Earth's climate. The transition with the Silurian is separated and highlighted by a late Ordovician large drop in diversity, which records the lowest taxonomic richness of the studied interval.

Our results suggest that radiolarian microzooplankton have responded during all the major diversity events of the marine biosphere recognized for the GOBE. However, although the long-term trends in radiolarian biodiversity are robust, the documented patterns remain partly and locally biased by uneven sampling through space and time.

Keywords: Radiolaria, microzooplankton, biodiversity dynamics, Early Paleozoic, Ordovician

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Overlooked exceptional crinoid preservation: "phosphatized" Ordovician versus Modern stereom microstructure

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Abstract

Echinoderm ossicles are ubiquitous sedimentary components of Phanerozoic shelf carbonates, although these disarticulated elements are rarely considered valuable for understanding echinoderm biology. However, echinoderm microstructure reflects interpenetration by soft tissue, therefore disarticulated ossicles may illuminate distribution of connective tissue in extinct echinoderms. Growth of syntaxial calcite cement obscures stereomic microstructure, but deposition of phosphate (calcium fluorapatite, CFA) and other diagenetic minerals may more faithfully preserve primary microstructure signals.

To investigate the role of diagenetic minerals in preserving this microstructure, we compared thin sections of "phosphatized" Ordovician (Katian) crinoids from the Cincinnati, Ohio, USA

area to those of the modern isocrinid *Endoxocrinus* from the Florida Straits. The “phosphatization” process begins as CFA coats the internal surfaces of the stereom, eventually infilling empty space within stereom as tissues decay. This process produces a potential mechanism for detailed analyses of this aspect of echinoderm morphology.

Both species bear five petals in their articular facets and have galleried stereom. We compared the stereom in these petals between the two species by generating plastic molds of *Endoxocrinus* to compare with natural phosphatic molds of *Cincinnaticrinus*. From these we generated 3D models, which, when inverted, reproduce the original calcitic microstructure.

The models show that the calcitic components of each structure are comparable, with longitudinally-oriented subcircular tunnels in each that pass through screen layers of stereomic calcite. However, the structure of *Endoxocrinus* is almost perfectly rectilinear, with the tunnels arranged in square grids, while the tunnels in *Cincinnaticrinus* are more or less evenly spaced, but do not appear to be organized in a pattern in the transverse view. *Endoxocrinus* also differs in that the screen layers are minimally mineralized and can be described as reticular, whereas the screen layers in *Cincinnaticrinus* are relatively thick and fully mineralized to the point that the tunnels appear to be “cut out” of them; they are clearly perforate. Measurements of model volumes suggest that while the petal stereom volume is approximately 25% calcite in *Endoxocrinus*, it is about 50% in *Cincinnaticrinus*.

This comparison demonstrates that the two species are remarkably similar in their internal structure despite their taxonomic and temporal separation. An understanding of how CFA precipitation produces micromolds allows accurate reconstruction of extinct echinoderm microstructure and soft tissue morphology.

Keywords: phosphate, crinoid, echinoderm, isocrinid

New Ordovician chitinozoans from the Central Andean Basin, Argentina

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Abstract

New micropaleontological data from eastern-most localities (Santa Ana and Caspalá) in the Cordillera Oriental of Argentina are herein examined. The Ordovician strata in these localities exceed 500 m thick and constitute one of the most complete lower Palaeozoic sections within the Central Andean Basin of South America. The chitinozoan record from the lowest to the uppermost Ordovician strata in the Santa Ana and Caspalá areas is shown. The Ordovician siliciclastic succession includes: 1) a dark gray massive shally-interval, 2) a thick sandy-rich rhythmic shelfal and shallow-marine interval, 3) a purple-reddish, possibly fluvio-estuarine interval, 4) a greenish thoroughly bioturbated transgressive package, and 5) a glacially related

massive and thin-bedded diamictites. The chitinozoan association recovered from the dark gray interval contains *Euconochitina paschaensis* and *Lagenochitina* sp. cf. *longiformis*. A late Tremadocian age is suggested by the chitinozoan association, supported by the records of the *Araneograptus murrayi* and *Hunnegraptus copiosus* graptolite zones and the lower part of the *Acodus deltatus-Paroistodus proteus* conodont Zone. The above rhythmic olive to grayish-green sequence contains short forms of *Eremochitina* sp. and *Velatachitina* sp. The last two chitinozoan species are also present in the green bioturbated levels above the purple-red interval. *Lagenochitina* sp. cf. *longiformis* and *Desmochitina* sp., interpreted as a reworked material, are also observed in a level of this interval. *Eremochitina brevis*, *Velatachitina veligera* and *Conochitina* spp. characterize the middle-upper part of the succession. The upper part of the greenish package contains, in addition, *Lagenochitina* sp. A. This assemblage indicates a middle to late Floian age. A late Floian age has been also reported in the area according to the record of the *Baltoniodus* cf. *triangularis* conodont Zone. The bioturbated upper part of the studied section is characterized by an early Katian association composed of *Pistillachitina comma*, *Belonechitina* gr. *micracantha*, *Belonechitina robusta*, and long forms of *Belonechitina*. The uppermost rich-chitinozoan level contains a late Katian-early Hirnantian assemblage including *Tanuchitina* sp. cf. *fistulosa*, *Conochitina elegans*, and *Belonechitina* sp. cf. *llangrannogensis*. Within the uppermost glacial interval, thin interbedded shally partitions were barren. Its sharp basal boundary together with its barren nature made indicate a lacustrine or highly restricted origin for this Hirnantian interval. The Ordovician chitinozoan assemblages indicate Northern Gondwana affinities. *B. llangrannogensis* has been only recorded in Avalonia.

Keywords: chitinozoans, stratigraphy, Lower Palaeozoic, Cordillera Oriental, Central Andean Basin, northwestern Argentina

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Ordovician of Russia

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Abstract

On the territory of Russia there are two big Ordovician palaeocontinents (Baltica and Siberia), which are represented by the East European or Russian Platform and the Siberian Platform as well as many other smaller Ordovician blocks and/or microcontinents sometimes of unclear affiliation. The most studied and well known part of Baltica is the Ordovician basin of Baltoscandia the easternmost part of which belongs to Russia. It is a classical area of the Ordovician research. The Ordovician (Lower Silurian at that time) was established in the St.Petersburg region by Sir R. Murchison. Moscow basin on the other hand is known only by boreholes. However, fauna and facies in Moscow basin are not the same as in Baltoscandian basin. It has its own regional scale. Ordovician rocks of Timan-Pechora basin belong to that part of Baltica which collided with the Russian platform in early Cambrian during the Timan orogeny. The Ordovician of Urals is subdivided into Elets and Lemva zones. The Elets zone is characterized by open shelf carbonates, while the Levma zone is a deep water slope or

abyssal facies. On the Southern Urals, Ordovician exotic blocks with trilobites of Gondwanan affinity are known. In terms of facies evolution, the Ordovician of Baltica is closer to the Yangtze platform.

Siberian Platform included several separate Early Paleozoic sedimentary basins. The largest ones were the Irkutsk and Tungus epicontinental basins. Comparative analysis of the Ordovician successions of the Siberian and North American platforms demonstrates a striking similarity in the long-term lithological development. On both platforms, the Ordovician succession starts with tropical stromatolite-bearing carbonates, which abruptly change to siliciclastic deposits and terminate with cool-water carbonates. Numerous K-bentonite beds in the Upper Ordovician of North American and Siberian platforms stress this similarity. Biota of the Siberian Ordovician basins is also close to Laurentia.

The Ordovician of Kara block in the Russian Arctic (Severnaya Zemlya) combines characteristics of Baltica and Siberia. There are also Ordovician volcanic rocks there. The Ordovician of Novosibirsk islands and Chukotka is closer to Siberian platform both in respect of fauna and lithology. Affiliation of the Ordovician blocks in Verhoyansk-Kolyma region on the north East of Russia is much debated. Faunas of those blocks are closer to Siberia, Laurentia and North China. However long-term lithological development of the Omulev Mountains at least demonstrates more similarity with North China Platform. In contrast with Siberia and Laurentia the Upper Ordovician here is represented by warm-water carbonates.

Altai-Sayan region to the south of the Siberian platform is a tectonic collage of many Ordovician blocks. Some of these blocks were rifted from Siberia. The others demonstrate Gondwanan affinity. There are also fragments of volcanic arcs and deep water oceanic floor. The Ordovician of Western Siberia is poorly known only from deep boreholes. In general it reminds the Ordovician of Kazakhstan and Altai-Sayan region.

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Keywords: Ordovician, Russia, facies, biota, sea-level changes

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New data on the Ordovician succession at Moyero River, Siberia

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Abstract

Ordovician outcrops along the Moyero River valley compose one of the most complete and best exposed Ordovician sections on the entire Siberian Platform. However, due to difficulties in accessibility from 1976 till 2013, the section has not been visited by geologists. We visited this section in 2013 and in 2020. Preliminary results of the field work are as follows: 1) the Upper Ordovician (Sandbian-Katian) Dzerom Formation (Chertovskian, Baksian and Dolborian regional stages) is represented by cool-water carbonates. Similar to Mangazea and Dolbor formations on the south-western margin of the Tungus basin the sediments are dominated by intercalation of greenish-grey siltstones and grey bioclastic limestones. Trilobites, brachiopods and ostracods are the most common bioclasts with a significant number of bryozoans, pelmatozoans and mollusks. The most typical and widespread sedimentary structures are indicative of storm-induced sedimentation; 2) Dzerom Formation consists of two depositional sequences. Mangazea sequence corresponds to Chertovskian and Baksian regional stages. Dolbor sequence corresponds to the Dolbor regional stage; 3) despite significant efforts, no K-bentonite beds have been found in the Dzerom Formation. Absence of any traces of volcanic eruptions along the eastern margin (in present day orientation) of the Siberian Platform points to the position of a subduction zone along the western but not the eastern margin of the Siberian palaeocontinent at this time; 4) in the relatively thick (31m) Kirensko-Kudrinian interval of the section, two depositional sequences instead of one previously established on the south-western margin of the Tungus basin have been identified; 5) in the quartz sandstones of the uppermost Kirensko-Kudrinian regional stage (Moyero Formation) abundant well preserved *Cruziana, Rusophycus, Phycodes and Lockea* trace fossils have been found for the first time. These *Cruziana* traces differ markedly from contemporaneous *Cruziana* of the Gondwanan affiliation; 6) massive thick-bedded *Thalassinoides* ichnofabric have been identified in limestone of the Volginian regional stage (lower part of the Moyero Formation). That could be regarded as an independent evidence for a near equatorial position of this part of the Tungus basin in the Darriwilian time; 7) onset of the cool-water condition seems to happen at the end of Vikhorevian time (mid-Darriwilian). At that time oolitic grainstones and stromatolites disappeared and *Angarella-Moyeronia* bioherms appeared in the section; 8) Lower Ordovician warm-water succession of the Moyero River valley turns out to be more complete and thicker than previously suggested.

This is a contribution to the IGCP Projects 653 and 735.

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Keywords: Ordovician, Siberian platform, Moyero reference section

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Early part of Paleozoic biodiversity — bias or signal?

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Abstract

By downloading all Eumetazoa data collected in the early part of Paleozoic (Cambrian and Ordovician) from the Paleobiology Database (PBDB), this study using the time division method with the highest resolution (42 time bins) at present, and analyzed the patterns of global biodiversity, fossil spatial extent (minimum spanning tree, the number of equal area grid cell), and sampling intensity (the number of collection) (Fig. 1). The result shows that although biodiversity, fossil spatial extent, and sampling intensity data have no correlation with marine sedimentary extent data, but the three varieties are well correlated with each other. After removing the influence of sampling intensity, the correlation between biodiversity and fossil spatial extent is significantly weakened. This indicates that sampling intensity not only affects biodiversity pattern, but also influences the fossil spatial extent. Therefore, the impact of fossil spatial extent on biodiversity exhibited by initial researchers, may also represent an artifact caused by the intensity of sampling. This sampling bias exists in all organisms, regardless of deep water organisms and shallow water organisms. At present, global biodiversity curve may be more of a sampling bias than a signal of true biodiversity, and cannot be calculated faithfully. More fossil collection is needed, especially for the intervals with little sampling intensity, to reduce sampling bias.

Keywords: early Paleozoic, biodiversity, sampling bias, spatial extent, Eumetazoa

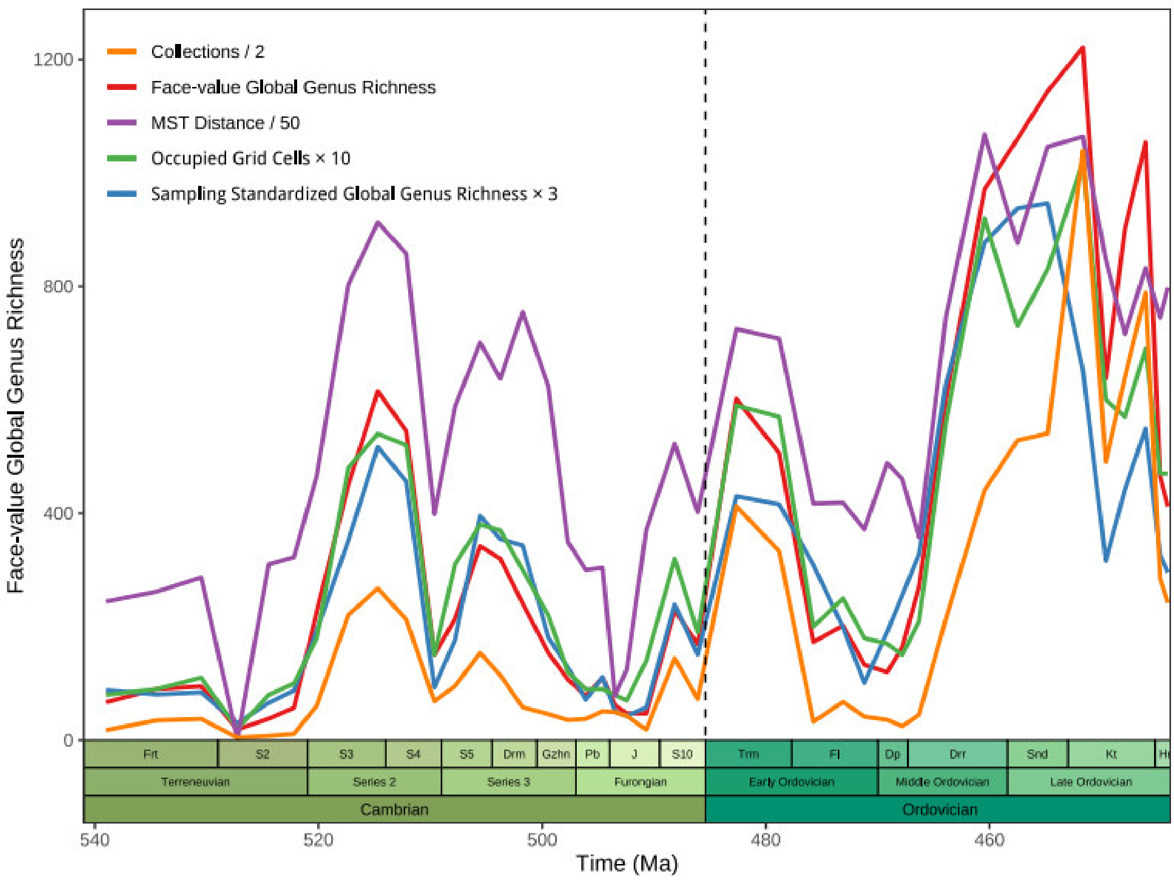

Figure 1. Fossil biodiversity, spatial extent, and sampling intensity of early part of Paleozoic

Colonial history and global economics distort our understanding of deep-time biodiversity

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Abstract

Sampling biases in the fossil record distort estimates of deep-time biodiversity, and much attention in recent decades has been dedicated to documenting and mitigating their effects. However, these biases not only reflect the geological, taphonomic, and spatial aspects of the fossil record, but also the historical and current collation of fossil occurrence data. Examining data recorded in the Paleobiology Database (www.paleobiodb.org) over the last 30 years, we find that the legacy of colonialism and socio-economic factors, such as wealth, education and political stability, impact the global distribution of fossil occurrence data, which palaeobiologists use regularly for estimates of deep-time biodiversity. A global power imbalance persists in palaeontology, with researchers in high or upper middle income countries holding a monopoly over palaeontological knowledge production by contributing to the majority (97%) of fossil occurrence data. As a result, some countries or regions tend to be better sampled than others, ultimately leading to heterogeneous spatial sampling across the globe. These global patterns also illuminate exploitative research practices, or 'parachute science', which threaten the integrity and future of palaeontology. This work illustrates how efforts to mitigate sampling biases to obtain a truly representative view of past biodiversity are not disconnected from the aim of diversifying and decolonising our discipline.

Keywords: palaeobiodiversity, scientific colonialism, research ethics, databases

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The rising and falling of the Ordovician marine life: a high-resolution perspective from South China

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Abstract

The Lower Paleozoic strata witnessed two major biological events: the Great Ordovician Biodiversification Event (GOBE) and Late Ordovician mass extinction (LOME). Many investigations have focused on taxonomic richness patterns during these events, providing insights into their timings and potential causes. However, previous analyses on the long-term biodiversity change were mostly based on coarse temporal resolutions, which cannot give the details of the evolutionary history of life. We use quality-controlled stratigraphic data, parallel computing, quantitative stratigraphic method, and unbinned biodiversity calculation to reconstruct a high-resolution diversity curve of marine invertebrates during the early Palaeozoic. The mean temporal resolution of the new curve is ~21.0 Kyr. This increased resolution clarifies the timing of the known diversification/extinction events. The result showed that the GOBE began in the early Tremadocian and ended at the Dapingian–Darriwilian boundary. During this interval species richness exhibited two major radiation phases, one in the early Tremadocian–middle Floian (the initiating phase of GOBE) and another in the late Floian–earliest Darriwilian (the main pulse of GOBE). The main pulse of GOBE exhibited a rapid species richness increase with elevated origination and extinction rates. Major marine groups showed no significant diachroneity during the GOBE, with most presenting richness peaks in the main pulse of the GOBE. The LOME, which was responsible for ~67% species loss in South China, can be divided into three phases, the Katian extinction, a moderate rebound in the late Katian, and the Hirnantian extinction.

Ordovician palaeontology and stratigraphy of Xizang (Tibet): recent expeditions and preliminary results

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Abstract

Since the 1950s, several comprehensive scientific investigations have been conducted in the Qinghai-Xizang (Tibet) Plateau by the Chinese Academy of Sciences and other institutes. During the expeditions in 2016 and 2021, plentiful Ordovician rocks and specimens have been sampled from the southern and central Xizang area by some of the authors. Accordingly, we review the establishments, divisions and correlations of Ordovician lithostratigraphic and biostratigraphic units in southern and central Xizang, and propose a newly-revised stratigraphic framework. As the dominant and index fossils in the carbonate sediments, abundant Ordovician cephalopods were collected and the faunas varied by regions through the Ordovician. This dynamic variation of regional cephalopod provincialism was affected by the absolute location of these blocks or terranes, and the relative position between them. Furthermore, the Ordovician biostratigraphy and lithostratigraphy of these regions are analysed and precisely correlated with those of South China, North China, Tarim and Australia, aiming to provide a clarified and standard stratigraphic framework for further studies of the Ordovician System in the Qinghai-Xizang Plateau, especially an improved age control for the facies analysis and palaeogeographic reconstructions.

Keywords: Ordovician, Xizang (Tibet), stratigraphy, palaeontology, palaeogeography

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Quantifying community ecological change during the Clarksville Phase of the Richmondian Invasion

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Abstract

This study establishes how biotic communities were impacted by the first successful phase of the Richmondian Invasion. The Richmondian Invasion has been the subject of many past studies in the Cincinnati arch region, which have identified general ecological and evolutionary patterns across the entire invasion interval. However, there were discrete pulses within the larger invasion that have received less attention (e.g. Clarksville Phase), largely due to the temporal constraints of the existing sequence stratigraphic framework. However, a recently published sequence stratigraphic revision provides a framework with which individual invasion pulses can be studied.

The biotic impact of the Clarksville Phase was analyzed using species abundance data collected from the Waynesville Formation, which is comprised of several fourth order sequences. The preinvasion data was collected from the C5B sequence and the post-invasion data was collected from the C5C sequence. Abundance data were collected for a diverse suite of invertebrate taxa using a quadrat sampling method, in which counts were collected from bedding planes. Data were then analyzed using a variety of methods including cluster analysis, detrended correspondence analysis, nonmetric multidimensional scaling, and

seriation. Depth distribution of taxa, richness and evenness, and guild membership were also considered.

Clear changes in patterns of community structure were observed before and after the Clarksville Phase. This analysis improves our understanding of how the Clarksville Phase impacted the niche parameters of native taxa, community composition and structure, alpha diversity, and ecospace utilization. Understanding how this invasion pulse impacted the biota not only improves our understanding of this event but contributes to our broader knowledge of biotic invasions and their impacts on biological communities.

Keywords: paleoecology, gradient ecology, invasive species, community ecology

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Jiangxigraptus Yu and Fang 1966 from the Upper Ordovician of South China

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Abstract

Identification of genus-level Middle to Late Ordovician Dicranograptids with two uniserial, horizontal to reclined rhabdosomes has always been complicated due to their long, torsional rhabdosomes. In recent studies of Chen et al. (2017), a rigorous revision method is proposed, that the species with strong prothecal folds, U-shaped $th1^1$ and $th1^2$, and V-shaped proximal end are transferred from *Dicellograptus* to the genus *Jiangxigraptus*. For the purpose of finding their biostratigraphic implication of *Jiangxigraptus* in the Ordovician of South China, this study sampled a continuous section (Shuangjiangcun section of Qidong County, Hunan Province) in South China across the boundary of the Sandbian and Katian. Based on the graptolite collection, 7 species assigned to one genus are identified, all confined to the Sandbian Stage. Palaeogeographically, *Jiangxigraptus* has been reported throughout the world, including South China and Scandinavia in low latitudes and England in high latitudes under a careful revision work (Fig. 1). An earlier diversification than the typical *Dicellograptus* can be observed worldwide. In some regions, the first appearance datum of *Jiangxigraptus* equals to the base of the *Nemagraptus gracilis* Biozone. *Jiangxigraptus* is thus suggested as an auxiliary tool for the biostratigraphic correlation of the base of Sandbian stage in those regions.

Keywords: *Jiangxigraptus*, Late Ordovician, South China

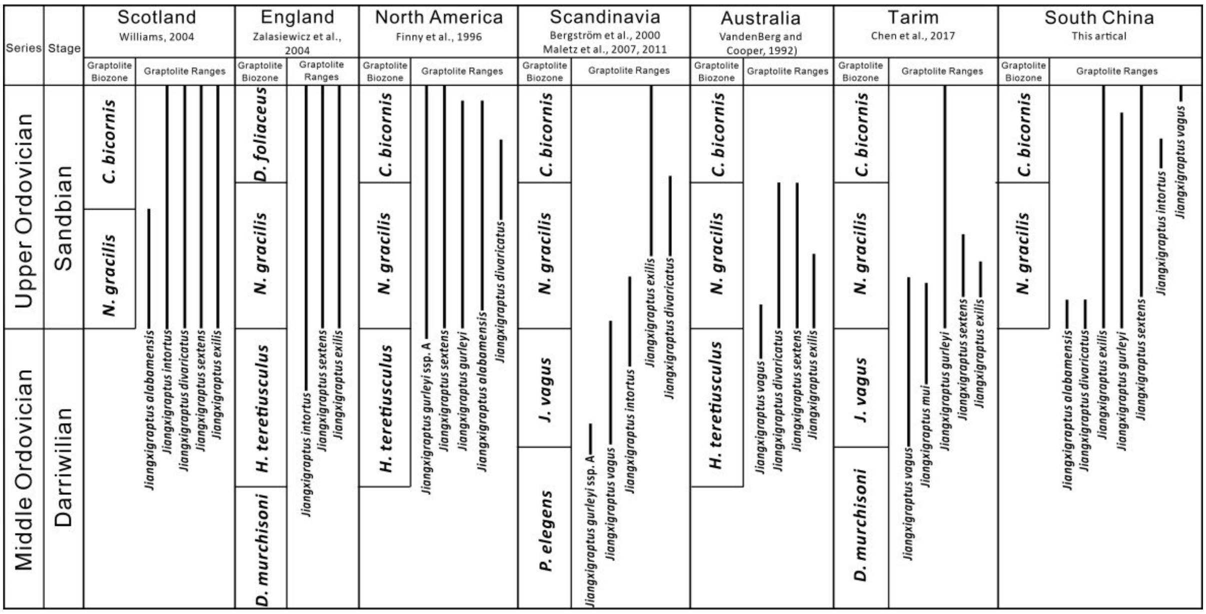

Figure 1. Biostratigraphy of *Jiangxigraptus* around the world (Vandenberg and Cooper, 1992; Finney et al., 1996; Bergström et al., 2000; Williams et al., 2004; Maletz et al., 2007; Zalasiewicz et al., 2009; Maletz et al., 2011; Chen et al., 2017).

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Peri-Gondwanan acritarchs and chitinozoans, from Ordovician succession in the Alborz Mountain Ranges, northern Iran: Regional stratigraphic significance and paleogeographic implications

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Abstract

A total of 1500 surface samples were collected from the Ordovician outcrops of the Alborz Mountains and treated for acritarch and chitinozoan taxa to determine the exact age of Ordovician rock units and paleogeographic position of these mountain ranges. The Alborz Mountains stretches from the border of Azerbaijan along the western and entire southern coast of the Caspian Sea and finally runs northeast and merges into the Aladagh Mountains in the northern parts of Khorasan province. The Alborz Mountains are divided into the Western, Central, and Eastern Alborz Mountains that the Ordovician rock units (e.g. Lashkarak, Abastu, Ghelli, and Abarsaj formations) extend throughout this mountain ranges. The Lashkarak Formation is well-developed in the whole Alborz Mountains, whereas Ghelli, Abastu, Abarsaj formations, and Gorgan Schists have exposure in the southern Caspian Sea and the northern parts of Khorasan province. The study localities consist of the Alam-Kuh, Hassanakdar, Simeh-Kuh, Gerd-Kuh, Deh-Molla, Kuh-e Saluk, Fazel Abad, and Deraznau areas. Except for the Gorgan Schists in the Deraznau area which has low metamorphic grade, the rest of Ordovician rock units are siliciclastic sediments. The study materials either metamorphic or non-metamorphic samples contain abundant and well-preserved palynomorph entities (e.g. acritarchs and chitinozoans), which permit the exact age of rock units and relationships of the Alborz Mountains to the paleocontinents (e.g., Gondwanan vs. Laurentia palaeo-provinces). Based on palynological analyses, the Lashkarak and Abastu formations contain several diagnostic acritarchs, consisting of *Arbusculidium filamentosum, Barakella felix*, *Coryphidium bohemicum*, *Dactylofusa velifera*, *Striatotheca principalis*, *Cymatiogalea messaoudensis var. messaoudensis*, *Aureotesta clathrata* var. *simplex*, and *Vavrdovella areniga* var. *areniga*. On the other hand, the presence of *Eremochitina brevis*, *Velatachitina veligera*, *Desmochitina ornensis*, *Belonechitina henryi*, *Siphonochitina formosa*, *Cyathochitina jenkinsi*, and *Armoricochitina armoricana* chitinozoan Biozones confirm the inclusion of the Alborz Mountains in the peri-Gondwanan paleoprovince during the Lower-Middle Ordovician. The Ghelli Formation is well-developed in Kuh-Saluk at the northern parts of Khorasan province, whereas the Abarsaj Formation and the Gorgan Schists are present in the southeastern Caspian Sea. The Ghelli and Abarsaj formations are characterized by the presence of Late Ordovician diagnostic acritarch taxa, consisting of *Acanthodiacrodium crassus*, *Villosacapsula setosapellicula*, *Multiplicisphaeridium irregulare*, *Multiplicisphaeridium bifurcatum*, *Orthosphaeridium insculptum*, *Orthosphaeridium bispinosum*, *Orthosphaeridium quadrinatum*, *Ordovicidium elegantulum*, *Dactylofusa cabottii*, *Baltisphaeridium oligopsakium*, *Baltisphaeridium perclarum*, *Dorsennidium hamii*, *Diexapllophasis denticulata*, *Neoveryhachium* sp. cf. *carminae*, *Veryhachium lairdii*, *Navifusa ancepsipuncta*, *Leiofusa litotes*, *Muzivum gradzinskii*, and *Veryhachium inflatum*. The aforementioned acritarch taxa are associated with the

Belonechitina robusta, *Tanuchitina fistulosa*, *Acanthochina barbata*, *Armoricochitina nigerica*, *Ancyrochitina merga*, *Tanuchitina elongata*, and *Spinachitina oulebsiri* chitinozoan Biozones, which have been previously established in the 'northern' Gondwanan Domain. Herein, it should be mentioned that the *Tanuchitina elongata* and *Spinachitina oulebsiri* Biozones are present in the glacial member of the Ghelli Formation in Kuh-e Saluk. Moreover, the treated samples of Gorgan Schists contain the same acritarch and chitinozoan taxa of the Ghelli and Abarsaj formations which reveal the Late Ordovician for the Gorgan Schists. Therefore, based on palynological data, not only the Zagros Mountains but also the Alborz Mountains were part of the peri-Gondwana/Gondwanan paleocontinent.

Keywords: Ordovician, Alborz Mountains, chitinozoans, acritarchs, Peri-Gondwana

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Advances in the Ordovician studies of the Middle East and Central Asia

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Abstract

The area of the Middle East (mainly Iran and Afghanistan) and Central Asia (nowadays Kyrgyzstan, Tajikistan and Uzbekistan) represented a complex collage of the early Palaeozoic terranes peri-Gondwana spread in the Ordovician from the temperate to subequatorial southern latitudes. In the Ordovician, the most of crustal blocks of Iran, Afghanistan and Pamirs were integral parts of Gondwana, located in a relative geographical proximity of each other. Ordovician faunal record available for these regions suggests strong biogeographical affinities to the west Mediterranean peri-Gondwana. Zagros was affected by the terminal Ordovician glaciation in the Hirnantian age. The most complete Ordovician faunal record presently available for Alborz and Kopet-Dagh reveals more complex recurrent pattern. A strong faunal affinity to South China prevailed through the Early to Middle Ordovician times; however, there were several episodes of proliferation of the cold-water faunal associations nearshore (e.g. *Protambonites*, *Thysanotos–Leptembolon* and *Neseuretus* associations), coincident with sea-level falls. Late Ordovician occurrences of low diversity benthic fauna with the brachiopod *Hindella* and trilobite *Vietnamia* in Kopet-Dagh and East-Central Iran can be taken as a sign of the cooler climate in the Katian time. Rich cryptospore and trilete spore assemblages preserved in Katian–Hirnantian shallow marine deposits of Kopet-Dagh may suggest on proliferation of the earliest terrestrial flora on the land nearby.

Central Asia represents a complex mosaic of heterogeneous first order Palaeozoic tectonic units. At the north, it includes the Karatau - Naryn and North Tien Shan microcontinents located along the south-west margin of the Altaid Orogen. They were amalgamated into a single larger microcontinent by the end of the Middle Ordovician series. From available palaeomagnetic data, it is well established that North Tien Shan was located at the subequatorial southern latitudes. The Lower to Middle Ordovician biostratigraphy of North Tien Shan is based on graptolites; however, it is considerably outdated. In Karatau – Naryn,

the Early Ordovician conodont, trilobite and brachiopod faunas are best documented from the carbonate succession of Malyi Karatau in South Kazakhstan, while in Kyrgyzstan sporadic occurrences of conodonts and radiolarians of that age are better known from siliciclastic offshore deposits of Sarydzhaz. The Late Ordovician (Sandbian to Katian) brachiopods and trilobites show strong affinities to Tarim and South China. The intermediate zone between the Altaid and Middle Eastern peri-Gondwana terrane assemblages includes the Alai Microcontinent and the Turan Domain. The Alai Microcontinent is commonly considered as peripheral to Tarim. The Ordovician faunas of Alai are poorly documented and mostly known from preliminary identifications, which are considerably outdated. The only exception is the Late Ordovician (Katian) trilobite fauna with strong affinities to Tarim, South China and southern Kazakh terranes. The Turan Domain lacks the Ordovician sedimentary record; however, the Zeravshan – Gissar region located along its northern boundary with Alai Microcontinent, should be considered as a part of the former composite tectonic unit. The Upper Ordovician succession of Zeravshan – Gissar contains the trilobite and brachiopod assemblages with strong affinity to the contemporaneous faunas of Zagros and Mediterannean peri-Gondwana, suggesting distinct palaeogeographical separation from Alai in Ordovician.

Keywords: Ordovician, palaeogeography, biogeography, Gondwana, Altaids

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The Ordovician timescale, 2020

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Abstract

The Ordovician Period encompasses two extraordinary biological events in the history of life on Earth. The first, the “Great Ordovician Biodiversification Event” or GOBE, is a great evolutionary radiation of marine life; and the second is a catastrophic Late Ordovician extinction. Understanding the duration, rate, and magnitude of these events requires an increasingly precise timescale. As part of an eight-year cycle of revision for the entire geologic timescale, ages for the Ordovician Period and its subdivisions have been rescaled and updated for 2020. Compared to GTS 2012, the GTS 2020 Ordovician scale is more reliable, the result of a biostratigraphic composite based on substantial new data and almost double the number of radioisotope dates, the majority of which have considerably less analytical uncertainty than in GTS 2012. The new Ordovician timescale is based on the subdivision of a global Lower Paleozoic CONOP9 composite graptolite range chart derived from 837 stratigraphic sections and 2651 graptolite taxa with interpolated radioisotopic dates. Thirty-seven new dates are used in the scaling of the 2020 Ordovician timescale. Unchanged from 2012, the base of the Ordovician Period is defined at the level of the first appearance of the conodont *Iapetognathus fluctivagus* at the Green Point Newfoundland section. Its top, the base of the Silurian Period, is set as the level of the first appearance of the graptolite *Akidograptus ascensus* at Dob's Linn, Scotland. However, the Cambrian-Ordovician boundary age is now estimated at 486.9 ± 1.5 Ma and the Ordovician-Silurian boundary at 443.1 ± 0.9 Ma. The new best estimate for the duration of the Ordovician Period is 43.8 million years. The largest differences from the GTS2012 timescale are a 1.5 Myr older Tremadocian base (C/O boundary), a 1.3 Myr older Dapingian base, and a 2.1 Myr older Darriwilian base. The estimated duration of the Hirnantian Stage has increased from 1.4 Myr to 2.2 Myr. Several new and expanded sections on chemostratigraphy, cyclostratigraphy, and understanding uncertainty in timescale construction are included in the chapter. Finally, for the first time an independently time-scaled global CONOP9 composite conodont range chart is included to compare with the graptolite-based timescale and facilitate the application of the timescale to carbonate facies sections.

Keywords: Ordovician, timescale, graptolite, conodont, CONOP9

Late Ordovician palynomorphs from the basal strata of the La Chilca Formation, Central Precordillera, Argentina

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Abstract

The first record of Late Ordovician palynomorphs is documented in the basal strata of the La Chilca Formation, Hirnantian–early Wenlockian in age, in the Poblete Norte section, Talacasto area, Central Precordillera of San Juan Province, Argentina. This unit unconformably overlies Early Ordovician shelf limestone of the San Juan Formation, and in turn is paraconformably overlain by shallow-water deposits of the Los Espejos Formation of middle Wenlockian–Pridolian age. In Talacasto area, palynologic works carried out in the La Chilca and Los Espejos formations at Quebrada Ancha and Baños de Talacasto sections were published by several authors. In the Poblete Norte section, the basal cherty pebble conglomerate of the La Chilca Formation is not recognized. Instead, a ferruginous reddish matrix-supported sandstone level, with a low carbonate cement content, occurs. Overlying in sharp contact there is a ferruginous reddish matrix-supported sandstone level bearing phosphate nodules and pebble-sized clasts of chert. This bed followed by a shaly siltstone layer with scattered ooids passing to a Fe-phosphate oolitic bed in sharp contact with the base of the Cuarcitas Azules Member. It is noteworthy that the Hirnantian–Rhuddanian graptolite-rich siltstones and shales of the Salto Macho Member have not been recognized in this section. From this oolitic bed, a diverse assemblage of well-preserved palynomorphs composed of ten species of chitinozoans, seven acritarchs and six cryptospores are documented. Several age- diagnostic of the late Ordovician are recorded such as an acritarch *Cheleutochroa diaphorosa* Turner and chitinozoans *Ancyrochitina* sp. cf. *Ancyrochitina* *merga* (Jenkins), *Armoricochitina* sp. cf. *Armoricochitina nigerica* (Bouché), *Calpichitina lenticularis* (Bouché), *Conochitina minnesotensis* (Stauffer), *Euconochitina lepta* (Jenkins), *Lagenochitina deunffi* Paris, *Spinachitina bulmani* (Jansonius). This association of chitinozoans and especially the presence of the Hirnantian *Armoricochitina* sp. cf. *Armoricochitina nigerica* allows the confirmation of a late Ordovician age (Hirnantian), mostly related with Gondwana-Perigondwana regions, in accordance with the dating of the studied interval based on graptolites from the *M. persculptus* Zone in the Talacasto area (Baños de Talacasto section). In Talacasto area, the Silurian species *Armoricochitina nigerica* and *Crassiangulina tesselita* Jardiné *et al.* emend. Wauthoz *et al*. are forms of the *Atavograptus atavus* Graptolite Zone (early–mid Llandoverian) at Baños de Talacasto section, and of the Llandoverian–Wenlockian of the top of the La Chilca Formation at Quebrada Ancha section, respectively. *Quadraditum deunffi* Pöthe de Baldis has been mentioned in the lower Member of the Los Espejos Formation of the Precordillera region (Los Azulejitos section). The temporal distribution of these species has been modified recently, therefore, a review is recommended to rule out reworking on the younger sediments.

Keywords: palynomorphs, Hirnantian, La Chilca Formation, Precordillera, Argentina

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First possible record of the Hirnantian glaciation in the Caparo region, Venezuelan Andes

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Abstract

Studies of the Ordovician rocks of the southern Andean flank have focused on the lithostratigraphic and biostratigraphic description of the Caparo Formation, the first descriptions of this unit assign it an Ordovician age, later that, three faunal levels were recognized whose age did not reach the Late Ordovician. In oil exploration projects, stratigraphic successions on eight localities of the Caparo region were reviewed, obtaining a composition of siltstones and sandstones intercalated with conglomerates for the Caparo Formation, and presence of Late Ordovician trilobites, brachiopods, corals, crinoids, bivalves, bryozoans and sponges, dated as Sandbian by the graptolite fauna of *Nemagraptus gracilis* Zone recorded with the assemblage. Overlying the Caparo Formation, a thick Silurian succession (early Llandovery to Wenlock) was defined, having yielded prolific brachiopod assemblages dominated by genera such as *Meifodia*, *Eostropheodonta*, *Eocoelia* and *Antirhynchonella*. The stratigraphic contact between the Ordovician and Silurian strata was proposed to be a hiatus involving the apparent absence of Katian to Hirnantian sedimentary record. However, the detailed study of three localities along of Uribante-Caparo dam reservoir (Paso Caparo, Caparito and El Cambur creek sections) has allowed to record a relatively thin (<50 m) sequence of conglomerates, lenticular sandstone bodies and possible diamictites

below the early Rhuddanian fossiliferous sediments of El Horno Formation. The new sedimentary succession is here named as the El Cambur Formation and in some way it could represent some previously unrecognized Hirnantian strata. The conglomerates, with chaotic fabric and clay and violet matrix, show a tillite-like aspect and mostly include sub-angular to sub-rounded clasts of 2 to 6 cm in diameter of sedimentary, igneous and metamorphic nature; the possible diamictites include pebbles and cobbles of quartzitic sandstone up to 80 cm in diameter, and the intercalated sandstone beds show load structures and extensional deformations quite similar to subglacial sandstones recorded from the wide area affected by the north-African end-Ordovician glaciation. In any case, the hypothesis raised by this preliminary communication on the glacial or glaciomarine influx on the sedimentation of the El Cambur Formation requires more detailed sedimentological, petrological and paleontological studies. If confirmed, these could corroborate by the first time the extent to the end-Ordovician glacial record to northern South America. For now what is certain is that the local Ordovician-Silurian succession for the studied area of the Venezuelan Andes is thus composed, in ascending order, by the Caparo Formation (Upper Ordovician, Sandbian), followed by the new El Cambur Formation (Upper Ordovician, Hirnantian?) and ending with El Horno Formation (Silurian, Llandovery to Wenlock).

Keywords: Ordovician glaciation, Caparo Formation, Southern Andean flank, Venezuela

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Biodiversity of marine faunas during the Ordovician radiations: a critical assessment of the data sources

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Abstract

Diversification is a key property of life. Building on John Phillip's (1860) classic, iconic curve, Phanerozoic biodiversity trajectories have been constructed by the availability of additional and renewed sets of data and increasingly sophisticated analytical methods. Using a relatively few single sources of data from global databases, the shapes of recent biodiversity curves for Ordovician biotas have predictably converged promoting acceptance of a few discrete events, aligned with relatively few peaks and associated with limited specific drivers. There has been a resistance to investigate under the curves and examine the many and varied causes of biodiversity, both local and regional. Critically, the majority of the data available pertains to the most abundant part of the benthos, the brachiopods, and more especially their occurrences in the palaeocontinents of Baltica and Laurentia together with South China. Decolonisation of data in terms of geographic scope and those who capture and manage it, will expand and support research out with the more familiar regions but also build capacity and expertise outside the routinely-accepted pool of researchers. Exploration of a number of regional datasets, deconstructed from global curves, for some key fossil groups indicates the regions that do have distinctive biodiversity signals, but also highlights

significant gaps in our knowledge, highlighting the need for a more inclusive approach to investigating the Ordovician radiations.

Keywords: Great Ordovician Biodiversification Event, radiations, palaeobiogeography, palaeobiodiversity, databases

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Updated biostratigraphic approach based on key graptolites from the Huancar section, eastern Puna of Argentina

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Abstract

A detailed taxonomic revision was carried out on previous and new graptolite collections from the Huancar section, as part of the Ph.D. thesis of one of the authors (N.C.H.S.), to fill gaps for high-resolution correlation of the biostratigraphic framework of the eastern Puna, Argentina. The studied area is located at the eastern side of the route from Huancar to Susques, in the western flank of the Sierra del Cobre, in the Jujuy Province. The material comes from bluish arcillites corresponding to the Chiquero Formation, which is included in the Puna Platform Complex and covered by the Cerro Huancar rhyolites. It is noteworthy the biostratigraphic significance of characteristic "H-shaped" tubaria assigned to *Paratetragraptus approximatus* that appears in the overlaying levels to those with *Hunnegraptus copiosus* and *Paradelograptus mosseboensis*. These records document for the first time the presence of the Tremadocian–Floian boundary in the Argentine Puna and allow recognizing the *Tetragraptus phyllograptoides* and *H. copiosus* biozones, respectively. The biostratigraphic analysis also confirms that the *Aorograptus victoriae* Biozone is developing at the lower stratigraphic levels of the studied section, based on the presence of *Kiaerograptus kiaeri* together with specimens of the genus *Clonograptus*. The Huancar graptolite succession contributes to accurate the regional correlation of the Lower Ordovician of the eastern Puna with those previously recognized in the Argentine Cordillera Oriental. The *A. victoriae* and *H. copiosus* biozones are present in deposits previously assigned to the Coquena, Saladillo, San Bernardo, and Santa Rosita formations; meanwhile, the *T. phyllograptoides* Biozone has been recognized in the lower part of the Acoite Formation exposed in Los Colorados, Sierra de Aguilar, and Santa Victoria areas. The studied succession is also linked with equivalent levels cropping out in the Cieneguillas and Culpina sections in southern Bolivia. Moreover, it is straight globally correlated with the Floian GSSP from Scandinavia, where *P. approximatus* has been used as the key taxon for defining the base of the second stage of the Ordovician at the Diabasbrotet section of southern Sweden; and a global correlation with North America and South China can be additionally proposed. *T. phyllograptoides* is a high latitudes element, commonly associated with *P. approximatus* in the shallow shelf deposits of the Cordillera

Oriental; however, it has not been recorded in the Huancar section until now. It could be related to the depositional environment of the Chiquero Formation, which consists of turbidite deposits developed in channel edges or banks in the slope of the basin, where deep-water pandemic taxa such as *P. approximatus* were dominants.

Keywords: Ordovician, graptolites, Argentine, Tremadocian, Floian.

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Testing tectonic hypotheses of the southern part of the Taconic Orogen through a provenance study of Upper Ordovician sandstones

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Abstract

The tectonic setting of the Taconic Orogeny along the southernmost part of the eastern margin of Laurentia remains unresolved. Stratigraphically closely associated with the major K-bentonites that were produced by explosive volcanism during this orogeny are mature to supermature quartz arenites. We conducted a provenance study of these arenites to further constrain and test competing models of the regional tectonomagmatic setting at that time.

Detrital zircons were dated using U-Pb geochronology, with results clustering mostly into three dominant age groups: ~440-490 Ma, ~900-1300 Ma, and ~1300-1500 Ma. In addition, a few cluster into older groups with ranges of ~1600-1800 Ma, ~1800-1900 Ma, and ~2600-2800 Ma. Detrital zircon ages ranging from ~900-2800 Ma have all been identified previously in Laurentian passive margin Cambrian sandstones, suggesting a multi-cycle source for some fraction of the framework grains in the Ordovician quartz arenites. The youngest age, ~440-490 Ma, although present in samples from Virginia, West Virginia, and Tennessee, is a more common age in the sandstones of Georgia and Alabama. We attribute this to incorporation of magmatic zircons from tephra layers after they entered the sedimentary depositional system. These zircons were then abraded by transport as detrital grains, which in Alabama and Georgia were deposited right after, or in some locations, during the eruptions, as indicated by stratigraphic relationships and confirmed from laser ablation ICP-MS "fingerprinting" of apatite phenocrysts from the Deicke and Millbrig K-bentonite beds. Furthermore, several Taconic magmatic detrital zircons have inherited cores of Grenville age.

The size and nature of the eruptions that generated the Deicke and Millbrig tephras point to an important inconsistency with any model having its presumptive tectonic setting based around an andesitic island arc volcanic system. In particular, the lack of an obvious silica-rich source for these massive Ordovician eruptions along a typical oceanic island arc is problematic. Our findings support a tectonic setting for the Laurentian margin during the late Ordovician that was analogous to a combination of select modern settings in the western Pacific and Indonesia, specifically (1) New Guinea, where mature quartz arenites occur in the foreland succession, and (2) Sumatra, where the enormous Toba caldera formed in association with subduction beneath the Cretaceous-aged continental crust of Sumatra.

The temporal and spatial proximity between the island arc system and the quartz-rich sandstone and conglomerates that were deposited contemporaneously with the K-bentonites originally generated as tephras from that island arc also requires an adequate explanation that accounts for the presence of thin and compositionally mature siliciclastics in the otherwise mud-rich redbed sequence. These coarser clastics provide evidence for appreciable chemical weathering that eliminated less robust grains like the feldspars, and of extensive transport across (and probably intermittent storage in) an extensive alluvial plain that transitioned from a predominantly fluvial/floodplain setting to a more marginal marine coastal plain setting. Weathering, transport, and deposition of these quartz-rich sandstones likely occurred in a humid and tropical climate, suggesting the possibility that some component – possibly an appreciable one – is comprised of first-cycle quartz arenite sand.

Keywords: Blountian tectophase, K-bentonite, U-Pb geochronology

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Latest Ordovician to early Silurian integrated bio- and chemostratigraphy in northern Lithuania, central East Baltic

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Abstract

The late Katian, Hirnantian and Rhuddanian carbonate succession of Baltoscandia has often served as a global reference. However, time correlations are still being debated in the region, and basin-wide patterns in geochemistry and biodiversity are not well resolved across the Ordovician–Silurian boundary. Here we studied the Likėnai 396 drill core from northern Lithuania in order to provide a late Ordovician to early Silurian bio- and chemostratigraphic reference section for the central East Baltic region, and to assess spatial variability of recorded events and fossil communities. Our primary focus was on the Hirnantian carbon isotopic event (HICE) interval as well as the smaller-amplitude late Katian Parovėja carbon isotopic excursion. The latter occurs within the Parovėja Fm., for which the Likėnai section serves as neostratotype. The Katian to Aeronian part of the section was sampled for paired carbonate

and organic matter carbon isotopes, other geochemical proxies and four groups of microfossils: chitinozoans, conodonts, ostracods and scolecodonts.

The $\delta^{13}C_{carb}$ data revealed a prominent HICE with a long falling limb, and distinct Moe and Parovėja excursions. The $\delta^{13}C_{org}$ records show a somewhat different pattern, with less prominent and stratigraphically shorter HICE, no expression of the Parovėja event, but positive excursions before it and higher up in the Silurian Remte Fm. The microfossil study revealed altogether more than 180 taxa, including the key species of chitinozoans, conodonts and ostracods. The late Katian *C. rugata* Chitinozoan Biozone corresponds to the basal part of the Parovėja Fm., the *S. taugourdeaui* and *C. scabra* biozones are identified in the Kuldiga and Saldus formations, and the Stačiūnai Fm. is characterized by the *S. fragilis* and *B. postrobusta* zones. Index conodonts are rare, but include *A. ordovicicus* and ?*Noixodontus* sp. The ostracod fauna comprises typical elements known from the Katian and Hirnantian of Baltoscandia, with an abrupt turnover within the Kuldiga Fm. where the *H. harparum* fauna appears. Scolecodonts revealed a rich polychaete fauna in the Kuldiga and Saldus formations, very similar to that reported previously from the Hirnantian of Estonia and Latvia. The new data allow integrating four microfossil groups and geochemical proxies for the first time and allow the assessment of origins of geo- and bioevents at the Ordovician-Silurian boundary interval in East Baltic.

Keywords: Hirnantian, Baltoscandia, end-Ordovician extinction, integrated stratigraphy, microfossils

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Life habits of Ordovician infaunal lingulids – A Baltic perspective

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Abstract

In the Ordovician of Estonia infaunal lingulids (assigned to *Pseudolingula* in a wide sense) are not uncommon in assumed vertical life positions. In the carbonate rocks of Uhaku and Vormsi stages, lingulids occur within deep vase-shaped trace fossils, broadly similar to *Gastrochaenolites*. The *Gastrochaenolites*-like trace fossils from the Uhaku Stage are strongly phosphatized, whereas the Vormsi Stage traces are less well defined. Well-documented records of lingulid brachiopods preserved in life position have previously been described from Ordovician and younger deposits, but these are the first known *in situ* occurrence of lingulids from within *Gastrochaenolites*-like trace fossils. There is no evidence indicating that the lingulids were responsible for producing the vase-shaped trace fossil, and they most likely settled within an existing trace, produced by another organism. If active burrowing was at all involved, it was most likely performed with the pedicle oriented downward into the soft sediment filling the pre-existing depressions. Lingulids preserved

inside pre-existing organic borings have previously only been documented from Late Ordovician and Silurian tabulate corals and stromatoporoids.

Keywords: infaunal lingulids, *Pseudolingula*, *Gastrochaenolites*, Ordovician, Estonia.

Hirnantian and Rhuddanian graptolite fauna from Yiyang, Hunan, South China

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Abstract

As standard fossils from Ordovician to Silurian, graptolites play a very important role in fine division and high-precision correlation of biostratigraphy. The author selected the Nanba section of Jiangnan slope belt in South China to study, and found that a large number of graptolite fossils were preserved in the strata from Late Ordovician to Early Silurian. The fossils are mainly from Wufeng Formation (Late Ordovician) and Zhoujiaxi Group (Early Silurian). The lithology is mainly black shale and black slate. Through preliminary study, a total of seven genera and nine species of graptolites were identified, including *Metabolograptus persculptus*, *Normalograptus mirnyensis*, *Normalograptus elegantulus, Akidograptus ascensus*, *Neodiplograptus parajanus*, *Neodiplograptus guantangyuanensis, Parakidograptus acuminatus, Avitograptus avitus, Streptograptus cyclodontus*. According to the graptolite fossils, it can be determined that the age is from Hirnantian (Late Ordovician) to Rhuddanian (Early Silurian). Three graptolite biozones can be identified from bottom to top: *Metabolograptus persculptus* Biozone, *Akidograptus ascensus* Biozone and *Parakidograptus acuminatus* Biozone. The graptolite data of the research section provide a basis for the study of regional graptolite strata and a new material for the accurate division and correlation of global contemporaneous strata.

Keywords: graptolites, Hirnantian, Rhuddanian, South China

The first record of the Floian (Early Ordovician) conodonts in the East-Central Iran (Kalmard Block)

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Abstract

The existing information on the Ordovician conodont faunas from the East-Central Iranian Platform is poor and mostly confined to the Tremadocian and Darriwilian time intervals. The study of the Lower Ordovician succession exposed at Kuh-e-Asheghan (Kalmards Block) west of the town of Tabas, provides the first record of the occurrence of Floian conodonts in the whole region. A moderately rich conodont assemblage, including *Trapezognathus diprion* (Lindström), *Gothodus costulatus* Lindström, *Drepanoistodus forceps* (Lindström), *Drepanoistodus basiovalis* Sergeeva, *Protopanderodus rectus* (Lindström), *Drepanodus arcuatus* Pander and *Erraticodon patu* Cooper, has been recovered from the carbonate unit in the upper part of the mainly siliciclastic succession, provisionally referred to the Katekoyeh Formation. This assemblage can be assigned to the *Trapezagnathus diprion* Zone, presently recognised in the upper part of the Floian Stage in South China, Peru, Bolivia and Argentina and it can be also correlated with the *Trapezognathus diprion* Subzone in the middle part of the *Oepikodus evae* Zone of the Baltoscandian biozonal scale. The underlying limestone beds contain *Triangolodus bifidus*. This species with a narrow stratigraphical range is the eponymous taxon for the recently introduced uppermost Tremadocian Zone in South China. It also ranges up into the lower part of the *Oepikodus evae* Zone. The Early Ordovician (Floian) conodont fauna of East-Central Iran can be assigned to the Temperate Domain of the Shallow-Sea Realm, following the biogeographical model introduced by Zhen and Percival in 2003, with the closest similarity to the contemporaneous faunas of South China and western South America.

Keywords: Floian, East-Central Iranian Platform, *Trapezognathus diprion* Zone, conodonta, biogeography

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First report on the presence of the *Baltoniodus triangularis* conodont Zone and position of the lower Dapingian Stage boundary in Iran

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Abstract

Conodonts characteristic of the *Baltoniodus triangularis* Conodont Zone have been recovered from the middle and upper parts of the recently established Qumes Formation in the eastern Alborz Mountains, northern Iran. In addition to the eponimous species, the faunal assemblage includes *Baltoniodus triangularis* (Lindström), *Scolopodus strianus* Pander, *Bergstroemognathus extensus* (Graves and Ellison), *Periodon flabellum* (Lindström), *Drepanoistodus basiovalis* Sergeeva, *Drepanoistodus forceps* (Lindström), *Drepanoistodus contractus* (Lindström), *Drepanodus arcuatus* Pander, *Cornuodus longibasis* (Lindström), *Gothodus costulatus* Lindström, *Trapezognathus diprion* (Lindström), *Oistodus lanceolatus* Pander and *Protopanderodus rectus* (Lindström). In the Simeh-Kuh section, north-west of the city of Damghan, the base of the Dapingian can be defined by the lowermost occurrence of *Baltoniodus triangularis* (Lindström) at 16.5 m above the base of the Qumes Formation. The conodont assemblage of the *Baltoniodus triangularis* Zone ranges up to the top of the carbonate unit in the middle and upper part of the Qumes Formation. It permits to estimate a duration of the hiatus between the Qumes and Lashkarak formations, which covers most of the Dapingian Stage and the lowermost Darriwilian up to the *Lenodus variabilis* conodont Biozone. The conodont fauna recovered from the Qumes Formation shows distinct similarity to the contemporaneous faunas of Baltoscandia, Central Andean Basin in Argentinean Cordillera Argentina and South China. The siliciclastic Raziabad Member developed in the upper part of the Qumes Formation westward in the Gerd-Kuh section. It contains a moderately diverse rhynchnelliform brachiopod assemblage including *Dirafinesquina antiqua* Popov and Cocks, which is among the oldest yet known strophomenoids and the earliest member of the family Rafinesquinidae. Correlation with the Simeh-Kuh section suggests that the Raziabad Member could not be younger than the Dapingian *Lenodus variabilis* Biozone and may have a Floian age in the lower part. It supports earlier brachiopod based correlation, supported in particular by the occurrence of *Paralenorthis* cf. *suriensis* Benedetto, probably conspecific with the taxon, originally described from the the Suri Formation (uppermost Floian Stage, *Oepikodus evae* conodont Biozone) of the Famatina Range, at north-west Argentina.

Keywords: Alborz, *Baltoniodus triangularis* Zone, Conodonta; Dapingian.

Stromatoporoids from the uppermost Hirnantian Shiqian Formation of South China and their implications for stromatoporoid faunal recovery

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Abstract

Similar to other marine benthic invertebrates, stromatoporoids were severely affected during the phases of the Late Ordovician Mass Extinctions (LOMEs), related to glaciation and the expansion of anoxia in the subsequent deglaciation. Hirnantian stromatoporoids are rare and have been reported from only Estonia, Norway, and Anticosti Island of Canada. The scarcity of Hirnantian stromatoporoids may possibly be a consequence of the abrupt glacioeustatic sea-level fall, which reduced significantly their geographic distribution. Here we report a stromatoporoid assemblage with three genera (clathrodictyids *Camptodictyon*, *Ecclimadictyon*, and labechiid *Cystostroma*) from the Hirnantian Shiqian Formation in northeastern Guizhou Province, South China. The formation, consisting of near-shoal facies, yields brachiopod *Cathaysiorthis*, and records the Hirnantian Carbon Isotope Excursion (HICE). This stromatoporoid assemblage is characterized by abundant *Camptodictyon*, associated with other warm-water organisms such as tabulate corals (*Catenipora* and *Paleofavosites*), calcareous algae (*Amsassia* and *Dimorphosiphon*), and *Girvanella* oncoids. The clathrodictyid-dominated assemblage is interpreted herein to indicate resurgence of shallow warm-water marine environments after the maximum of the glaciation. Furthermore, subsequent expansion of anoxia from the deep marine environment during the deglaciation, which has been proposed by many scholars to have caused the second phase of the LOMEs, might not have reached the near-shoal shallow environment, a case beneficial for the stromatoporoid recovery in the aftermath of mass extinction. Abundant occurrences of clathrodictyid stromatoporoids in the uppermost Hirnantian of South China is evidence that they pioneered the post-extinction recovery.

Keywords: Late Ordovician Mass Extinctions, Hirnantian, stromatoporoids, South China

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The ichnogenus *Balanoglossites* Mägdefrau 1932 from San Juan Formation (Middle Ordovician), Central Precordillera, Argentina

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Abstract

The San Juan Formation from Central Precordillera, western Argentina, is represented by a carbonate succession deposited during Middle Ordovician (Darriwilian) in a marine shelf environment. The uppermost 30 m of this unit at Talacasto section consist of wackestones, packstones and grainstones with some calcareous breccias interbedded, and contain diverse invertebrate faunas (*e.g.* brachiopods, gastropods, conodonts, sponges, trilobites, crinoids, among others) and biogenic structures. Abundant trace fossils and bioturbation were recognized in this stratigraphic interval. The ichnological analysis based on macro and microscopic aspects (such as orientation, shape, length, diameter, wall, branching of burrows), indicates low ichnotaxa diversity. The ichnogenus *Balanoglossites* Mägdefrau 1932 was recognized as predominant, together with *Thalassinoides* isp. and *Ophiomorpha* isp. in lesser proportion. *Balanoglossites* isp. corresponds to a boxwork complex trace fossil characterized by tunnels and galleries with irregular branching pattern, which have a considerably size variation. The morphology consists of U and Y shaped elements, with extended chambers between branching points (bifurcations). Burrows are circular or elliptical in cross section, with a maximum diameter of 20 mm. All burrows are unlined and filled with yellow-ocher fine grain sediments (marls), that contrasting strongly with the host rock. The extensive bioturbation observed in the upper portion of the San Juan Formation and the development of considerably size burrows could reflect increased oxygenation at the time of generation of these structures. The occurrence of *Balanoglossites* isp. defined omission surfaces of shallow marine setting and has been documented globally from Ordovician carbonate deposits to Holocene, both on softground and firmground substrates.

Further ichnological study in the San Juan Formation outcrops from other localities within Precordillera basin is needed to establish comparisons between the assemblages, identifying ichnofacies and to characterize the prevailing palaeoecological and palaeoenvironmental conditions.

The specimens from Talacasto section are housed in the Repository of Instituto de Geología Emiliano Aparicio (INGEO), Facultad de Ciencias Exactas Físicas y Naturales, Universidad Nacional de San Juan, Argentina.

Keywords: Ordovician, Ichnology, Precordillera, Argentina

High frequency fluctuations in marine oxygen associated with the Late Ordovician mass extinction

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Abstract

The second most devastating mass extinction in the Phanerozoic occurred at the end of the Ordovician Period (~445 million years ago) and extinguished ~85% of marine species between two extinction pulses. Traditionally the first pulse is attributed to cooling of global climate and Gondwanan glaciation, while the second pulse is typically associated with an expansion of reducing conditions. New thallium isotope records from two globally distributed paleobasins of Late Ordovician anoxic organic-rich rocks observe two distinctive shifts in sedimentary thallium isotope compositions, likely indicating two periods of rapid fluctuation in marine oxygenation. Thallium isotopes are likely responding to major changes in manganese oxide burial in the oceans at these times. We find a strong temporal link between these shifts in thallium isotope compositions and the two pulses of mass extinction in the Late Ordovician. We conclude that dynamic fluctuations in oceanic oxygen levels likely played an important role in driving the first of the "Big Five" mass extinctions.

Keywords: Late Ordovician Mass Extinction, biogeochemistry, anoxia, manganese oxide, thallium, paleoceanography

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Dendroid graptolites of the Prague Basin during the GOBE

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Abstract

Dendroid graptolites are a minor component of the rich, diversified and benthos-dominated fossil associations of the Šárka (lower and middle Darriwilian) and Dobrotivá (upper Darriwilian to lowermost Sandbian) formations. Compared to the underlying Klabava Formation (Floian to Dapingian) the diversity of dendroid graptolites significantly decreased and their abundace dropped from locally very common to generally rare. It appears as their initial diversity and frequency reduction after the flowering period because their decrease continued throughout the entire Ordovician up to the lower Silurian where dendroids became locally abundant again. In contrast to the decreased diversity and abundance of dendroid graptolites, the Šárka Formation is a unit where the overall diversity of fossil associations rapidly increases. It can be considered as a response of the GOBE as that formation is of the early Darriwilian age. On the other hand, the rapid changes in the diversity were apparently significantly influenced by local environmental changes in the Prague Basin. Thus, the final diversity dynamics was a combination of the environmental variations, and a migration and radiation of highly diversified fauna that is a response to the global trend of the explosive development of new taxa. In this respect, the main factor of the dendroid graptolite decline during the GOBE in the Prague Basin is a disappearance of habitats. Based on actualistic parallels with erected colonial sessile benthic organisms of similar morphologies, the dendroid graptolites needed a firm ground for their attachment. The Klabava Formation reflects an early stage of the sedimentary basin development with boulders rising from the muddy bottom or rocks flanking the depressions, which represented depocentres. The dendroids were transported short distances from their habitats during destructing events related to the markedly increased water energy and current dynamics. Therefore, there are many accumulations of dendroid graptolites on bedding planes in the Klabava Formation whilst dendroids are infrequent outside these accumulations. The Darriwilian transgression and a continuing subsidence caused a deepening of the Prague Basin. Former elevations became parts of depocentres and the former firm grounds were covered with fine muddy sediments destructing the dendroid graptolites habitats.

Keywords: sessile benthos, biodiversity, paleoecology, Middle Ordovician, Barrandian

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Babies from the Fezouata Shale: insight into trilobite development during Ordovician Radiation

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Abstract

The Lower Ordovician Fezouata Shale is renowned for its exceptionally preserved invertebrate fossils, including numerous species of trilobites, some of which show appendages and traces of the digestive system. Little attention has been paid to the early developmental stages of trilobites from this formation, even though they are quite common in localities north of the city of Zagora. In this contribution, we describe the early post-embryonic stages of eight Fezouata Shale trilobites belonging to five families, namely: *Symphysurus ebbestadi* (Nileidae), *Platypeltoides magrebiensis* (Nileidae), *Ampyx priscus* (Raphiophoridae), *Asaphellus* sp. (Asaphidae), *Megistaspis hammondi* (Asaphidae), *Bavarilla zemmourensis* (Bavarillidae), *Anacheirurus adserai* (Cheiruridae), and one undetermined species.

Developmental stages of these Lower Ordovician taxa allow us to understand the first steps of post-Cambrian trilobite diversification. Early post-embryonic stages of Fezouata trilobites show in particular that: 1, all known nileids have extraordinarily large early post-embryonic stages; 2, juveniles of Early Ordovician raphiophorids show some characters typical for the larvae of younger species; 3, early stages of numerous asaphids share very similar morphology; 4, the earliest known stages of *Bavarilla* confirm the placement of Bavarillidae to Calymenina; 5, juveniles of *Anacheirurus* show allometric growth of posterior trunk spines; and 6, minute stages of an undetermined trilobite have been found in association with a colony of *Araneograptus murrayi*.

Keywords: Trilobita, development, Fezouata Shale, Ordovician Radiation

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The Ordovician of the Korean Peninsula: a synthesis

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Abstract

The Ordovician succession of the Korean Peninsula is mainly represented by the Cambro–

Ordovician Joseon Supergroup that is distributed in the Taebaeksan Basin in South Korea and the Pyeongnam Basin in North Korea. In this talk, we will summarize recent advances that were made on the Ordovician of the Korean Peninsula during the last 15 years, including sedimentological, paleontological, and geochemical works. The Taebaeksan Basin comprises Taebaek, Yeongwol, Yongtan, Pyeongchang, and Mungyeong groups, among which the Taebaek and Yeongwol groups have been studied in detail due to their relatively good preservation. All these strata represent mixed carbonate-siliciclastic platforms that are deposited in peritidal to deep subtidal environments. The Ordovician of the Taebaek Group comprises the Dongjeom (Tremadocian; inner shelf sandstone), Dumugol (Tremadocian–Early Floian; subtidal shale-carbonate), Makgol (Floian–Darriwilian; peritidal to subtidal carbonate), Jigunsan (Darriwilian; outer shelf shale), and Duwibong (Darriwilian; subtidal carbonate) formations in ascending order. Fossils including trilobites, conodonts, graptolites, echinoderms, brachiopods, cephalopods, sponges, bryozoans, and stromatoporoids are reported and studied from the Taebaek Group. The strata in the Taebaek Group are litho- and biostratigraphically well correlated to coeval successions in North China. In comparison, the Ordovician of the Yeongwol Group is represented by the Mungok (Tremadocian; carbonate ramp) and Yeongheung (Floian?–Darriwilian?; peritidal to subtidal carbonate) formations, which bear fossils including graptolites, trilobites, conodonts, cephalopods, sponges, bryozoans, and stromatoporoids. The Pyeongnam Basin of North Korea comprises the Lower Ordovician Singok and the Middle Ordovician Mandal groups, which are generally similar to the Taebaek Group as well as coeval strata in North China. In addition, the Upper Ordovician to the Devonian fossiliferous strata are found in the Imjingang Belt, which show affinity to coeval successions in South China.

Keywords: Korean Peninsula, Joseon Supergroup, Taebaeksan Basin, Pyeongnam Basin

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New isolated specimens of *Psigraptus* from Northeast China illustrating the proximal development

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Abstract

Well preserved graptolites are abundant in the upper Tremadocian in Baishan City of Jilin province of China. Large number of isolated specimens of *Psigraptus* was obtained from dissolved rocks. This exceptional, often 3-D preserved material allowed to study many features of rhabodosome (tubarium), especially its proximal development previously known from specimens flattened on the bedding planes.

The genus *Psigraptus* is interesting among anisograptids. It is an early reclined graptolite typifed by isolated autothecae at least in the proximal part of the colony. This taxon is also

significant in the biostratigraphy. It was originally defined as two- or three-branched. Later, it was recognized that there are two primary stipes and one or more, which were called as pseudo-primary. Subsequent branching can produce up to eighth-order stipes.

Based on the isolated specimens of *Psigraptus*, we found its proximal development very complex and complicated, of isograptid type, either dextral or sinistral. The studied specimens clearly show a prosicular origin of th 1^1. Three successive branchings give usually rise to pseudo-primary stipes. Despite this uniform pattern proximal parts of colonies range from compact to open illustrating a morphological variability. However, the question how to classify distinct morphologies of these graptolites, if on species or genus level, remains still open.

Key words: graptolites, proximal development, Ordovician, Tremadocian, Northeast China

Appendix：

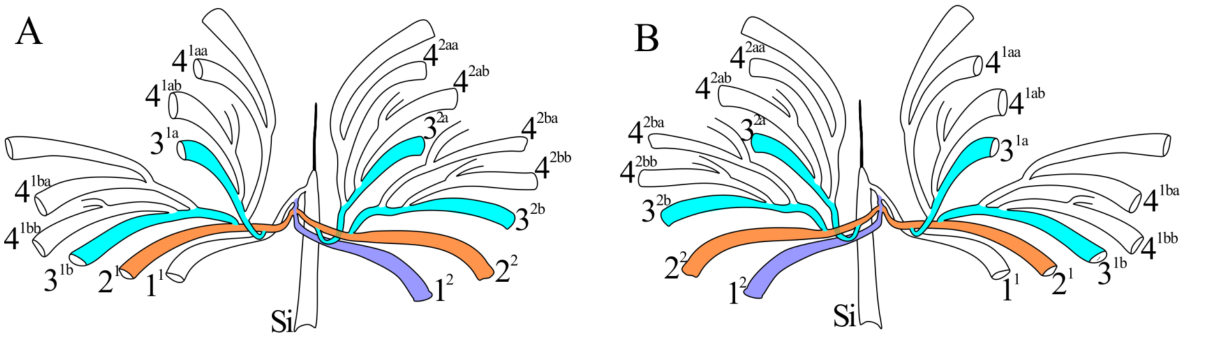

Figure 1. The proximal development in *Psigraptus* (bitheca are omitted). Dicalycal thecae are coloured.

The Geobiodiversity Database: a new tech team and novel perspectives

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Abstract

Initiated by Nanjing Institute of Geology and Palaeontology (NIGPAS) in 2006, the Geobiodiversity Database (GBDB) has gradually developed into one of the most important section-based databases in the world for the last decade. GBDB provides an information hub among taxon-based and collection-based palaeontological data. In December 2018, "Big Data Center", a new division of NIGPAS, was formally established. The purpose of "Big Data Center" is to provide various kinds of support for GBDB and related researches. Here, we introduce our new tech group that undertakes the maintenance and improving of the database. New version of GBDB aims to integrate more thorough palaeontological data for a broader

utilization. A few steps are being taken in order to achieve this goal: (1), with new website (http://geobiodiversity.com/) online in May 2020, GBDB now presents a more user-friendly interface and hosts more extended data (partly from the Paleobiology Database) compared to the old version; (2) by emphasising the studies concerning high-resolution sequencing, GBDB is enhancing the credibility and accessibility of the data for paleobiologists and stratigraphers; (3) for the studies legitimately built from collections, we are maximizing the research potential by both enhancing the quality of occurrence data and integrating sophisticated analysis applied largely in almost all earlier diversity studies; (4) by taking over the international fossil insect database of the International Palaeoentomological Society, the holotype data of fossil insects is naturally mirrored in GBDB now; (5) based on convolution neural network algorithm of machine learning, an additional function of automatic identification system for fossils was integrated in GBDB; (6) automatic data capture function is being developed in GBDB for data extracting and mining. Taken together, new GBDB aims to provide more accessible research opportunities for deep time studies along with other successful fossil databases such as the Paleobiology Database and the Neptune Database.

Keywords: high-resolution sequencing, occurrence data, neural network, section-based database

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Relation between the *Periodon-Paroistodus* biofacies and change in redox conditions: a case of study in Darriwilian uppermost beds of the San Juan Formation, Precordillera Argentina

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Abstract

The *Periodon-Paroistodus* biofacies recognized in the uppermost beds of the San Juan Formation was first identified in Middle Ordovician successions of western Newfoundland, and then it has been recognized in other regions of the world, as characteristic of deep open-sea biotopes, which occupied upper to lower slope environments. The conodont assemblage of the last one meter of the San Juan Formation was studied in three sections of the Central Precordillera and one of the Eastern Precordillera. The *L. crassus* Zone was registered in the La Pola and Del Aluvión creek section and the *L. pseudoplanus* Zone was recorded in the Cerro La Chilca and La Brecha creek sections. In the Cecilia and Cerro La Chilca section there is a predominance of *Periodon* in the lower levels and it decreases to the top whereas the *Paroistodus* is a minority in the lower beds and it increases to the top. The genus *Periodon* represents around 50 % of the population in the Del Aluvión section, in contrast the *Paroistodus* is present in equal percentage in the La Brecha creek section.

The microfacies analysis allows the recognition of a well-oxygenated setting in the Del Aluvión creek and dysoxic conditions in the La Brecha creek, both in a relatively shallow subtidal environment. The La Pola and Cerro La Chilca sections show a progressive decrease in oxygenation along the studied beds from well-oxygenated in the base to a dysoxic

condition in the top in a relatively shallow subtidal environment. The relation between *Periodon* and *Paroistodus* genera, as well as the change in redox conditions are registered in two different time intervals in the *L. crassus* to the east and *L. pseudoplanus* to the west. The genus *Periodon* seems to prefer a well-oxygenated environment and the genus *Paroistodus* would have inhabited in dysoxic environment, but both in relatively shallow subtidal conditions.

Based on these preliminary results, we recognize that the redox condition in the water column can be a strong control in the relation between *Periodon* and *Paroistodus* genera. The San Juan Formation is overlain by black shale and mudstone deposits from the Los Azules and Las Aguaditas formations. This facies change has been interpreted as flooding, however, this change is diachronic from the proximal to the distal part of the platform. This phenomenon should be explored looking for other mechanisms that could have controlled the platform drowning and redox change in the Middle Ordovician in the Precordillera.

Keywords: conodont, Precordillera, redox, carbonate.

The GOBE record in the Ordovician San Juan Formation: a new perspective of this global event in the Precordillera

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Abstract

The GOBE (Great Ordovician Biodiversification Event) constituted the most important rise in biodiversity for the Paleozoic, registering a rapid diversification at the lower taxonomic levels in different Ordovician basins. However, the GOBE record in the Ordovician carbonate successions from the Precordillera remains unknown.

The preliminary analysis of the San Juan Formation conodont data from the Floian to the Darriwilian shows an interval with low diversity between two main diversification peaks. The first peak is registered during the middle–late Floian, followed by Dapingian low diversity interval. The second and more significant rise in the conodont diversity is recorded in the base of the Darriwilian reaching a peak in the middle Darriwilian. The biodiversification information of different benthonic and nektonic groups from the Ordovician of the Precordillera (Sanchéz et al., 2003) is coincident with those provided by conodont data.

The preliminary record of the GOBE in the Precordillera exhibit a particular pattern, showing that the first pulse of the GOBE would occur in the middle–late Floian, beginning earlier than several regions of the world, except to South China (Deng et al., 2021). This pulse seems to end in the base of the Dapingian, this time interval is a period of low biodiversity which includes all Dapingian time representing a significant event within the GOBE. The speciation rates increase dramatically in the lowest Darriwilian in coincidence with the global records (Stigall et al., 2019).

This complex local pattern indicates a variety of drivers and factors that combined to initiate and promote this event, such as the input of fine sediment to the basin, local tectonic control, paleogeographic location, climate changes and/or the k–bentonite layers present in both the Floian and Darriwilian beds. An interdisciplinary study is required in the future, that provides new insights to better understand the biotic and abiotic drivers of the GOBE in the Precordillera Argentina.

Keywords: Precordillera, conodont, diversification, San Juan Formation

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Soft tissue in Ordovician graptolites

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Abstract

Soft-tissue remains are extremely rare in graptolites, despite the presence of the group in Cambrian and Ordovician Konservat-Lagerstätten. Remains of pterobranch-type zooids have been discovered in several benthic graptolites from the Castle Bank fauna: a newly discovered Middle Ordovician Konservat-Lagerstätte in siltstone of the Gilwern Volcanic Formation in the Builth–Llandrindod Inlier (mid-Wales, UK). The graptolite zooids are preserved as carbon, with multiple zooids in each of several colonies, and appear to show some details of the lophophore. There is only a single zooid per theca, and many thecae are empty. The preserved zooids are consistent with a rhabdopleurid-like interpretation of graptolite soft

tissue, consistent with phylogenetic analyses recovering rhabdopleurids within Graptolithina and cephalodiscids as their sister group.

Keywords: Graptolithina, Dendroidea, exceptional preservation

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Revision of selected morphotypes of Ordovician acritarchs from northeastern Iran

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Abstract

Organic-walled phytoplankton (acritarchs) reached its highest diversity in the Ordovician and was a significant element of primary producers in the Paleozoic especially Ordovician oceans. Due to their abundance and high morphological variability in the Ordovician, the classification and taxonomy remain major problems for the study of the group. In recent years the taxonomy, biostratigraphy and palaeobiogeography of some important acritarch taxa were revised. Two important acritarchs *Aryballomorpha* Martin and Yin, 1988 and *Orthosphaeridium* Eisenack 1968. emend Navidi-Izad et al., 2020 are reassessed based on new materials from northeastern Iran and other localities.

The comprehensive revision indicates that *Aryballomorpha* is a monospecific Early Ordovician taxon and that its distribution is notably confined to the late Tremadocian, with no records in the Floian or younger rocks. *Aryballomorpha grootaertii* is restricted to low-moderate palaeolatitude, with no previous record from high palaeolatitude yet.

Orthosphaeridium Eisenack 1968. emend Navidi-Izad et al., 2020 is one of the most frequently recorded acritarch taxa from the Middle and Late Ordovician strata worldwide. Among more than 20 species attributed to *Orthosphaeridium*, only the following four species can be retained as valid taxa; *viz*., *O. bispinosum*, *O. ternatum*, *O. rectangulare* and *O. octospinosum*. Accordingly, all other species previously assigned to the genus are considered as synonymous or must be excluded from the genus. Based on the presence or lack of ornamentation on the vesicle and the processes surface four varieties are proposed for *O. rectangulare* and *O. octospinosum*. The First Appearance Datum of *Orthosphaeridium* occurs in the early Dapingian of South China in the *Expansograptus hirundo* graptolite Biozone and it has not been recorded from the Silurian yet. Palaeogeographically, *Orthosphaeridium* has been recorded from the margins of all palaeocontinents and palaeoecologically it seems to be an eurythermic taxon.

Keywords: acritarch, biostratigraphy, paleobiogeography, Ordovician, Iran.

Exceptional preserved starfish bed from the Upper Ordovician of the Barrandian area

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Abstract

Recently, a new locality called the Blýskava Hill (previously named Chrustenice after the nearby village) was discovered in the Letná Formation (late Sandbian, Ordovician) of the Barrandian area (Czech Republic). The locality is characterized by mass occurrence of articulated echinoderms associated with other skeletal fauna (e.g. brachiopods and trilobites). Beds are dominated by the solutan genus *Dendrocystites*, but in the upper part of the excavation asterozoan echinoderms are a major faunal elements. The echinoderm fauna also includes diploporitans, coronates, rhombiferans, edrioasteroids, and stylophorans. Slopes of the Blýskava Hill are regarded as a locality with the highest diversity of echinoderms in the Letná Formation.

The asterozoan echinoderms are so far poorly known from the Letná Formation. There is no published data about the specimens belonging to the class Asteroidea (only mention about old undescribed material), while the class Ophiuroidea is represented by the single genus *Bohemura* described from that formation. The newly collected material contains at least five different ophiuroid morphotypes (or taxa) and one asteroid. Ophiuroid material from the Upper Ordovician of the Letná Formation (late Sandbian) shows marked similarities with the material from the Tafilalt area - the Lower Ktaoua Formation (late Sandbian–early Katian), a fauna that was previously regarded as endemic with many unique genera and species. The occurrence of similar echinoderm material (ophiuroids and solutans) from the Czech Republic and Morocco supports the existence of faunal affinities between these regions in Late Ordovician times.

Keywords: Echinodermata, starfish bed, Ophiuroidea, Ordovician, Barrandian area

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Progress in study of Upper Ordovician radiolarians from the western part of the Altai-Sayan Folded Area

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Abstract

The Ordovician radiolarians have been reported from deep and shallow water marine sediments from a number of localities worldwide, showing best state of preservation from the shelf environments. Though throughout the Ordovician were defined several biostratigraphically valuable radiolarian assemblages (Danelian et al., 2017), most of them still require age verification by significant for Ordovician conodonts or graptolites. Well preserved Upper Ordovician radiolarian assemblages were found from the siliceous mudstone of so-called Siliceous-terrigenous Body and Tekhten' Formation at the north-east of Gorny Altai, western part of the Altai-Sayan Folded Area, South of West Siberia. Both sequences composed of mudstone, siltstone, sandstone, with intercalated siliceous mudstone and rare carbonate lenses, were accumulated in relatively deep shelf environments. Age of radiolarian-bearing siliceous rocks was dated by graptolites and conodonts from underlain strata (Sennikov et al., 2019). Thus, the Siliceous-terrigenous Body yielded graptolites of supernus-(?) ojsuensis Zone proving upper Katian – lowermost Hirnantian age. Reinvestigation of carbonate layers, underlain radiolarian bearing siliceous mudstones, yielded the conodonts *Periodon grandis* and *Protopanderodus insculptus* of Katian age. Graptolites belonging to the upper Katian supernus-ornatus-pacificus zones were found in the Tekhten' Formation. Recovered conodont association includes *Amorphognathus* cf. *tvaerensis*, *Scabbardella altipes*, *Yaoxianognathus* sp., *Protopanderodus insculptus* characteristic for Katian.

The revealed radiolarians contain seven species of genera common for the Upper Ordovician *Kalimnasphaera, Secuicollacta, Protoceratoikiscum* and *Inanigutta* known before from two Katian and Hirnantian assemblages defined in NSW and eastern Australia: *Kalimnasphaera maculosa* - *Protoceratoikiscum crossing* and *Secuicollacta ornata* - *Protoceratoikiscum chinocrystallum* (Noble & Webby, 2009). Notable for the found assemblages are representatives of genus *Protoceratoikiscum* reported from deep water facies of NSW Australia, Nevada USA, West China, Scotland UK, pylomate shell *Kalimnasphaera* and of genus *Secuicollacta* which taxonomic diversity increases in Silurian (Danelian et al., 2017).

Keywords: Upper Ordovician, radiolarians, conodonts, Gorny Altai

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Preliminary palynofacies analysis results of two boreholes drilled through the Upper Ordovician (potentially Hirnantian) sequences, southeastern Turkey

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Abstract

Palynofacies analysis is a study of organic matter composition in kerogen on the purpose of interpreting depositional environment and analysing hydrocarbon potential. In other words, palynofacies is the study of palynological matter in the sedimentary rocks. Different types of palynological matter and palynofacies methods have been previously defined and suggested by many researchers. Nowadays palynofacies and palaeoenvironmental analysis are widely performed in solving geological problems such as stratigraphy, sequence stratigraphy, petroleum geology and environmental indicators.

Different palynofacies classifications, schemes and terminology can be used depending on the scope of the study. In this study the schemes classifying palynological matter into three categories, namely palynomorphs, structured organic matter and structureless organic matter have been used. A total of two hundred organic matter particles have been counted for each sample prior to the palaeoenvironmental interpretations. Based on the relative abundances of palynomorphs, amorphous organic matter and other structured particles, an approach to the depositional environments for the Diyarbakır and Akçakale Basins in the southeastern Turkey have been suggested. A total of forty-seven core samples derived from the Upper Ordovician rocks yield moderate to abundant, moderately preserved palynomorphs and organic matters. Amorphous organic matter is considerably less with respect to the overlying lower Silurian rocks indicating potential source rock character. High amount of acritarchs with sporadic chitinozoans may suggest an inner to outer shelf environment. Local cryptospore abundance could be an indicator of shallowing trend in the inner part of the Diyarbakır Basin.

Keywords: Upper Ordovician, palynomorphs, palynofacies, depositional environment

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Brief information about the Ordovician deposits of Tajikistan

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Abstract

The first information about the findings of the Ordovician on the territory of Tajikistan dates back to the end of the 1920s, when A.P. Markovsky (1928) discovered limestones in the

valley of the Pakshif River containing Ordovician fauna. On the territory of the Zeravshan-Gissar mountain region, this location remained the only one until 1956. Subsequently, it was proved that organic remains are here in a secondary burial (Shadchinev, 1969), but by this time Ordovician deposits in bedrock had already become known. In the summarizing work "Stratigraphic Dictionary of the Phanerozoic of Tajikistan (Northern, Central and South-Western Tajikistan)", published by a group of authors (Ashurov, Bardashev, Bardasheva et al., 2012), 38 Ordovician stratons are characterized, including several subdivisions from the stratotype area, located in the neighboring territory of Uzbekistan. The total number of stratons presented in this edition (from Precambrian to Anthropogen) is 1018. In the "Atlas of the Upper Ordovician heliolitids of the Southern Tien Shan", the author (Ospanova, 2014) has described heliolitid corals from 17 localities, 10 of which are located on the territory of Tajikistan, and 7 - on the territory of Uzbekistan.

A. I. Kim (1959, 1963 and others), P. D. Vinogradov (1961), A. I. Lavrusevich with co-authors (Lavrusevich, Grinenko, Leleshus, 1962; A. Lavrusevich, Starshinin, V. Lavrusevich, Saltovskaya, 1972; A. Lavrusevich, V. Lavrusevich, Karapetov, 1976), P. D. Vinogradov and N. S. Torshin (1963), Z. Z. Muftiev (1964; Muftiev, Starshinin, Leleshus, Korsakov, 1971), V. I. Lavrusevich with co-authors (V. Lavrusevich, A. Lavrusevich, 1972; V. Lavrusevich, A. Lavrusevich, Leleshus, 1973) and other researchers studied the Ordovician sediments on the territory of the Southern Tien Shan.

In the Pamir, the first literary information about Ordovician findings dates back to the middle of the 20th century (Khamidov, 1956; Dufour, 1958). "The Pamir Stratigraphic Dictionary" (Dronov, Melnikova, Salibaev et al., 2013) includes characteristics of 669 regional and local stratigraphic units, of which 13 are Ordovician units.

The study of Ordovician sediments in the Pamir was carried out by V. I. Dronov and co-authors (Dronov, Leven, Melnik, Pashkov, 1960; Dronov, 1968, 1980), E. Ya. Leven (1960), B. P. Barkhatov and G. G. Melnik (1961; Barkhatov, 1963), N. G. Vlasov (1961; Vlasov, Gnilovsky, 1970), B. R. Pashkov (1961, 1962, 1964), S. S. Karapetov (1961, 1963, 1965), E. A. Balashova (1966), V. I. Lavrusevich with co-authors (Lavrusevich, Karjakin, 1977; V. Lavrusevich, A. Lavrusevich, Saltovskaya, 1981) and by other researchers.

Due to the completeness of the data collected in stratigraphic dictionaries, it can be seen that the number of Ordovician age units in relation to the total number of strata is slightly more than 3.5% for the territory of Tajikistan, excluding the Pamir, and about 2% for the Pamir. These numeric data shows that Ordovician deposits are not widespread in the region.

Keywords: Ordovician, Tajikistan, Tien Shan, Pamir, stratigraphic dictionary

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The Ordovician System in Australia – an overview of scientific research over the past decade

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Abstract

In this presentation we highlight advances made since 2012 in understanding the stratigraphy, palaeontology, geochronology and geochemistry of Ordovician rocks that are widely distributed across Australia. In the western two-thirds of the present-day continent, Ordovician strata formed in predominantly shallow-water marine intracratonic rift basins, whereas in the eastern third, clastic sediments accumulated in deep-water marine settings, sometimes around volcanic islands with fringing limestones. In the Canning Basin of northern Western Australia, stratigraphic and petroleum exploration drilling has cored through a Tremadocian to Darriwilian carbonate and clastic succession over 1500 m thick. Conodonts from the carbonates have been extensively revised, underpinning a new biozonation constrained by radiometric ages from interspersed tuffaceous beds. These results are especially important in precisely dating the Floian–Dapingian interval. Dapingian conodonts from the Nambeet Formation in the Canning Basin closely resemble those described from the Horn Valley Siltstone in the Amadeus Basin of central Australia. Trilobites (including the largest genus known from Australia) have recently been documented from the overlying Stairway Sandstone and Stokes Siltstone in the Amadeus Basin. Further north, the Florina Formation in the Daly Basin of the Northern Territory yielded a middle to late Tremadocian conodont fauna. *Iapetognathus fluctivagus*, zonal indicator for the base of the Ordovician, was identified from the eastern edge of cratonic Australia in far western New South Wales (NSW). Ordovician research over the past decade has been most active in eastern Australia. Revision of graptolites from the classic Pacific Province in Victoria continues with 5 new genera and 14 new species described; there has also been renewed interest in documenting Ordovician graptolites from central and southern NSW. A detailed conodont biozonation spanning the late Tremadocian to early Sandbian has been established in deep-water cherts and siliceous siltstones from the Lachlan Orogen of central and southern NSW. The mid Katian record of corals from island-fringing carbonates of central NSW and the New England Orogen in northeast NSW is now substantially revised with updated identifications. Deeper water (Benthic Assemblage 4) lingulate brachiopods from the Lachlan Orogen of central NSW are now fully described, with several key taxa also known from allochthonous limestone in the Broken River Province of central north Queensland, associated with mid-Katian conodonts. The first Late Ordovician deeper water fauna from the northern New England Orogen in Queensland was recently described. A new tectonic interpretation for the depositional setting of turbidites in the Lachlan Orogen, in a rifted back-arc basin active throughout the Early and Middle Ordovician, has been proposed based on geochemical analyses of cherts in which deep-water conodonts occur. Evidence for East Antarctica being the source of sediments forming these turbidites has been determined from geochronological data obtained from isotopic analyses of detrital zircons. Remnants of the frontal arc and open ocean basin are interpreted to be preserved in the Port Macquarie and Narooma areas, respectively, on the NSW coast. These many and diverse areas of research demonstrate that Ordovician studies are actively progressing in Australia in recent years.

Keywords: Australia, Ordovician, biostratigraphy, palaeontology, geochronology

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Hirnantia Fauna from the Condroz Inlier, Belgium: another case of a relict Ordovician shelly fauna in the Silurian?

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Abstract

The end-Ordovician mass extinction, linked to a major glaciation, led to profound changes in Hirnantian-Rhuddanian biotas. The *Hirnantia* Fauna, the first of two Hirnantian biotas survival brachiopod-dominated communities, characterizes the lower–middle Hirnantian deposits globally, and its distribution is essential to understand how the extinction took place. Herein, we describe and discuss the first macrofossiliferous *Hirnantia* Fauna assemblage from Belgium, occurring in the Tihange Member of the Fosses Formation at Tihange (Huy), within the Central Condroz Inlier. Six fossiliferous beds have yielded a low-diversity brachiopod-dominated association. Besides the brachiopods (*Eostropheodonta hirnantensis*, *Plectothyrella crassicosta*, *Hirnantia* sp., and *Trucizetina*? sp.), one trilobite (*Mucronaspis* sp.), four pelmatozoans (*Xenocrinus* sp., *Cyclocharax* (col.) *paucicrenulatus*, *Conspectocrinus* (col.) *celticus* and *Pentagonocyclicus* (col.) sp.), three graptolites (*Cystograptus ancestralis*, *Normalograptus normalis* and ?*Metabolograptus* sp.), together with indeterminate machaeridians and bryozoans were identified. Prior to this work, an Hirnantian age was proposed for the Tihange Member based on the *Hirnantia*-Fauna brachiopods, the stratigraphical position overlying the upper Rawtheyan (uppermost Katian) Faulx-les-Tombes Member and underlying the Silurian Bonne Espérance Formation; in addition, the lithological succession reflects a relative sea level drop consistent with the pronounced glacio-eustatic sea-level fall, globally, recorded in Hirnantian sediments. Nevertheless, the graptolites now reported are indicative of the *Akidograptus ascensus*-*Parakidograptus acuminatus* combined biozone, suggesting an early Rhuddanian (Rh1 stage slice) age for the uppermost part of the Tihange Member, an unexpectedly late occurrence of a typical *Hirnantia* Fauna. Assuming an early Rhuddanian age for the upper part of the Tihange Member, we propose different hypotheses to explain this (apparent or not) incongruent occurrence of normally temporally separated faunal-representative assemblages. Based on all the available data, a relict *Hirnantia* Fauna is the most robust interpretation. This Belgian association may represent an additional example of relict *Hirnantia* Fauna in the Silurian, sharing characteristics with the only other known from Rhuddanian rocks at Yewdale Beck (Lake District, England), although reworking has not been completely ruled out. The survival of these Hirnantian taxa into the Silurian might be linked to delayed post-glacial effects of rising temperature and sea-level, which may have favored the establishment of refugia in these two particular regions that were paleogeographically close during the Late

Ordovician–early Silurian.

Keywords: Ordovician–Silurian boundary, Rhuddanian, graptolites, biostratigraphy, refugia

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The first Iberian cyclopygid trilobites: an unexpected record from the 'shallow' peri-Gondwana

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Abstract

The highly specialized Cyclopygidae trilobites characterized Ordovician deep-water environments. The usefulness of the so-called 'cyclopygid biofacies' to infer bathymetric limits and paleoenvironments has been widely demonstrated. This group of mesopelagic trilobites occupied estimated depths between 200 to 700 m, although some records suggest they could inhabit slightly shallower environments. During the Early and Middle Ordovician, cyclopygids typified the ocean-facing upper part of the continental slope and deep marginal basins on the high and mid-latitude margin of Gondwana and peri-Gondwana terranes, becoming widespread during the Late Ordovician, particularly in Katian times, just prior to the Hirnantian extinction.

Cyclopygids have hardly ever been found in Ibero-Armorica, contrary to what occurred on other high-latitude peri-Gondwana regions (e.g., Bohemia, Morocco). Even in deeper-water assemblages, such as the *Foliomena* Fauna from the late Katian of the Portuguese Central Iberian Zone, cyclopygid trilobites remain absent. In the French Armorican Massif, cyclopygids were only reported from two Darriwilian and Katian localities of southeastern Britain (Ancenis and Châteaupanne) set in a complex Carboniferous mélange zone.

Herein we describe the only known cyclopygid trilobites recorded from Iberia, coming from two localities of the Ossa-Morena Zone of the southwestern Iberian Massif. The first locality, Venta del Ciervo (Huelva), belonging to the upper Tremadocian Barriga Formation, yielded one single exoskeleton, representing a new undescribed *Heterocyclopyge* species retaining a primitive number of six thoracic segments instead of five. This is the oldest record for the genus. The new species strongly resembles the five-segmented *H. shelvensis* (Whittard) from the Darriwilian Hope Shales of Shelve Inlier (Wales), also bearing some similarities with other cyclopygid genera. No additional trilobite specimens were ever recovered from this Iberian unit. The second locality, in the Cerrón del Hornillo Syncline (Seville), belongs to the upper Katian 'Pelmatozoan Limestone' Formation and yielded *Symphysops* cf. *armata* (Barrande) and *Cyclopyge* sp. This low-diversity assemblage is composed almost entirely (95%) of the trilobite *Cekovia perplexa perplexa* Hammann, and, to a lesser extent, cyclopygids, a microdomatid gastropod and fragments of brachiopods, crinoids, bryozoans and ostracods.

The occurrences of cyclopygid trilobites in Iberia are relevant to determine peripheral continental sites with free access to the open ocean, being a key element for pre-Variscan palaeogeographical reconstructions of southwestern Europe. Their restriction to the Ossa-Morena Zone supports its more distal position in relation to the neighbouring Central Iberian-Zone, being the two areas juxtapositioned by tectonics during the Variscan Orogeny.

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Keywords: Ossa-Morena Zone, Cyclopygid Biofacies, Tremadocian, Katian, Ibero-Armorica

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The Ordovician ocean circulation: a modern synthesis based on data and models

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Abstract

Surface currents constitute an efficient transport agent for (larvae of) marine faunas, while the circulation of water masses in the ocean interior drives nutrient redistribution and ocean ventilation and largely contributes to shaping surface biological productivity and the benthic redox landscape. Therefore, the robust understanding of ocean circulation, both shallow and deep, and of its response to climate change, is required to interpret paleobiogeographic signals, biological productivity patterns and biodiversity trends. This is especially critical during periods of dynamic biological change, such as the Ordovician. Yet, the ocean circulation leaves no direct evidence in the geological record and can therefore be reconstructed solely based on indirect indicators, such as the distribution of faunas and geochemical proxies. General circulation models offer independent, physically robust insights onto the coupling between climate change and ocean circulation. Integrated approaches based on the assimilation of geological data in numerical models thus constitute a promising way forward. We here provide a literature review and updated synthesis of the current understanding of the Ordovician ocean circulation, based on data and models.

Keywords: Ocean circulation, paleobiogeography, general circulation models

Exploring feedback loops among ecological niche evolution, dispersal, and speciation using Late Ordovician brachiopods of eastern Laurentia

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Abstract

Quantifying the relative stability of ecological niches of taxa during intervals of environmental change is important for understanding of how taxa and communities change through time. In this study, we used ecological niche modeling to quantify trends in niche dynamics and the stability of eastern Laurentian brachiopod genera during the Sandbian through Katian Stages of the Late Ordovician.

Niche dynamics were quantified using ordination methods to assess niche stability, expansion, and unfilling between time slices, and D and I statistics were calculated to assess niche similarity and equivalency between time slices. Brachiopod genera exhibited substantial niche expansion and limited niche stability between their reconstructed Sandbian and early Katian niches. Conversely, comparisons between early Katian and late Katian niches indicated high levels of niche stability, similarity, and equivalency but limited niche expansion or unfilling.

Niche patterns are best explained by a feedback loop linking tectonics, sea level, and climate with geographic connection and disconnection of depositional basins, speciation, and dispersal processes. During the Sandbian to early Katian interval, intermittent dispersal events between basins alternated with basin isolation, fostering increased diversification, which manifests as genus-level niche expansion. During the late Katian, basin connectivity increased, facilitating widespread regional dispersal events. The lack of isolation and spread of invasive taxa hindered speciation, thus diminishing niche expansion, resulting in increased genus-level niche conservation. These results indicate that generic niche analysis can be a useful proxy for underlying diversity dynamics. Investigations of niche response over long intervals should consider both broader ecological and geographic context that incorporates the influence of diversity and dispersal.

Keywords: paleoecology, niche stability, niche expansion, Late Ordovician

The Ordovician of Serbia

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Abstract

The Ordovician of Serbia has not been documented until the second half of the 20th century. During these systematic investigations of the older Paleozoic in Serbia, the first biostratigraphic data has been collected and used for interpretation and correlation of Ordovician rocks. The Ordovician formations are located in the central parts of the Carpatho-Balkanides and Dinarides, both representing different realms of the Alpine orogen formed by collisional processes during post-Cretaceous time. Due to Alpine, and also Variscan events, the Ordovician successions are often intensely deformed making observations challenging. Nevertheless, parts of the Ordovician system have been documented so far based on the lithostratigraphic correlation and various paleontological material (i.e., brachiopods, rare trilobites, acritarchs) collected from several localities in the Carpatho-Balkanides of east Serbia. The low-metamorphosed rocks of Lower and Middle Ordovician are interpreted as littoral siliciclastics deposited in a high energy environment, while the Upper Ordovician is represented by fine-grained rocks of calm depositional setting. The situation in the Dinarides of west Serbia is partially obscured by higher degree of metamorphism but Lower Ordovician acritarchs are described from the Paleozoic of the Drina-Ivanjica composite tectonic unit. The stratigraphic division into stages in both realms was mainly undertaken in the regional context of central and south-eastern Europe. In addition to stratigraphic data, the paleomagnetic investigations allowed reconstruction of the paleogeographic position of some of the studied successions in the Carpatho-Balkanides. The primary location of deposition of the Lower and Middle Ordovician rocks was calculated to about 20-30° south of the paleoequator, equally distant between Gondwana and northern Europe at a span ranging from 5.000 to 5.500 km.

Some of the next steps in research of the Ordovician of Serbia could be taken into the paleontological studies aimed at better correlation of studied sections with other localities in Europe and elsewhere and also the potential recognition of major events of biodiversification and extinction.

Keywords: acritarchs, Carpatho-Balkanides, Dinarides, Ordovician

A temporal framework for the Mid–early Late Ordovician of Baltica

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Abstract

Two limestone cores – the Kårehamn P4 and Tingskullen-1 – from Northern Öland, Sweden, have been studied using an integrated bio-, chemo- and cyclostratigraphical approach. The studied succession covers the Dapingian–upper Sandbian interval (*Baltoniodus triangularis–Amorphognathus tvaerensis* conodont biozones). An XRF-corescanner was applied to identify changes in elemental concentrations at the mm-scale specifically with the purpose of searching for fluctuations in detrital elements and carbonate content as an indirect means of climatically induced orbital changes. Together with the ^{13}C data this facilitated the recognition of a 405 kyr-eccentricity framework that forms the basis for a correlation across the Ordovician Baltoscandian Palaeobasin based on high-resolution conodont and chitinozoan biostratigraphy, as well as ^{13}C- chemostratigraphy. This reveals the temporal dynamics of an intra-cratonic setting that became increasingly affected by the rising Caledonides.

As our cyclostratigraphical framework can be anchored using existing U/Pb ages from known biostratigraphically well-defined horizons in the Baltic successions it allows for an astrochonologically calibrated geochronology through this important phase of the GOBE.

Keywords: Dapingian–Sandbian, XRF-corescanner, cyclostratigrapy, astrochonology, GOBE

Palynology of the Ordovician–Silurian boundary, Paraná Basin: glacial / post-glacial transition

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Abstract

Moderately preserved palynological assemblages were recovered from the Iapó and Vila Maria formations, Rio Ivaí Group, Ordovician – Silurian boundary, Paraná Basin. The majority of studied palynomorphs were recovered from Aldeia creek and Três Barras Farm sections, both located in Bom Jardim de Goiás Municipality, Goiás State, Brazil. The glacial deposits of the Iapó Formation, Upper Ordovician, include conglomerates, diamictites, and shales with dropstones underlain by transgressive shales, siltstones, and sandstones of the Vila Maria Formation, Lower Silurian. In South America, the composition and taxonomic details of palynological assemblages from the Ordovician – Silurian interval are poorly known, except research from deposits of Argentina. The taxonomic study allowed the identification of 51 species of palynomorphs comprising cryptospores, chitinozoans, acritarchs, prasinophytes, scolecodonts and undetermined organic fragments. In an unprecedented way, the diversity of palynomorphs of the Iapó Formation totals 30 species comprising cryptospores, acritarchs, prasinophytes and fungi. Greater diversity was observed for the Vila Maria Formation, totaling 44 species distributed among cryptospores, chitinozoans, acritarchs and prasinophytes and scolecodonts. Indeterminate organic fragments are reported for both formations. The analysis of the stratigraphic distribution of the species indicates a continuous transitional deposition between the Iapó and Vila Maria formations, since, of the total of 51 species, 24 are shared between the two formations. Some of these species persist throughout the transgressive shales of the Vila Maria Formation. Additionally, the stratigraphic distribution of chitinozoan species allowed to present a chronostratigraphic framework covering the Hirnantian - Rhuddanian - Aeronian interval. The Hirnantian - Rhuddanian interval was recognized in the lower portion of the basal shales of the Vila Maria Formation through the occurrences of *Spinachitina* cf. *S. oulebsiri, Spinachitina* cf. *S. verniersi* and *Plectochitina* cf. *P. longispina*. The Hirnantian - Rhuddanian limit was assigned from the record of occurrence of *Spinachitina debbajae*. Additionally, the base of the Aeronian was suggested from the occurrence records of *Sphaerochitina silurica* and *Sphaerochitina* sp. A. The analysis of the abundance between the elements of marine and continental origin allowed to infer the dominance of marine elements throughout the studied section. Three palaeoenvironmental scenarios were inferred: glacio-marine, marine under glacial influence and post-glacial. The proximal glacial marine context attributed to the depositional environment of the Iapó Formation related to diamictites and shales with dropstones. The marine under glacial influence context attributed to the deposition of the lower portion of the basal shales of the Vila Maria Formation, characterized by cold water conditions evidenced by the occurrence of chitinozoans common to low-latitude deposits. Finally, the post-glacial context related to offshore conditions evidenced from the reduction in the diversity of palynomorphs and the positioning of the maximum flood surface defined through the geochemical analysis.

Keywords: Palynomorphs, Ordovician–Silurian boundary, Paraná Basin, Iapó Formation, Vila Maria Formation.

Morphological background of the Ordovician radiation in pelmatozoan echinoderms

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Abstract

The explosive growth in the number, taxonomic and morphological diversity of the benthic skeletal fauna in the Ordovician was associated with a sharp increase in organogenic-detrital carbonate deposits. This explosive growth was due to the emergence of a positive feedback between organogenic-detrital grounds, consolidated and solidified through the mediation of cyanobacteria, and the animal community that settled on them. This positive feedback became possible, first of all, due to the sharply increased calcite productivity of pelmatozoan, or stemmed, echinoderms (Blastozoa + Crinozoa) and the appearance of bryozoans. As a result, from the Middle Ordovician, organogenic-detrital sedimentation began to prevail over terrigenous in many shallow seas, especially in the cold-water Baltic and warm-water Laurentia. The rapid increase in the calcite productivity of stemmed echinoderms was associated with a noticeable increase in the size of individuals and with a rapid reproduction of numerous small paedomorphic forms, in which the period of puberty was noticeably reduced. Both of these evolutionary processes were accompanied by the emergence of new important morphological features or the improvement of those that appeared earlier. Many morphologically similar new adaptations appeared in parallel in various groups of echinoderms on a different morphogenetic basis. The main morphological novelties were associated with improvement of the food-gathering system, which made it possible to increase the size of the body and the rate of its growth, lengthen the stem and strengthen its attachment to the ground for the possibility of collecting food in the higher tiers of water and life in moving water, and the enhancement of the respiratory system. Improvement of the food-gathering system consisted in the appearance of arms in crinoids, their further branching and pinnulation. In parallel, branching and "pinnulation" of brachioles took place in a part of blastozoan echinoderms, accompanied by an increase in the width of the food-collecting grooves. In crinoids, a true stem was formed, first pentameric and then holomeric, with a well-defined five-chambered organ in the axial canal and several growth zones. At the end of the Early and Middle Ordovician, almost all possible variety of holdfast was formed, including branching in crinoids and hemicosmitid rhombiferans. Strengthening of the respiratory system was associated with the formation of thin folds near the junction of the ossicles, the system of suture pores, diplopores and pore rhombs. A special type of strengthening of the respiratory system is associated with a significant thinning of the stereome with a simultaneous flattening of the theca, which we observe in rhipidocystids. The flat theca with a thin stereome allowed oxygen to osmotically penetrate the interior of the animal and more easily reach the internal organs.

This study was supported by the Russian Science Foundation (project no. 19-14-00346).

Keywords: Great Ordovician Biodiversification Event, Crinoidea, Blastozoa, morphology, adaptation, calcite productivity

Diversity analysis of middle Floian conodonts from Precordillera and Cordillera Oriental, Argentina

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Abstract

A number of factor affects the completeness of the fossil record, such as the regime of depositional environments, diagenetic processes and tectonic events, which overprint and condition biodiversity as documented at local and regional scales. The Precordillera and the Cordillera Oriental basins are located in northwestern Argentina, separated by about 300 km nowadays. The compared diversity analysis of the conodont faunas from these basins is restricted to the middle Floian stage slice (Fl2), corresponding to the synchronous biostratigraphic intervals of the *Oepikodus evae* Zone (*Juanognathus variabilis* Subzone) and the *Gothodus andinus* Zone, respectively. Diversity patterns are generated from the absolute frequency of conodont species collections either from published articles or under study. The conodont fauna from the Precordillera was recovered from the middle part of the San Juan Formation that represents a carbonate open-platform environment. About 50 species, mainly cosmopolitan taxa, were recorded from ca. 50 m stratigraphic thickness of the referred subzone. Comparatively, the correlative biostratigraphic interval of the Cordillera Oriental spans ca. 300 m in the middle-upper section of the Acoite Formation, mainly represented by laminated shales, sandstones, and occasional coquinas. These rocks yielded about 20 species dominated by endemic taxa of middle to inner shelf environments. Only seven conodont species are shared by contemporaneous communities of the Precordillera and Cordillera Oriental, whose fossil assemblages present low similarity and high complementarity values. The global marine transgression, lower latitudinal position and open ocean environment favored the higher richness of the Precordillera during the Floian. Conversely, the lower richness of the Cordillera Oriental is related to a terrigenous-influenced depositional environment at higher latitudes, with lower temperatures alongside Southwestern Gondwana.

Keywords: conodont diversity, Floian, *Gothodus andinus* Zone, *Oepikodus evae* Zone, Argentina

Fossil preservation in the Fezouata Shale with implications in understanding the early stages of the Ordovician Radiation

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Abstract

The Fezouata Shale (Early Ordovician, Morocco) is a unique site that preserved a diverse assemblage of soft parts at the transition between the Cambrian Explosion and the Ordovician Radiation. Herein, classical sedimentological approaches and a large spectrum of microanalyses techniques are applied to investigate the preservation of this assemblage. Fossils from the Fezouata Shale share the same mode of preservation with Cambrian Burgess Shale-type sites defined by carbonaceous compressions and accessory authigenic mineralization. However, the mechanism of preservation (e.g., flow dynamics) is different. Using probabilistic approaches, it is shown that the mechanism for soft part preservation in the Fezouata Shale under-preserved fully cellular taxa such as jellyfishes while preserving equally different modes of life (i.e., endobenthic, epibenthic/nektobenthic, and planktonic/nektonic). This is not observed within the Walcott Quarry (Cambrian, Canada), one of the most famous fossil sites, in which the mechanism for exceptional preservation allowed for the conservation of entirely cellular taxa while underestimating the nekton. Accounting for these preservational biases made it possible to investigate community assembly within the Fezouata Shale and draw conclusions highlighting the complex initial stages of the Ordovician Radiation.

Keywords: Ordovician, ecology, taphonomy, exceptional preservation

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Atlas of the Ordovician World

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Abstract

The Ordovician was a time of extremes. Beginning with a stifling hothouse where tropical temperatures often rose above the lethal limits for marine plankton (39˚C) and ending in a killer icehouse (Hirnantian Ice Age) that saw the South Polar Ice cap extend into tropical latitudes (35˚S) and wipeout out most of the warm-adapted shallow water fauna (46% extinction). The Hirnantian extinction event ranks second in terms of taxonomic severity

(~46% marine genera extinct). Only the Permo-Triassic Extinction (58% marine genera extinct) was more cataclysmic.

Like the modern world, the Ordovician was characterized by widely dispersed continents separated by growing ocean basins. Subduction zones ringed the continents and active, volcanic island arcs formed the perimeter of rapidly opening and closing back-arc basins. Unlike the modern world, however, the northern hemisphere was largely empty (only 10% continental). Ordovician continents were arrayed along the equator and the Gondwana supercontinent covered much of the southern hemisphere. During the Early Ordovician (~480 Ma) more than 21% of the Earth's surface was covered by shallow seas (a maximum for the Phanerozoic); 75% of those epeiric seas were located in the tropics. Shallow marine faunas diversified (GOBE) and expanded across these immense flooded continental platforms. All was going well until the latest Ordovician, when the Khione bolide, larger than the Chicxulub impactor, smashed into the Panthalassic Ocean plunging the Ordovician world into a relatively short-lived (a few million years), extreme ice house.

In this talk we will present an "Atlas of the Ordovician World" with maps illustrating: active plate boundaries, the rate and direction of plate motions, the depth and age of the ocean basins, the topography of the continents, the extent of land and shallow sea, the pattern of surface ocean currents, the temperature profile of the oceans, the location of major upwelling zones, pole-to-equator temperature gradients, the temperature of the sea surface and land, the pattern of rainfall and runoff, seasonal changes in the direction of surface winds, and the extent of the late Ordovician polar ice cap. In addition, an attempt will be made to relate the physical conditions that prevailed during the Ordovician to the changing biogeography of the Ordovician seas, the origination of land flora and fauna, and the evolution, diversification, expansion, and ultimate extinction of marine taxa.

Keywords: plate tectonics, paleogeography, paleoclimate, paleoceanography, paleobiogeography

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Ordovician cyclostratigraphy and astrochronology: a synthesis

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Abstract

Cyclostratigraphy is an important tool for understanding astronomical climate forcing and reading geological time in sedimentary sequences, provided that an imprint of insolation variations caused by Earth's orbital eccentricity, obliquity and/or precession is preserved (Milankovitch forcing). Understanding astronomical climate forcing has proven fundamental for the study of Cenozoic climate systems and the construction of high-resolution continuous time scales (astrochronologies) with 10^4 year precision. Pre-Cenozoic astrochronologies face several challenges relating to (1) uncertainties in the deep-time astronomical solutions and parameters; (2) less-complete and less-well-preserved strata; and (3) the sparsity of

geochronologic anchor points. Consequently, Paleozoic astrochronologies are typically based on identification of the stable 405 kyr eccentricity cycle instead of shorter astronomical cycles, which have the potential to provide an order-of-magnitude increase in temporal resolution.

Here, a state-of-the-art overview and compilation of Ordovician cyclostratigraphy and astrochronology is presented, as well as suggestions on how to apply these techniques robustly in the Ordovician context. Pioneering publications started in the early 1990's, with a strong increase in number of related publications from the 2010's. Besides the number of publications, also the extent of acquired data and analysis complexity has increased. Ordovician astronomically driven climate dynamics are suggested to have influenced processes like sea-level variations, changes in biodiversity and glacial dynamics. Ordovician cyclostratigraphic studies can also help to construct high-resolution numerical time scales (astrochronology), ideally in combination with high-quality radio-isotopic dating. As such, cyclostratigraphy is becoming an increasingly important part of an integrated stratigraphic approach to help disentangle Ordovician stratigraphy and paleoenviromental changes.

Keywords: Ordovician, cyclostratigraphy, astrochronology, integrated stratigraphy, paleoclimate

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The evolution of early *Zygospira,* one of the earliest spire-bearing brachiopods in North America

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Abstract

Although the mid-Paleozoic spiriferides and atrypides are perhaps the best know of the Paleozoic spire-bearing brachiopods, the earliest spire-bearers evolved during the Katian. The early evolution of this lineage remains understudied, in part because of their small size making collection more difficult but also due to our lack of knowledge of the spiralia in the shell interior that supported the filter feeding organ in these brachiopods.

***Zygospira* was one of these early spire-bearing brachiopods that was relatively common in the shallow carbonate platforms and basins of eastern North America and less common in the equatorial epicontinental seas that covered the interior of the continent. Similar to other Ordovician brachiopod lineages, *Zygospira* species became progressively larger towards the end of the Katian with the largest, *Z. kentuckiensis*, being approximately 50% larger than the type species *Z. modesta* earlier in the Katian. Unlike other brachiopods during this**

time, this increase in size was only evident in eastern North American species. Shells from the interior evolved a more elongate shell with more numerous ribs. This pattern of evolution is also the opposite of other brachiopods common in the same settings.

This divergence may be related to the evolution of the spiralia in this lineage. *Zygospira* has a distinctive jugum that connects the base of the spires that may have supported the mouth part of the brachiopod in life, a trait that is common in other North American atrypide lineages but absent in most species elsewhere in the world. As such, modifications to this structure and to the shapes of the spires themselves could represent major shifts in filter feeding and perhaps ecology of these brachiopods.

A better understanding of the evolution of key morphological features of these early spire-bearers may provide insight into the evolutionary pressures acting on the shallow marine fauna in different paleogeographic settings during the Ordovician when most Paleozoic brachiopod orders first evolved.

Keywords: brachiopod, evolution, Katian, Atrypida, Anazygidae

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A review of the Late Ordovician (Katian) Richmondian Invasion of eastern Laurentia

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Abstract

Biotic Immigration Events (BIMEs) in which a group of organisms that originated in one geographic region invade and become established in a new geographic region are common in Earth history, and many such events have been documented from the Middle and Late Ordovician, in particular. One of the best studied of these events is the Richmondian Invasion, which constituted a several waves of biotic invasion from mutliple source regions into the Cincinnati Basin of eastern Laurentia during the Katian Stage. The major features of this invasion were first appreciated in the early 1900's and have received significant study since that time. General patterns of the Richmondian invasion, including the influx of over 50 taxa that span ecological roles and taxonomic groups, the significant restructuring of paleocommunities, and differential survival of generalist taxa relative to specialist taxa, have been well documented and establish this invasion as a « coordinated invasion » within the Invasion Hierarchy of Stigall (2019).

Substantial research to further delineate and clarify the details of the Richmondian Invasion has progressed on multiple fronts over the past two decades. These novel analyses into sedimentology, stratigraphy, and geochemistry coupled with detailed paleoecology, evolutionary, and biogeographic studies provide a framework for increased synthesis and understanding of invasion dynamics during this interval. This presentation will provide a general overview of the current state of knowledge of the Richmondian Invasion and outline some of they key implications for other intervals of Earth history.

Keywords: Ordovician, speciation, Biotic Immigration Event, paleocommunity, coordinated invasion

Trilobite enrollment evolution and morphological diversification as a GOBE consequence

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Abstract

Enrollment has been an adaptative behavior implemented by a high range of animals. Trilobites were one of the first organisms to use this adaptative behavior, recording the first appearance in the early Cambrian. We have analyzed in detail all different enrollment styles used by trilobites from Cambrian to Ordovician times within an ecological framework. Our methodology is based on the use of geometric morphometrics and multivariate statistics to assess the morphological trends. Our results suggest a clear differentiation between Cambrian and Ordovician enrollment styles, reflected in the diversity and disparity of morphology and in the morphospace occupation, as well as different ecological occupation by trilobites using different enrollment styles. This differentiation seems to be closely related with the Great Ordovician Biodiversification Event, when new adaptions appeared in trilobites.

Keywords: trilobites, enrollment, Ordovician, morphology

Rhythmic bedding and potential parasequences in peritidal-shallow subtidal facies of the Ordovician (Sandbian) Crown Point Formation of northeastern New York state, USA

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Abstract

The Darriwilian–Sandbian Chazy Group consists of relatively shallow-water carbonates deposited during an interval of tectonic stability immediately before the onset of significant Taconic-associated subsidence in the Lake Champlain region of northeastern New York, USA. The Sandbian Crown Point Formation is the middle of three formations in the Chazy Group, comprising the highstand (HST) and falling stage (FSST) systems tracts of the M1A sequence, a third-order sequence boundary, and the transgressive systems tract (TST) and part of the HST of the overlying M1B sequence. Bioherms were developed in the upper portion of the Crown Point Formation (M1B TST) at multiple localities, laterally separated by thicker successions consisting of biomicrites that were deposited in peritidal to shallow subtidal (inner to middle storm-influenced ramp) settings. To date, stratigraphic research has concentrated nearly entirely on the biohermal sections of the Crown Point Formation, with little attention paid to the sedimentology and refined stratigraphy of inter-bioherm sections. The present study focuses on a non-biohermal section of the upper Crown Point Formation, located north of Plattsburgh, Clinton County, New York, that is relatively complete and allows stratigraphic patterns of meter- to sub-meter scales to be documented. The M1B TST is expressed as a series of dense, tabular limestone beds displaying an internal tripartite division: a basal coarse biosparite with a relatively diverse open-marine fauna; a middle, thicker, dark gray biomicrite-biosparite (packstone-grainstone) composed of comminuted crinoid ossicles; and an upper sparsely fossiliferous, bioturbated biomicrite (wackestone) with discontinuous dolomitic laminae. These appear to be upward-shallowing rhythms (i.e., parasequences) and are tentatively correlated to the horizons from which bioherms initiated growth elsewhere. The overlying HST is much thicker and is dominated by roughly meter-thick, very argillaceous dolomitic limestone beds. An idealized internal pattern consists of a basal set of several 10-20 cm-thick biomicrites (wackestones-mudstones) that become increasingly argillaceous upwards, overlain by a thicker (~50-60 cm) biomicrite that becomes oncoidal in its upper half, capped by a thin interval of micritic limestone interbedded with dolomitic laminae. This thick HST package is interrupted by a return to argillaceous limestones with a more open marine fauna (probably representing a 4th-order TST) with a different rhythmite motif: a basal few centimeters of siliciclastic shale overlain by 2-3 decimeter-scale, highly argillaceous limestone beds with irregular contacts, capped by a thicker, less argillaceous limestone. These meter-scale rhythms also appear to represent parasequences. Collectively, these findings comprise the first detailed integrated sedimentologic and stratigraphic interpretation of non-biohermal facies of the upper Crown Point Formation and demonstrate that apparently rhythmic bedding in this interval can be reconciled with a sequence stratigraphic framework.

Keywords: Chazy Group, Crown Point Formation, sequence stratigraphy, carbonates, rhythmic bedding, Sandbian

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Discovery of rich Katian-Hirnantian jawed polychaete fauna from the Prague Basin, Czech Republic

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Abstract

Jawed polychaetes evolved and diversified extensively during the Ordovician. However, for many regions, Ordovician polychaete jaws (scolecodonts) have remained poorly documented. This applies also for the Prague Basin of peri-Gondwana, from where the last study on Late Ordovician scolecodonts was published more than 70 years ago, with just two species preliminarily identified.

We studied organic-walled microfossils from the boundary interval of Králodvor and Kosov formations (Katian–Hirnantian) at the Levín locality. We discovered that scolecodonts were much more diverse and abundant in these strata than previously thought and that the samples were also rich in chitinozoans with at least 15 taxa present. The recovered jawed polychaete fauna contains at least 17 species from 13 genera. The assemblage is taxonomically similar to the previously studied coeval Gondwanan faunas. Taxa with labidognath and prionognath type of maxillary apparatuses predominate in samples, whereas placognath and ctenognath taxa are relatively rare, which is in contrast to the Baltic polychaete faunas. Polychaetaspids predominate the Levín assemblage, followed by other families such as ramphoprionids, paulinitids, and atraktoprionids. The studied interval in the Levín section is represented by a succession of thin-bedded silty shales with various degree of bioturbation and practically devoid of shelly fossils. Reduced diversity and abundance of scolecodonts was recorded in the uppermost part of the Králodvor Formation, which correlates with lower intensity of bioturbation and finer silt fraction. The reported discovery shows wide geographical distribution and diversity of jawed polychaetes before and during the Hirnantian glaciation and mass extinction.

Keywords: Ordovician, Katian, Hirnantian, scolecodonts, jawed polychaetes, Prague Basin

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Links between bioerosion and oversized benthic fossils: insights from the Upper Ordovician of Estonia, Baltica

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Abstract

Baltica was possibly the birthplace of bioerosion. Rapid diversification of bioeroding animals took place during the Late Ordovician and was related to the availability of various substrates including shelly fossils. The lower boundary of the Upper Ordovician marks also the beginning of a major increase in the diversity of bryozoan endobionts. In this study we explore the idea that the diversity and abundance of bioerosional trace fossils were enhanced by larger size of shelly fossils.

We analysed the size of selected common shelly fossils, together with the distribution of bioerosional traces, based on large paleontological collections and previous research in

Estonia. Within the Upper Ordovician, two time intervals stand out for oversized or even gigantic fossils. Firstly, in the Kukruse and Haljala stages, middle Sandbian, huge trepostome bryozoans are common and include some of the largest colonies known from the Ordovician worldwide. Secondly, in the Vormsi and Pirgu stages, late Katian, oversized bryozoans, corals, gastropods, bivalves, and brachiopods are well known. Rugose and tabulate corals reach gigantic size in the next, Porkuni Stage, Hirnantian. In the Baltic region nine bioeroding ichnogenera are known from the Sandbian and six from the Katian, with distinct diversity peaks in the Kukruse-Haljala and Vormsi stages. On the other hand, Keila to Nabala stages are characterized by smaller average size of body fossils as well as less diverse bioerosional traces. Thus, in the pre-Hirnantian Upper Ordovician, there may be a link between the diversity of bioerosional traces and the size of body fossils.

The large body size of marine invertebrates has been explained by colder climate, elevated oxygen levels, high taxonomic diversity or other causes. We, too, cannot pinpoint a single factor controlling the large body size of benthic shelly fossils in Estonian succession. Most likely it was a coincidence of multiple factors, including water chemistry, oxygen availability, stability of the sea level and increasing phytoplankton availability. Regionally, low sedimentation rate, water circulation, coastal upwelling and input of nutrients from pyroclastic material may have supported larger body size – and enhanced bioerosion. However, for some long-lasting gastropod and brachiopod genera, the large size may be a result of gradual evolution rather than the environment. No bioerosional trace fossils have hitherto been reported from the Porkuni Stage, Hirnantian, suggesting that the end-Ordovician extinction had strong effect on various bioeroding taxa.

Keywords: Late Ordovician, bioerosion, trace fossils, Baltoscandia, shelly fossils, gigantism

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Hirnantian freshwater palynomorphs from Saudi Arabia: phylogenetics and paleoecology

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Abstract

Non-marine deposits of Lower Paleozoic age are somewhat rare when compared to Devonian and younger sedimentary sequences. In fact, it can be difficult to establish the non-marine character of a sedimentary deposit based on lithic characters alone. Palynological recovery can be helpful in this regard if a sample contains elements whose non-marine provenance can be established. Here we review a deposit from the Hirnantian of Saudi Arabia which is characterized by an overwhelming abundance of sphaeromorph acritarchs, but which contains significant numbers of *Moyeria* Thusu, which is known to belong to the photosynthetic euglenids (Euglenaceae). The palynoflora also contains a variety of acritarchs, whose biological affinities are unknown. Intriguingly, however, there are literally no typical

acanthomorph acritarchs in the palynoflora. Almost all euglenids today are freshwater in distribution, so we can now use the presence of *Moyeria* as indicator of freshwater provenance. This assumption facilitates the interpretation of some interesting taxa as being of possible freshwater origin. These include examples of hypnozygotes of Zygnematophycean algae (*Gelasinicysta* Head) in addition to coenobial Hydrodictyaceae and some poorly preserved examples of vegetative Scenedesmaceae. Thus, both phylogenetic branches of the green algae, chlorophyta and charophyta are represented in the assemblage. The Hirnantian occurrence of *Gelasinicysta* Head adds support to molecular data from extant species that infer *Zygnema* Agardh to be the sister group to the Embryophyta.

Keywords: Hirnantian, Saudi Arabia, acritarchs, palaeoecology, freshwater algae, terrestrialization

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New bioclaustration in trepostome bryozoans from the Late Ordovician (Sandbian) of Estonia

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Abstract

Bioclaustrations (i.e., embedment structures) formed by the living tissues of host organisms are among the best examples of symbiosis in the fossil record. In the Late Ordovician of Estonia, bryozoans often formed symbiotic associations with other invertebrates such as rugosans, cornulitids, and conulariids. Similarly, worm-like organisms left diverse bioclaustrations in the bryozoans. A new broad conical bioclaustration has been discovered from the growth surfaces of hemispherical trepostome colonies from the early Sandbian of Estonia. The base of the bioclaustration is connected to an irregular, somewhat pouch shaped boring. The new bioclaustration occurs in *Diplotrypa bicornis*, *Mesotrypa orientalis* and *Mesotrypa excentrica*. The organism responsible for the formation of bioclaustration either settled in an abandoned boring in a living bryozoan created by a different organism and then started to form a bioclaustration, or bored itself into the skeleton of the living bryozoan, then stopped boring and grew further at the same pace with the host bryozoan. The bioclaustration did not cause malformations in the bryozoan zooecia and lacked the strong negative effect on the host bryozoan. The broad conical shape of the body with radial symmetry as in sea-anemones (*Actiniaria*) and many corals suggests a cnidarian affinity for the symbiont.

Keywords: bioclaustrations, bryozoans, Baltica, Sandbian

Ordovician conodonts and ostracods from the Katkoyeh Formation at the Banestan Section, Kerman Province of East-Central Iran

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Abstract

Ordovician marine sedimentary sequences deposited in several widely separated structural blocks in Iran, along the northern margin of Gondwana. In the Kerman Province to the south of Tabas, the Ordovician sedimentary interval is known as the Katkoyeh Formation, which encompasses a ~70-300 m column of siliciclastic rocks with scarce carbonate and thick pyroclastic beds in its upper part. Few studies have focused on its fossil content, generally supported by the relative dating of conodont or graptolite spot samples. These provided variable ages ranging from the Tremadocian up to Hirnantian, and indicating the presence of regionally important stratigraphic gaps. In order to enhance the conodont biostratigraphy of the Katkoyeh Formation, new conodont samples were obtained from the Banestan Section, located about 12 km northwest of the city of Zarand, in the vicinity of the Banestan Village, in northern Kerman Province. There, the Katkoyeh Formation consists of ~150 m of silty shales, diabase, pillow lava, basaltic tuff, red sandstone, red silty claystone, marl, limestone and sandy limestone. It rests above the upper dolomites of the Kuh-Banan Formation and is in turn overlain by the Niur Formation, a lateral stratigraphic equivalent to the Shabdjereh Formation. Based on the occurrence of important biostratigraphic species, we determined three conodont intervals in ascending order in the Katkoyeh Formation, namely the 1) *Rossodus manitouensis/Paltodus deltifer* Zone (middle Tremadocian, Lower Ordovician), characterised by the eponimous species along with *Acanthodus lineatus* (Furnish), *A. uncinatus* Furnish, *Cordylodus angulatus* Pander, *C. caseyi* Druce & Jones, *Drepanoistodus* sp. and *Paroistodus* sp. The index species *R. manitouensis* Repetski and Ethington and *P. deltifer* (Lindström) are valuable for intercontinental correlation, with records in Laurentia, Baltica, China, Kazakhstan, Korea, Thailand, and the southern South American margin of Gondwana (e.g., Central Andean Basin and the Argentine Precordillera). Regionally, *P. deltifer* is also known from central (Derenjal and Kalmard Mountains) and north Iran (Alborz Region). The overlying conodont samples yielded 2) a Floian (Lower Ordovician) assemblage, characterised by *Bergstroemognathus extensus* (Graves & Ellison) and *Juanognathus variabilis* Serpagli; and 3) a Late Ordovician monospecific assemblage of *Icriodella superba* Rhodes. The latter is accompanied by two new species of ostracods: *Satiellina* n. sp. and *Ceratopsis* n. sp., both suggesting palaeobiogeographical affinities mainly with Gondwana and peri-Gondwana. The fauna discussed herein was obtained by two of us (A. Bahrami and F. Poursalehi), and makes up part of a larger PhD project at the University of Isfahan, providing new significant information on the biostratigraphy and intercontinental correlation of the Ordovician faunas of East-Central Iran.

Keywords: biostratigraphy, microfossil, Tremadocian, Floian, Katian, Gondwana

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The Ordovician of Argentina

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Abstract

Widespread early Paleozoic exposures, locally over 6.000 m thick, extending from Northeast Patagonia to Venezuela, represent the remnants of the early history of the active Proto-Pacific margin of Gondwana. Major geological units include autochthonous cratonic basins developed on and around the Gondwana basement (e.g. Cordillera Oriental and Sierras Subandinas that extend into Bolivia and Perú) and early Palaeozoic subduction-related volcanic arcs and associated volcano-sedimentary basins fringing Gondwana (e.g. Famatina–Puna arc, further extended to northern and central Andes). As well, crustal fragments accreted to the Andean margin of Gondwana through the Paleozoic are also involved (e.g. Cuyania terrane). In the context of South America, Ordovician successions and faunas from Argentina are comparatively well-known.

At the Northwest of Argentina, a large-scale retroarc foreland basin system developed during the Ordovician. From West to East this system includes several depozones represented by the Puna (volcanic arc and foredeep), Cordillera Oriental (peripheral bulge), and Sierras Subandinas (back bulge). A wealth of stratigraphical and paleontological information comes from the Cordillera Oriental. Widespread Furongian (Stage 10) –Dapingian successions are interpreted as shallow marine deposits punctuated by valley incisions and deltaic progradation. They provide interesting insights on diversity patterns and ecosystem structure during the interval. Middle Ordovician records and Hirnantian glacigenic deposits crop out as isolated remnants.

The Sierra de Famatina, the southern prolongation of the Puna magmatic arc, is regarded as a major volcanic chain, largely at sea level, located on continental crust. Preserved stratigraphy encompass Furongian (Stage 10) to Tremadocian siliciclastic rocks and Floian–Dapingian volcanic and volcanoclastic deposits in discontinuous and largely disconnected outcrops, increasingly deformed towards the North of the basin. This over 3000 m thick succession has been interpreted as a back arc foreland basin fill. Environmental conditions in this arc-related setting triggered differential diversity trends among disparate fossil groups.

Finally, the Cuyania microplate (extended Precordillera terrane) has been interpreted as a drifted-rifted crustal block from the southeastern Laurentia that accreted to western Gondwana by Middle–Late Ordovician time. Its most outstanding feature is the c. 2500 m thick succession of Cambrian (basal Series 2) to Middle Ordovician passive-margin, shallow water platform carbonates. This succession is overlain by siliciclastic deposits and olistostromes representing deeper slope and basinal environments, finally capped by Hirnantian glacial deposits. Ordovician stratigraphy preserved in Precordillera is almost

complete and facies and faunas broadly mirror its drifting, collisional, and post-collisional history.

In sum, there is a lot of disparity in the preserved stratigraphic record of each basin, as well the stratigraphical and paleontological knowledge is uneven among them because of multiple reasons (tectonic deformation, depositional gaps, dense forest cover, lack of fossils, etc.). Global chronostratigraphical stages of the Ordovician System and their boundaries are currently recognized, but with different degrees of resolution depending on the region and interval considered. In general terms, the biota, patterns of diversification and paleoecological signals are fairly idiosyncratic to each basin probably due to contrasting geodynamic contexts and depositional settings.

Keywords: Northwest Basin, Famatina, Precordillera, biota, diversity

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Short- and long-term climate change driven by volcanism at the en-Ordovician in South China

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Abstract

It is widely believed that the late Ordovician mass extinction was widely linked to dramatic changes in climate, especially temperature. Large scale volcanism which led to releasing of greenhouse gases have proven to play a key role in controlling temperature shifts in geological history. However, the high frequency of volcanism recorded by volcanic ash deposited at the end of the Ordovician significantly predates and is not concentrated around the LOME, which seems to weaken the impact of volcanism on the LOME.

To better understand the relationship between volcanism, the climate and biological evolution in the end Ordovician, geochemical analyses of an Ordovician–Silurian sedimentary succession in the Upper Yangtze region in South China are conducted. The results show that the high frequency volcanic ash interlayers occurred in the Katian graptolite *P. pacificus* (Lower Subzone) and *T. typicus* biozones, coinciding with the Boda warming Event. Moreover, significant negative shift of organic carbon isotopes has been widely observed in these graptolite biozones in South China in recent years, which might reflect a perturbation of the global carbon cycle caused by CO_2 released from volcanic eruptions. After volcanism weakened, the proxy of clastic flux (Ti/Ca) and chemical index of alteration (CIA) increased significantly and lasted to the lower boundary of Hirnantian, which is consistent with the intensification of global weathering revealed by the osmium (Os) and lithium (Li) isotopic systems in equivalent levels from Laurentia. Therefore, a model of short- and long-term climate effects caused by volcanism at the end-Ordovician in South China provides a potential explanation for the above phenomenon. That is, the CO_2 released by volcanism briefly interrupted the long-term cooling and led to temporary warming. Subsequent climate feedback effects, i.e., the increased weathering of erupting magmatic rocks, might have reduced the atmospheric CO_2 concentration and induced the Hirnantian glaciation, which eventually triggered the biological crisis at the end-Ordovician.

Keywords: mass extinction, weathering, climate feedback effect, CO_2, glaciation

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Taphonomy and record of Ordovician invertebrates in Paraná Basin, Brazil: new findings

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Abstract

The end of the Ordovician is marked by a global glacial event that represents one of the five mass extinctions that punctuated the history of life. The records of this lattermost Ordovician glaciation are characterized by diamictites and sandstones followed by fine-grained lithologies, usually dark shales. In South America recent evidence from several fossil groups tends to date the glacial event as Hirnantian. This work presents research on the Rio Ivaí Group, mostly from data collected at two outcrops located on the northwestern part of the Brazilian Paraná Basin. Outcrop 1 is located at Barra do Garças City, Mato Grosso State, and the outcrop 2 occurs at the Bom Jardim de Goiás Municipality, Goiás State. In both sections, diamictites, orthoconglomerates and sandstones are succeeded by shale with dropstones, interpreted as being deposited under subaqueous conditions. The dropstones are sourced from melting icebergs, and the glacially influenced facies were deposited in marine settings as indicated by the fossil content (presence of discinoids). The post-glacial period is marked by transgressive deposits, represented by massive or thinly laminated mudstones deposited in offshore settings. Although both outcrops have the similar rock successions and stratigraphy, they differed significantly in their fossil content. Bioerosion, corrasion, rounding, and dissolution were not present in any collected bioclasts. Two taphofacies could be erected and are described as follows: the taphofacies 1 is represented by type and size-selected, disarticulated, and fragmented fossils carried (allochthonous) by currents formed by the melting glacier. This taphofacies is found at section 1, and represents the transitional offshore setting, developed between the fair-weather wave-base and the storm wave-base. Tf1 is abundant in discinoid brachiopods (*Kosoidea australis*). Taphofacies 2 occurs at section 2 and is represented by articulated or life-positioned fossils, autochthonous to para-autochthonous; in most of the section no glacier influence these sediments, that represent an offshore setting, below the SWB in a transgressive post-glacial setting. Tf2 has bivalves (?*Paleoneilo*, ?*Cuneamya*) and ostracods (*Satiellina paranaensis*, *Harpabollia* sp.) as the most common fossils. Faunal affinities are difficult to establish because of the paucity of the Brazilian´s fossil record compared to other South American basins. However, the fossils here described suggest affinities with the low diverse Bani-type assemblages.

Keywords: taphofacies, glacial influence, low diversity

Evolution and diversity of Late Ordovician brachiopods in the Latvian shallow sea shelf.

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Abstract

The position of the territory of the modern day Baltic states was located close to the equator, moving from 40º south, during the span of the Ordovician period. Latvia was in the central part of the Baltic palaeobasin with sea levels ranging from deep sea, to littoral zones, due to several sea transgressions and regressions. As a result, the Baltoscandian territory has a vast array of marine facies zones. There are significant lateral changes in facies belt deposits in the modern day territory of Latvia, with evident changes in brachiopod communities. The main deposit types of this region are limestones, marlstones, and mudstones, but dolostones, argillite, and clays are also commonly found. Most brachiopod samples are acquired from cores due to the only Ordovician outcrops in the Baltics being found in northern Estonia.

Over 1000 brachiopod samples were collected and analysed, spanning 7 regional stages of the Upper Ordovician (Haljala, Keila, Oandu, Rakvere, Nabala, Vormsi, and Pirgu), from 8 different drill-cores from eastern Latvia and southern Estonia (Karula 320, Baltinava 17, Ludza 15, Moroziki/Berzini 33, Kraslava 104, Malta 105, Mezciems, and Atasiene 9). A range of statistical analyses were done, including an Incidence based rarefaction analysis and extrapolation of diversity, Zipf-Mandelbrot model of ranked occupancy distributions, and Nonmetric multidimensional scaling analysis of brachiopod assemblages. The resulting Hill number patterns, assemblage turnover, and Zipf-Mandelbrot power law model parameter patterns show congruent patterns of increased diversity and complexity of brachiopod communities before the Hirnantian: increased fluctuations in genus level richness mirrored

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fluctuations in Simpson and Shannon indexes that are also consistent with changes in the parameter values of the Zipf-Mandelbrot model. Preliminary results concur with other leading hypothesis about community structure changes during the LOME.

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Keywords: Late Ordovician, Baltica, brachiopods, evolution of paleocommunities

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Singh Birendra Pratap	Chandigarh (India)
Sinnesael Matthias	Durham (UK)
Smith Kenia	Siedlce (Uruguay)
Soucy Corinne	Montréal (Canada)
Sproat Colin	Saskatoon (Canada)
Steeans Philippe	Liège (Belgium)
Stigall Alycia	Athens (USA)
Stocker Chris	Wigston (UK)
Stouge Svend	Copenhagen (Denmark)
Strother Paul	WatWestonertown (USA)
Strullu-Derrien Christine	London (UK)
Suárez Pérez María Gabriela	Madrid (Spain)
Sullivan Joseph	West Seneca (USA)
Thibault Nicolas	Copenhagen (Denmark)
Thomka James	Plattsburgh (USA)
Thurley Olivia	Enfield (UK)
Tinn Oive	Tartu (Estonia)
Tolmacheva Tatiana	Saint-Petersburg (Russia)
Tonarova Petra	Prague (Czech Republic)
Toom Ursula	Tallinn (Estonia)
Toro Blanca Azucena	Córdoba (Argentina)
Tyler Carrie	Cincinnati (USA)

Van Vranken Nathan	New Creek (USA)
Vasaikar Swarali	Baroda Vadodara (India)
Vecoli Marco	Dhahran (Saudi Arabia)
Verniers Jacques	Ghent (Belgium)
villamizar meza fanny	Bogota (Colombia)
Vinn Olev	Tartu (Estonia)
Vodrazkova Stanislava	Prague (Czech Republic)
Voldman Gustavo	Córdoba (Argentina)
Waisfeld Beatriz	Córdoba (Argentina)
Wang Yong	Changsha (China)
Wang Wenhui	Changsha (China)
WANG Kai	Beijing (China)
Wang Guangxu	Nanjing (China)
Wei Xin	Beijing (China)
Wilby Phil	Keyworth (UK)
Wong Romeo	Cambridge (UK)
Wright Davey	Washington (USA)
Yan Kui	Nanjing (China)
Young Seth	Tallahassee (USA)
Zabini Carolina	Campinas (Brazil)
Zambito Jay	Beloit (USA)
Zamora Samuel	Zaragoza (Spain)
Zans Aija	Vilnius (Lthuania)
Zaw Khin	Hobart (USA)
Zbik Edward	Rydalmere (Australia)
Zguaid Maryem	Tiznit (Morocco)
Zhan Renbin	Nanjing (China)
Zhang Yuandong	Nanjing (China)
Zhang Lejun	Hobart (Australia)
Zhen Yong	Londonderry (Australia)
Zhu, Ge	Changsha (China)
Zicha Ondřej	Prague (Czech Republic)
Zigaite-Moro Zivile	Uppsala (Sweden)