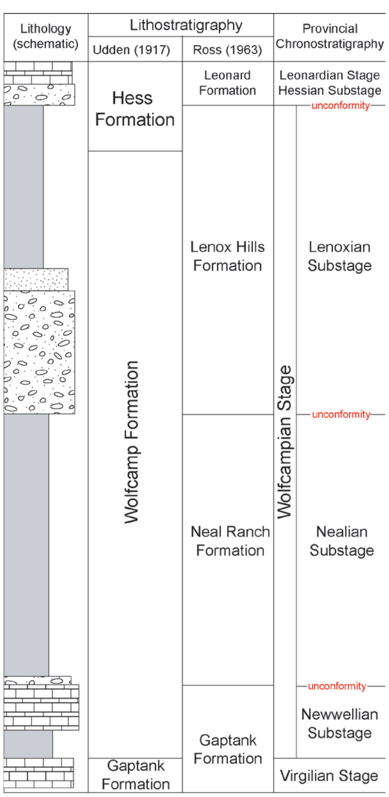
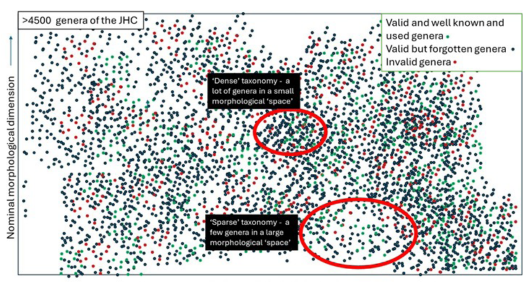
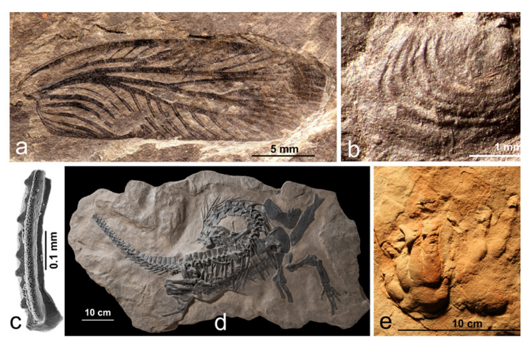
Permophiles

International Commission on Stratigraphy







Newsletter of the Subcommission on Permian Stratigraphy

Number 80

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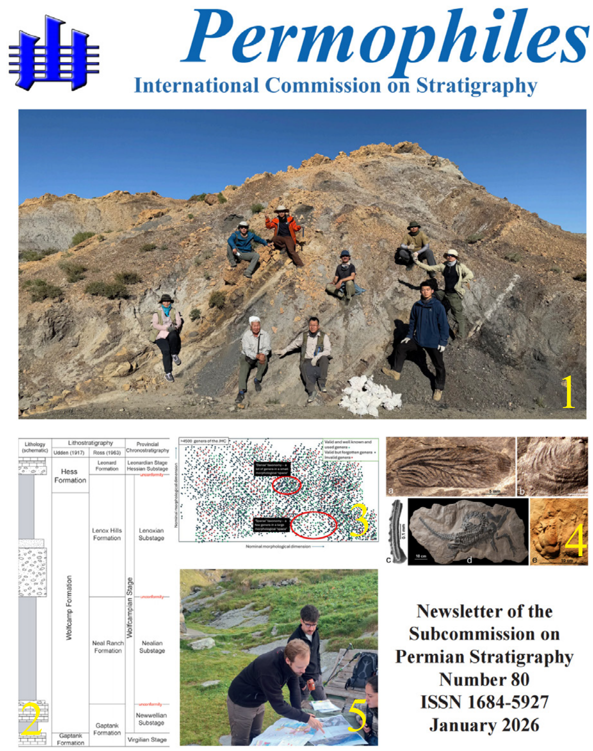

Notes from the SPS secretary
Yichun Zhang

Introduction and thanks

Time flies, it is time to edit this issue of *Permophiles* once again since the publication of last issue in September 2025. This is the issue 80 of *Permophiles* since the initiation of this journal in 1978. The Permian subcommission has maintained the proud tradition of publication of average two issues for one year. I start to edit *Permophiles* since issue 69 (2020). I have deeply and strongly felt the tremendous support from our senior professors, which has propelled the full-scale advancement of Permian research work, including establishment of GSSPs, promoting the correlations of biostratigraphy between continents, and the correlation between marine and terrestrial stratigraphy during the Permian. As I always highlighted, *Permophiles* is always an open platform for research, discussion and communications related to Permian studies.

STRATI 2026 will take place in Suzhou, China between 28 June and 3 July. It's a formal ICS meeting and a good platform for communications. I request your attention to S6 and G11 sessions, which focus on Permian stratigraphy and Tethyan paleogeography respectively.

This issue of *Permophiles* contains articles covering the biostratigraphy, new methodology in taxonomy study and fieldwork reports. Thanks to all contributors of this issue: Charles M. Henderson, Spencer G. Lucas, Joerg W. Schneider and Sebastian Voigt, Hans Kerp, Michael H. Stephenson and co-authors, Iván R. Barreiro and co-authors, Alessandro P. Carniti and co-authors.

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As usual, this issue starts with Henderson's Harangue #16. He emphasizes again the significance of correlations. Incorrect correlation of biostratigraphy or strata will mislead several geological studies. Thanks Charles for his reminder several times.

Spencer G. Lucas reviews the Wolfcamp Formation (lithostratigraphic unit) and the Wolfcampian stage (chronostratigraphic unit). He suggests to abandon the Wolfcamp Formation but keep the Wolfcampian as a provincial stage.

Joerg W. Schneider and Sebastian Voigt review the definition of regional Western European Stages (Autunian, Saxonian and Thuringian). This review will help to avoid misunderstanding in applying these stages.

Hans Kerp comments on the Triassic age assignment for the terrestrial Umm Irna Formation of Ahmad et al. (2024) based on palynological study. He suggests the Triassic age is not justified.

Michael H. Stephenson and co-authors introduce the application of a large language model in assisting the identification of pollen and brachiopod. They indicate the challenges and difficulties in training and also suggest the bright future of application of AI in paleontology.

Iván R. Barreiro and co-authors summarize the CALDERA project including scientific publications of several important papers, conference contributions and fieldwork in Alps.

Alessandro P. Carniti and co-authors report their fieldwork in Shanaga, Nomgon and Bulgan Uul areas in Mongolia, with the purpose to improve the classification and correlation between Permian units in Mongolia as well as paleoclimatic reconstructions.

Future issues of Permophiles

The next issue of *Permophiles* will be the 81st issue. We welcome contributions related to Permian studies around the world. So, I kindly invite our colleagues to contribute harangues, papers, reports, comments and communications.

The deadline for submission to Issue 81 is 31 July 2026.

Manuscripts and figures can be submitted via email (yczhang@nigpas.ac.cn or Ivan.RodriguezBarreiro@naturmuseum.it) as an attachment.

To format the manuscript, please follow the TEMPLATE on the SPS website.

Notes from the SPS Chair
Elizabeth A. Weldon

Wominjeka to *Permophiles* #80. Wominjeka is a way of saying welcome in the Woiwurrung language of the Wurundjeri people of the Kulin Nation, the traditional owners of the lands where I am writing this note. But I'm not using welcome in the common sense of being 'pleased to see you'. So why did I choose Wominjeka? It translates more specifically to 'come, with purpose', and I want to encourage you to read this issue **with purpose**. So, if you have made it this far through reading my Note, excellent - keep on reading and try not to flick through the remaining pages, only looking at the headings and the figures. Rather try to read every contribution from your Permian colleagues with intent. We are very fortunate in the Permian community to have a broad range of good quality and interesting contributions to *Permophiles* each issue that can spark new ideas or provide important information relevant to our research, prompt healthy debate on complex topics and provide useful additional information on specific field sties. In this issue there are also opportunities to be updated on Permian specific projects, hear how colleagues are implementing the use of new techniques, and find out more about ICS, SPS, and STRATI. Perhaps *Permophiles* will even be the prompt you need to start a conversation with a Permian worker you don't know at STRATI.

STRATI is taking place between 28 June and 3 July 2026, in Suzhou, China STRATI 2026. It is an official ICS meeting and during the conference a SPS Business Meeting will be held, as well as a diverse range of general sessions and a specific Permian Subcommission Session: S6. Perspectives on Permian Stratigraphy. Mid-conference you can attend an excursion to Meishan Geopark. The Meishan sections show the Changhsingian Stage and the GSSP at the base of the Changhsingian and the GSSP at the base of the Induan. Please consider your ability to attend this important event for enhancing global collaboration. Abstract submission is now open and closes on 15 March, and registration will open on 31 January. As part of our proposed

2026 budget in the 2025 ICS Annual Report, the SPS Executive plan to financially support several Early Career Researchers (ECRs), and SPS members (voting or corresponding) from the Global South (a region that was poorly represented at the ICCP in 2025) to attend. Further details can be found later in this issue.

A copy of the SPS 2025 Annual Report can also be found in this issue. For those of you familiar with this document you will notice several changes have been made to the reporting format. Consequently, moving forward it will be even more important for our working groups to develop and deliver on SMART (Specific, Measurable, Achievable, Relevant, Time-bound) goals that align with the UN's SDGs (Sustainable Development), and as an entire Subcommission we will need to be able to demonstrate how we support ECRs, and consistently acknowledge the use of IUGS in publications.

Finally, before I let you read the rest of our 80th issue of *Permophiles* with purpose, I would like to draw your attention to the ICS prize home page https://www.stratigraphy.org/prizes. Nominations for the Digby McLaren Medal and the ICS Medal are now open and the deadline for submissions is 13 March, 2026.

Hope to see you at STRATI!

SUBCOMMISSION ON PERMIAN STRATIGRAPHY ANNUAL REPORT 2025

IUGS	**IUGS – Annual Report 2025** Permian International Commission on Stratigraphy	

IMPORTANT NOTES - Please adhere to the following:

1) Follow the style and fonts as shown in the template, and do not alter them.
2) Provide all the requested information and adhere to the specified word limit.
3) Please return the completed document to Charles Henderson at cmhender@ucalgary.ca by Nov. 21.

1. BACKGROUND INFORMATION

Name of the ICS Constituent Group	**Subcommission on Permian Stratigraphy**
Nature of the Constituent Group (commission/task group/initiative)	**commission**
Website/social media links	**International Commission on Stratigraphy**
Year of reporting	**2025**
Submitted by:	
Given Name	**Elizabeth**
Family Name	**Weldon**
Gender	**Female**
Role in the ICS Constituent Group	**Chair SPS**
Year of appointment to the position in the ICS Constituent Group	**2024 Chair (2022 Voting Member)**
Institution/Affiliation	**Deakin University**
Country	**Australia**
Email address	**l.weldon@deakin.edu.au**

2. ORIGINAL WORKPLANS FOR 2025

Provide a short summary (in bullet points of maximum 100 words) of what was planned for 2025 as stated in your Annual Report for 2024

- Revise the Guadalupian base Roadian and base Wordian GSSPs and prepare a proposal for a base Roadian SABS at Maweishan, China.
- Prepare and vote on the proposal for the Kungurian-base GSSP at Rockland section of Nevada, USA.
- Support the activity of the working groups on correlation of marine and continental Carboniferous-Permian transition and correlation of Gondwana to Euramerican sections.
- Organize several webinars and hold a face-to-face meeting at the ICCP in Toulouse, France.
- Publish two issues of *Permophiles*.

3. ACHIEVEMENTS IN 2025[1]

3.1 Publications

List publications in 2025 that include research sponsored by *IUGS Funds and where IUGS* is acknowledged (insert rows if needed).

Paper	Authors and Journal info (year, volume, pages)	Link to pdf
1)		
2)		
3)		

3.2 Conferences/congresses/workshops

Provide information on <u>all early-career researchers and postgraduate students</u> who attended scientific conferences/ congresses/workshops and meetings related to the constituent group activities/fieldworks, using IUGS funds allocated for the year 2025 (insert more columns if more than one participant attended the same event, and insert more tables if more than one event was participated in)

Name of participants (insert rows if needed)	*Name of participant 1*	*Name of participant 2*	*Name of participant 3*
Gender			
Age			
Affiliation			
Country			
Name of event (conference/congresses/workshops, dedicated meetings, fieldworks.)	Geotolosa (conference), which included Devonian, Carboniferous and Permian subcommissions; 34 post-grads and early career researchers were supported and		

[1] until 30 Nov 2025. For December please indicate planned activities and respect the ceiling of granted funds for 2025.

	are listed in annual report of the International Commission on Stratigraphy as well as the annual report of the Carboniferous Subcommission		
National/International	International		
Type of presentation if any (poster/oral presentation)	Poster and Oral		

3.3 Other results

List any relevant activity that was supported by funds allocated by IUGS

Nature of the activity	Conference - Geotolosa
Objective of the activity	Convened Permian session of ICCP and chaired SPS business meeting
Outcome	In the primary Permian session 14 oral and five poster presentations were delivered. Another 18 oral presentations and four posters on Permian themes were delivered in other sessions A new Editor for *Permophiles* was recruited from early career researchers at the conference. Every SPS working group gave an update at the business meeting.
National/International	International
Name of participant(s) (insert rows if needed)	Elizabeth Weldon
Gender	Female
Career status (early/mid/late)	Mid
Affiliation	Deakin University
Country	Australia

Nature of the activity	Fieldwork Apillapampa, Bolivia
Objective of the activity	To provide high resolution stratigraphy and biostratigraphy using multiple taxa of a key section for Gondwana to Euramerica correlation. Late arrival of 2025 funds are being used for deposits on 2026 fieldwork costs.
Outcome	Preliminary reports presented at the Paleontological Bolivian Congress and the Paleontological Argentinian Congress in 2025. Next field trip scheduled for 2026.
National/International	International
Name of participant(s) (insert rows if needed)	Mercedes di Pasquo/Gabriela Cisterna/Abner A. Calle Salcedo/Shirley López-Velásquez
Gender	Female/Female/Male/Female
Career status (early/mid/late)	Late/Late/postgrad student/Late

Affiliation	Laboratorio de Palinoestratigrafía y Paleobotánica, CICYTTP (CONICET-ER-UADER) and CONICET (Consejo Nacional de Investigaciones Científicas y Tecnológicas)/ Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Instituto Superior de Correlación Geológica (INSUGEO)/Universidad Mayor de San Andrés in La Paz, Bolivia
Country	Argentina/Argentina/Argentina/Bolivia

4. INTERACTIONS

4.1 Interaction with other IUGS constituent group(s)

Name of the IUGS Constituent Group(s)	type of interaction and which are the results (e.g., joint workshop/publication/session at international conferences, etc.)
Subcommission on Devonian Stratigraphy, Subcommission on Carboniferous Stratigraphy	Geotolosa (conference) included 20th International Congress on the Carboniferous and Permian and the Variscan meeting. Business meetings for Devonian, Carboniferous and Permian subcommissions were held.

4.2 Interaction with other international organizations and/or projects outside IUGS

Name of the International Organizations and/or Projects	type of interaction and which are the results (e.g., joint workshop/publication/session at international conferences, etc..)

5. INCOME IN 2025

SUBVENTIONS	EURO
From IUGS	$3500 USD
From other sources (specify the source and amount, insert rows if needed)	
Private (Chair SPS ICCP attendance)	$2000 USD
TOTAL	**$5500USD**

6. EXPENDITURES IN 2025

Provide a summary of the activities that were supported financially by the funds allocated by IUGS in 2025. Further detailed about the expenditures must be provided in the spreadsheet “Reported Expenditures” in IUGS Annual Report 2025 NAME OF THE Constituent Group.xls
Insert categories in new rows if necessary.

ACTIVITIES	USD/EURO
Conferences/congresses/workshops attended by members of the constituent group	$1000 USD
Conferences/congresses/workshops attended by early-career researchers and postgraduate students	
Costs related to committee meetings/fieldworks of the of the constituent group	
Costs related to committee/fieldworks of the Constituent Group attended by early-career researchers and postgraduate students	$2500 USD
Publications fees	
Dissemination/outreach/website	
Other costs (specify the type of costs)	
TOTAL EXPEDITURES	**$3500 USD**

7. OBJECTIVES AND WORKPLANS FOR THE YEAR 2026

Objectives (maximum 100 words presented in bullet points)	Finalise the last GSSP needed to complete the Permian component of the timescale. Foster a supportive environment for postgraduate students and ECRs to participate in Working Groups, publish and present their research on the Permian, and develop their leadership capacity. Disseminate information and promote discussion to enhance collaboration and new initiatives on the Permian. Ensure current GSSPs continue to be fit for purpose, and auxiliary markers and SABS are published for global correlation.
Achievable Workplan (in bullet points; max 5 bullet points; more details can be provided in the annex)	Vote on base-Kungurian GSSP Conduct field work at Apillapampa (Gondwana Euroamerican correlations WG). Publish two issues of *Permophiles*. Support Hold four webinars, including at least one presenter that is ECR and one M-LCR that are unable to attend STRATI.

Planned conferences (in bullet points; more details can be provided in the annex)	STRATI 2026 – Permian session (including part funded ECR, and global south participants that were absent from ICCP) and SPS Business meeting
Planned publications on research to be supported by IUGS funds; more details can be provided in the annex)	Offer support to ECRs for publication costs.
Other activities in bullet points; more details can be provided in the annex)	Offer a seed grant for new ECR lead project with an international team.

8. BUDGETARY PROPOSALS FOR 2026

The budget proposal for activities supported by IUGS/ICS in 2026 must align with the work plans for that year.

Detailed Budget must be provided in the spreadsheet "Proposed Budget" in IUGS/ICS Annual Report 2025 NAME OF THE Constituent Group.xls Insert categories in new rows if needed.

ACTIVITIES	**EURO/USD**
Conferences/congresses/workshops to be attended by members of the constituent group	1700/2000
Conferences/congresses/workshops to be attended by early-career researchers and postgraduate students	3400/4000
Costs related to committee meetings/fieldworks of the constituent group	
Costs related to committee meetings//fieldworks of the constituent group to be attended by early-career researchers and postgraduate students	2150/2500
Publications fees	650/750
Dissemination/outreach/ website	215/250
Other costs (specify the type of costs)	
TOTAL REQUESTED BUDGET	**Euro8115/USD$9500**

Annex:

1) **DESCRIPTION** (maximum 100 words)

Name of the Constituent Subcommission	Permian Stratigraphy
Divisions (e.g., subcommission/working groups)	Working Group on Gondwana-Euroamerican Correlations.
Aims and Objectives	Fossils from the South American Apillapampa Section are being compared to the Sakmarian GSSP in Russia, India and West Texas for correlation. Submit the first manuscript of the Apillapampa Section (South America), with information from invertebrates, conodonts, and palynology. A preliminary report was presented at the Congress of Paleontology of Bolivia, and Congress of the Paleontological Association of Argentinian. Conduct further field work at neighbouring sections to compliment the work conducted at Apillapampa, providing maximum correlation opportunities with Euroamerica and other parts of Gondwana.
Indicate, if possible, how your activities align with the goals of the United Nations Sustainable Development, see https://sdgs.un.org/goals	**SDG 5.5/10/17** This WG is led by a woman from a developing country (according to UNESCO in the context of SDGs). SPS is offering financial support through IUGS funds to support the work of this group that also includes a majority of women, and a majority of representatives from the Global South. This WG enhances North-South and South-South and triangular regional and international cooperation on science and enhances knowledge sharing.

Name of the Constituent Subcommission	Permian Stratigraphy
Divisions (e.g., subcommission/working groups)	Working Group on Base-Kungurian
Aims and Objectives	To ratify the GSSP for the Kungurian Stage. This is the only stage that has not been ratified with a Global Stratotype Section and Point within the Permian System. The final report is being prepared for distribution and voting to take place. We

	hope to have the voting completed in time to announce the GSSP at STRATI.
Indicate, if possible, how your activities align with the goals of the United Nations Sustainable Development, see https://sdgs.un.org/goals	**SDG 4/13/17** GSSPs provide a global standard for geologic time, improving consistency in teaching Earth history. They support open scientific data and international collaboration, enhancing education and research capacity. Precise stratigraphic boundaries help reconstruct past climate changes, informing models for future climate scenarios. Understanding ancient carbon cycles and extinction events aids in predicting responses to current climate stressors. This is particularly important in the Permian when the climate changed from a cold polar climate (like we have today) to a much hotter climate with coinciding increase in extinction. Ratification involves global scientific cooperation through bodies like the ICS and IUGS.

2) DIRECTORY OF OFFICERS 2025-2028

Please provide a summary of information on all officers and voting members of your subcommission and, if possible, your active working groups in the spreadsheet Directory Officers" in IUGS Annual Report 2025 NAME OF THE Constituent Group.xls

Personal data are protected in accordance with the GDPR 2016/679 - European regulation on the protection of personal data.

APPENDICES

Names and Addresses of Current Officers for 2024-2028

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Email: l.weldon@deakin.edu.au

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Prof. Yichun Zhang (SPS Secretary)
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Names and Addresses of Current Voting Members:

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Dr. Valeriy K. Golubev
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Working groups and leaders

1) Base-Kungurian Working Group
Leader: Prof. Charles Henderson
2) Base-Roadian Working Group
Leader: Prof. Charles Henderson
3) Base-Wordian Working Group
Leader: Prof. Shuzhong Shen
4) Correlation Between Marine and Continental Carboniferous-Permian Transition Working Group
Leader: Prof. Joerg Schneider
5) Gondwana to Euramerica Correlations Working Group
Leader: Prof. Mercedes di Pasquo

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Henderson's Harangue #16

Charles M. Henderson
Department of Earth, Energy, and Environment, University of Calgary, Calgary, Alberta, Canada T2N 1N4

Take Care of your Correlations

As an attempt to stimulate debate or perhaps simply because something smells fishy, I deliver my sixteenth harangue for *Permophiles* #80. In Italian, it would be "L' arringa di Henderson" (the double "r" is important).

"Take care" is a secular phrase often used today to say goodbye to someone we care about. It apparently originated from Middle English as words for concern or interest shortened from "take care of yourself" to express care for the health and safety of someone in dangerous times, especially before a trip. Perhaps we should use this parting phrase more often as we enter 2026, given the disturbing times in which we live. If you are reading this harangue, you probably care about stratigraphic correlations, especially as they pertain to the Permian. As I reflect on all the correlations that I have attempted during my career I wish someone had said to me "take care of your correlations" as you set off into the confusing world of the Permian.

The Permian is much like the last million years on planet Earth, experiencing global cooling, global warming, evolutionary radiation, migrations, and extinctions. All these events could be simultaneous on a global basis or regionally sequential at different times. With so much change we really should carefully take care of our correlations.

The history of any species starts with its evolution, followed by dispersal and migration, acme if successful, and eventually extinction. The appearance, preservation and discovery of that species in any given section will depend on its arrival time, the occurrence of appropriate environmental conditions, sampling strategy, and taxonomic identification. *Sweetognathus whitei* is a species of conodont that I have mentioned many times (Henderson, 2018; several issues of *Permophiles*, etc.), but its history is not simple it turns out. It was first recognized in the Tensleep Sandstone in Wyoming (Rhodes, 1963) and later in the mid-continent USA (Ritter, 1986; Boardman et al., 2009) from the Barneston cyclothem (Florence and Fort Riley limestones) of Kansas. In these locations the taxon occurs in association with abundant *Streptognathodus* spp. Elsewhere, including the GSSP section for the base-Artinskian (Chernykh et al., 2023), the taxon apparently first occurred well above the extinction of *Streptognathodus*. For a long time, all these locations were correlated as Artinskian meaning that the mid-continent USA (and later Bolivia) were the only places in the world in which *Sweetognathus whitei* was recovered from high frequency cyclothems in association with species of *Streptognathodus*. This correlation suggested that the P1 phase of the late Paleozoic Ice Age (LPIA) continued into Artinskian. However, it was later interpreted that two lineages included homeomorphs through parallel evolution (Petryshen et al., 2020). The older form (including the holotype of *Sweetognathus whitei*) is now regarded as late Asselian age (may extend into earliest Sakmarian) and the younger form (*Sweetognathus asymmetricus*) first occurs in many locations at the base of the Artinskian (Chernykh et al., 2023), well above the last high frequency (and relatively high amplitude) cyclothem. This means that the P1 phase of the LPIA terminates in the earliest Sakmarian with a major flooding surface and later development of a Sakmarian 3rd order sequence. This dramatically affects global correlation of Earth's penultimate ice age pointing to the importance of taking care of your correlations. There are many that still seem to cling to the idea that all these occurrences relate to a single nearly synchronous species or at least to the idea that the cyclothems in mid-continent USA continue into the Artinskian. It is human nature to cling hard to our previously published correlations. I have appealed in past Henderson's Harangues to consider these new correlations. I have been fairly criticized for not yet fully documenting these two lineages and this work is underway. I have asked Dongxun Yuan and Michael Read to co-author with me in hopes that I can find new energy to complete the task and to bring different perspectives to the discussion. It is possible that some modifications to these correlations will become apparent, but the overall picture has been tested several times now. We will take care of our correlations.

In my opinion, another interval that requires greater correlation care relates to the so-called "mid-Capitanian extinction" in high latitude locations (Bond et al., 2020 and earlier publications). This geographically extended a questionable low latitude Capitanian extinction (Wignall et al., 2009; Bond et al., 2010). I reviewed and accepted the Wignall et al. paper but asked the authors to elaborate on "where is the extinction". Without the dark grey rectangles to highlight the 'extinction interval' I suggested that many different positions might be considered, including the possibility there was no major extinction. The 'extinction interval' coincided with the *Jinogondolella altudaensis* Zone (early to mid-Capitanian; ~262 Ma). Shen et al. (2020) discussed this interval indicating that there were multiple carbon isotopic excursions during the Capitanian that vary from section to section and multiple extinctions (e.g. mid-Capitanian, end-Capitanian) that also vary suggesting that the end-Capitanian extinction was less severe than previously considered, but it might be more profound in higher latitudes.

Bond et al. (2015, 2020) interpreted Capitanian mass extinction in higher latitudes including in Spitsbergen (2015) and Ellesmere Island in the Canadian Arctic (2020). Correlating Middle Permian in high latitudes is difficult because *Jinogondolella* and many other taxa are restricted or absent because of significant levels of provincialism. Bond et al. (2020) interpreted a mid-Capitanian extinction of brachiopods and bryozoans at the contact between the Degerbols and Lindstrom formations at Borup Fiord on Ellesmere Island. This extinction level would correspond to the earliest Capitanian based on the co-occurrence of *Mesogondolella bitteri* and *M. phosphoriensis* (Beauchamp et al., 2009) and the apparent extinction of brachiopods may be facies controlled as brachiopods are found, but rarely, in higher levels. Bond et al. (2020) indicated that this extinction was correlative to a Capitanian extinction in Spitsbergen. They used carbon and strontium isotopic signatures to interpret a mid-Capitanian age at a level high in the Kapp Starostin Formation in Spitsbergen when many brachiopods and bryozoans "became extinct" after deposition of three yellow limestone beds. The range chart looks convincing for an extinction, but Lee et al. (2022) questioned the ranges and taxonomy and noted that ranges for only part of the Kapp Starostin were provided. In the study by Lee et al. (2022), a paper that should be cited more in my opinion, their range chart for the entire Kapp Starostin Formation, including the basal Voringen Member, shows a more gradual or stepwise extinction. They interpret this long-term gradual extirpation of taxa as related to cooling throughout this entire interval. In my opinion they make a strong case for this interpretation, and you must wonder whether there is a global mid-Capitanian extinction. My experience working in the Canadian Arctic (MSc, PhD, numerous field seasons during and following graduate degrees) suggests many key taxa exhibit apparent extinction throughout much of the Permian including trilobites (mid-Sakmarian), calcareous algae and colonial rugose corals (earliest Artinskian), fusulinaceans (late Artinskian), solitary rugose corals (mid-Wordian), brachiopods and bryozoans (Wuchiapingian), and sponges (mostly demosponges; latest Permian). It seems to me we should take more care with our correlations before making cases for global extinction. The same holds true for the conodont correlations that I have made over the years.

In a previous harangue (*Permophiles* 79; Sept. 2025) I discussed some correlations of the Sakmarian where the conodont marker species was missing. We can discuss this more confidently now that we have a Sakmarian GSSP (Chernykh et al., 2020). In each section we find some taxon occurrences which we can call facts, and then we interpret how these facts correlate within the GSSP framework. One such fact is the occurrence of a fusulinid assemblage including *Schwagerina hyperborea*, *S. jenkinsi*, *S.* (*Parafusulina*) *belcheri* and *Schwagerina* cf. *mankomenensis*. It occurs in the Raanes Formation of Devon Island, Canadian Arctic, and in the upper Jungle Creek Formation of the Yukon Territory. It also occurs in the Hambergfjellet Formation of Bjornoya (Nakrem, 1991) which correlates with the Raanes Formation and with the Voringen Member of the Kapp Starostin on Spitsbergen. The associated conodonts from the Hambergfjellet and Voringen (Szaniawski and Malkowski, 1979; Nakrem et al., 1992) have been interpreted as upper Artinskian to lower Kungurian. However, these would now be interpreted as uppermost Sakmarian and lower Artinskian. This dramatic difference relates to part of the same Sweetognathid lineage revision mentioned above. Taxa in the Hambergfjellet and Voringen would correlate with bed 3 to lower bed 10 at Dalny-Tulkas (upper Sterlitamakian to top Burtsevian; Chernykh et al., 2023). Lee et al. (2022) indicated that the most striking biotic change in brachiopod species composition in the Kapp Starostin was between the lower Voringen and its overlying member. This biotic change coincides with an interval shortly after the demise of the LPIA-P1 phase and shortly after the closing of the Uralian basin (Beauchamp et al., 2022; Davydov, 2018) by Precaspian isthmus uplift. This tectonic event resulted in a cooling NW

Pangea while other regions exhibited warming.

Finally, in that same harangue (*Permophiles* 79; Sept 2025), I talked about "all the world's a stage". A stage, in the Permian at least, turns out to be a 3rd order T-R or depositional sequence. Bond et al. (2018) published a nice paper documenting the sequence stratigraphy of Svalbard indicating it could be a powerful correlation tool across NW Pangea. I agree! But take care with the correlations. If you accept the Voringen as uppermost Sakmarian to lower Artinskian then the seven sequences in the Kapp Starostin and in the Sverdrup Basin of the Canadian Arctic line up nicely!

Take Care!

References

Beauchamp, B., Henderson, C.M., Grasby, S.E., Gates, L., Beatty, T., Utting, J. and James, N.P., 2009. Late Permian sedimentation in the Sverdrup Basin, Canadian Arctic: the Lindström and Black Stripe formations. Bulletin of Canadian Society of Petroleum Geology, v. 57, n. 2, p. 167–191.

Beauchamp, B., Henderson, C.M., Dehari, E., Waldbott von Bassenheim, D., Elliot, S. and Calvo Gonzalez, D., 2022. Carbonate sedimentology and conodont biostratigraphy of Late Pennsylvanian-Early Permian stratigraphic sequences, Carlin Canyon, Nevada: new insights into the tectonic and oceanographic significance of an iconic succession of the Basin and Range. In Henderson, C.M., Ritter, S., Snyder, W.S. (eds.), Late Paleozoic and Early Mesozoic tectonostratigraphy and biostratigraphy of western Pangea. Special Publication 113, SEPM (Society for Sedimentary Geology), Broken Arrow, Oklahoma, p. 34–71. https://doi.org/10.2110/sepmsp.113.12.

Boardman, D.R., Wardlaw B.R. and Nestell, M.K., 2009. Stratigraphy and conodont biostratigraphy of uppermost Carboniferous and Lower Permian from North American Midcontinent. Kansas Geological Survey, Bulletin, v. 255, 146 pp.

Bond, D.P.G., Blomeier, D.P.G., Dustira, A.M., Wignall, P.B., Collins, D., Goode T., Groen, R.D., Buggishch, W. and Grasby, S.E., 2018. Sequence stratigraphy, basin morphology and sea-level history for the Permian Kapp Starostin Formation of Svalbard, Norway. Geological Magazine, v. 155, n. 5, p. 1023–1039.

Bond, D.P.G., Wignall, P.B. and Grasby, S.E., 2020. The Capitanian (Guadalupian, Middle Permian) mass extinction in NW Pangea (Borup Fiord, Arctic Canada): A global crisis driven by volcanism and anoxia. Geological Society of America Bulletin, v. 132, n. 5/6, p. 931–942.

Bond, D.P.G., Wignall, P.B., Joachimski, M.M., Sun Y., Savov, I., Grasby, S.E., Beauchamp, B. and Blomeier, D.P.G., 2015. An abrupt extinction in the Middle Permian (Capitanian) of the Boreal Realm (Spitsbergen) and its link to anoxia and acidification. Geological Society of America Bulletin, v. 127, n. 9/10, p. 1411–1421.

Bond, D.P.G., Wignall, P.B., Wang. W., Izon, G., Jiang, H.S., Lai, X.L., Sun, YD, Newton, R.J., Shao LY, Vedrine, S. and Cope, H., 2010. The mid-Capitanian (Middle Permian) mass extinction and carbon isotope record of South China. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 292, p. 282–294.

Chernykh, V.V., Chuvashov, B.I., Shen, S.Z., Henderson, C.M., Yuan, D.X. and Stephenson, M.H., 2020. The Global Stratotype Section and Point (GSSP) for the base- Sakmarian Stage (Cisuralian, Lower Permian). Episodes, v. 43, n. 4, p. 961–979.

Chernykh, V.V., Henderson, C.M., Kutygin, R.V., Filimonova, T.V., Sungatullina, G.M., Afanasieva, M.S., Isakova, T.N., Sungatullin, R.K., Stephenson, M.H., Angiolini, L. and Chuvashov, B.I., 2023. Global Stratotype Section and Point (GSSP) for the base-Artinskian Stage (Lower Permian). Episodes, v. 46, n. 4, p. 623–651.

Davydov, V., 2018. Precaspian isthmus emergence triggered the early Sakmarian glaciation: evidence from the Lower Permian of the Urals, Russia. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 511, p. 403–418.

Henderson, C. M., 2018. Permian Conodont Biostratigraphy. In Lucas, S. G. and Shen, S. Z. (eds.), The Permian Timescale. Geological Society, London, Special Publications, v. 450, n. 1, p. 119–142. http://doi.org/10.1144/SP450.9.

Lee, S., Shi, G.R., Nakrem, H.A., Woo, J. and Tazawa, J.I., 2022. Mass extinction or extirpation: Permian biotic turnovers in northwestern margin of Pangea. Geological Society of America Bulletin, v. 134, n. 9/10, p. 2399–2414. https://doi.org/10.1130/B36227.1.

Nakrem, H.A., 1991. Conodonts from the Permian succession of Bjornoya (Svalbard). Norsk Geologisk Tidsskrift, v. 71, p. 235–248.

Nakrem, H.A., Nilsson, I. and Mangerud, G., 1992. Permian biostratigraphy of Svalbard (Arctic Norway) – A review. International Geology Review, v. 34, n. 9, p. 933–959.

Petryshen, W., Henderson, C.M., De Baets, K. and Jarochowska, E., 2020. Evidence of parallel evolution in the dental elements of *Sweetognathus* conodonts. Proceedings of the Royal Society B, v. 287, n. 1939, 20201922. http://dx.doi.org/10.1098/rspb.2020.1922

Rhodes, F.H.T., 1963. Conodonts from the topmost Tensleep Sandstone of the eastern Big Horn Mountains, Wyoming. Journal of Paleontology, v. 37, n. 2, p. 401–408.

Ritter, S.M., 1986. Taxonomic revision and phylogeny of post-Early Permian crisis bisselli-whitei Zone conodonts with comments on Late Paleozoic diversity. Geologica et Palaeontologica, v. 20, p. 139–165.

Shen, S.Z., Yuan, D.X., Henderson, C.M., Wu, Q., Zhang, Y.C., Zhang, H., Mu, L.,Ramezani, J., Wang, X.D., Lambert, L.L., Erwin, D.H., Hearst, J.M., Xiang, L., Chen, B., Fan, J.X., Wang, Y., Wang, W.Q., Qi, Y.P., Chen, J., Qie, W.K. and Wang, T.T., 2020. Progress, problems, and prospects: An overview of the Guadalupian Series of South China and North America. Earth Science Reviews, v. 211, 103412.

Szaniawski, H. and Malkowski, K., 1979. Conodonts from the Kapp Starostin Formation (Permian) of Spitsbergen. Acta Palaeontologica Polonica, v. 24, n. 2, p. 231–264.

Wignall, P.B., Sun, Y., Bond, D.P.G., Izon, G., Newton, R.J., Vedrine, S., Widdowson, M., Ali, J.R., Lai, X.L., Jiang, H., Cope, H. and Bottrell, S.H., 2009. Volcanism, mass extinction, and carbon isotope fluctuations in the Middle Permian of China. Science, v. 324, n. 5931p. 1179–1182.

Use and misuse of the terms Wolfcamp and Wolfcampian in Permian lithostratigraphy and chronostratigraphy

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Introduction

In North America, and particularly in the Permian basin of Texas-New Mexico, the term Wolfcamp has long been used to refer to a lithostratigraphic unit, and the term Wolfcampian has been used as a chronostratigraphic unit, either as a provincial series or a stage of the lower Permian. Both of these terms, however, have been misused by various workers. Here, I briefly review use and misuse of these terms to clarify what I consider the proper use of Wolfcamp and Wolfcampian in Permian lithostratigraphy and chronostratigraphy.

Lithostratigraphic unit–Wolfcamp Formation/Shale

The term Wolfcamp entered the literature of stratigraphy when Udden (1917, p. 41) introduced it as the name of a lithostratigraphic unit of formation rank in the Glass Mountains of West Texas (Figs. 1-2). It was accepted long ago as a formal lithostratigraphic unit by the U. S. Geological Survey (Wilmarth, 1938). According to Udden, the Wolfcamp Formation is up to 152 m thick, and mostly shale (about 92% of the unit) with minor beds of limestone and conglomerate. It overlies the Gaptank Formation and underlies the Hess Formation, both units also named by Udden (1917). The name Wolfcamp comes from an abandoned dwelling on the southern flank of the Glass Mountains said to be frequented by wolves (Udden, 1917, p. 42). Udden (1917) listed fossil taxa from the Wolfcamp Formation, including a substantial assemblage of ammonoids from the lower part of Udden's original Wolfcamp Formation that Böse (1917) described.

However, disagreement about the base of the Wolfcamp Formation arose that centered on the age and stratigraphic assignment of the ammonoid-bearing shale and overlying limestone beds that Udden included in the Wolfcamp Formation but that were reassigned by subsequent workers to the underlying Gaptank Formation (Fig. 2). The issue of how many unconformities are present and where they are located in the Gaptank-Wolfcamp stratigraphic section also was a source of disagreement (e.g., Keyte et al., 1927; King, 1931, 1934, 1937; Sellards, 1932). These disagreements lead to an understanding that a substantial unconformity separates the limestones of the upper Gaptank from the basal conglomerate bed of the Wolfcamp Formation, and the age of the youngest fusulinids below the unconformity is early Wolfcampian (Fig. 2).

Ross (1959, 1963) abandoned the name Wolfcamp Formation in the Glass Mountains, replacing it with two new formation names, the lower, Neal Ranch Formation and the upper, Lenox Hills Formation (which also included the lower 61-91 m of Udden's [1917] Hess Formation) (Fig. 2). This became widely accepted, so that the term Wolfcamp Formation is no longer used

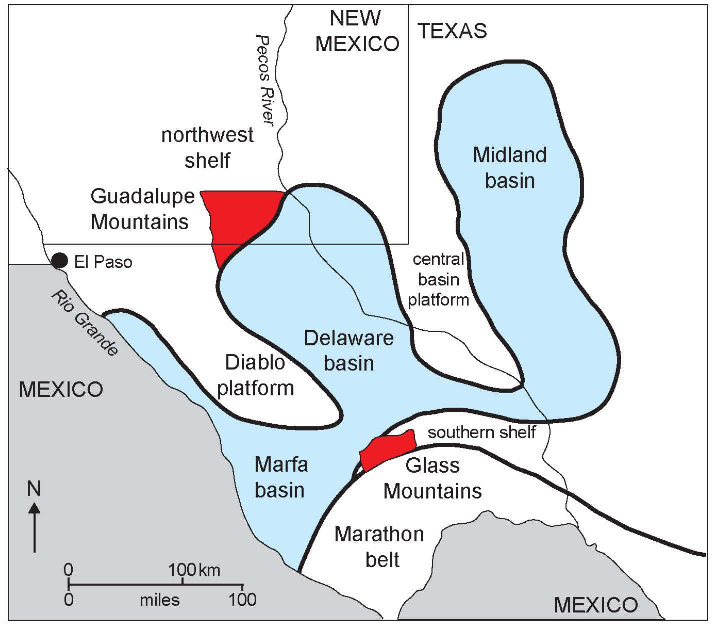

Fig. 1. Map of the Permian basin showing major features referred to in the text. Udden's (1917) type section of the Wolfcamp Formation is in the Glass Mountains.

for outcrops in the Glass Mountains. However, in my view it would have been better to consider the Neal Ranch and Lenox Hills as members of the Wolfcamp Formation or formations in a Wolfcamp Group. The fact is that the Neal Ranch and Lenox Hills formations contain distinctive fusulinid assemblages and are separated by an obvious unconformity, and biostratigraphy is largely what drove Ross's recognition of the units. Nevertheless, I accept longstanding usage of Ross's lithostratigraphic nomenclature and recommend its continued use for strata exposed in the Glass Mountains.

In surface outcrops, the name Wolfcamp Formation has only been used in the Glass Mountains. Nevertheless, the name Wolfcamp has been used to refer to subsurface strata over a much larger area encompassing the Delaware and Midland basins (Fig. 1). This usage began in the oil industry as early as the 1930s, though the first publication of such usage eludes me. The term Wolfcamp has been applied to a very thick section of subsurface strata across the greater Permian basin that are hundreds to thousands of meters thick and range in age from Late Pennsylvanian (Missourian) to early Leonardian. These strata are described as mostly dark marine shales, and they clearly are not the same lithostratigraphic unit as the Wolfcamp Formation of the Glass Mountains. Indeed, the type Wolfcamp Formation strata are marine and nonmarine strata that were deposited in a shallow marine embayment along the southern margin of the Permian basin (e.g., Ross and Ross, 2003). Their relationship to the thicker, deeper marine strata termed Wolfcamp in the Delaware and Palo Duro basins is unclear but likely limited to equivalence to only part of the subsurface section.

King (1942) may have been the first to draw attention to the lithostratigraphic problem of applying names like Wolfcamp to a lithostratigraphic unit very different from the unit to which they were originally applied. He stated that "the main problem in using lithologic [lithostratigraphic] names is how far they should

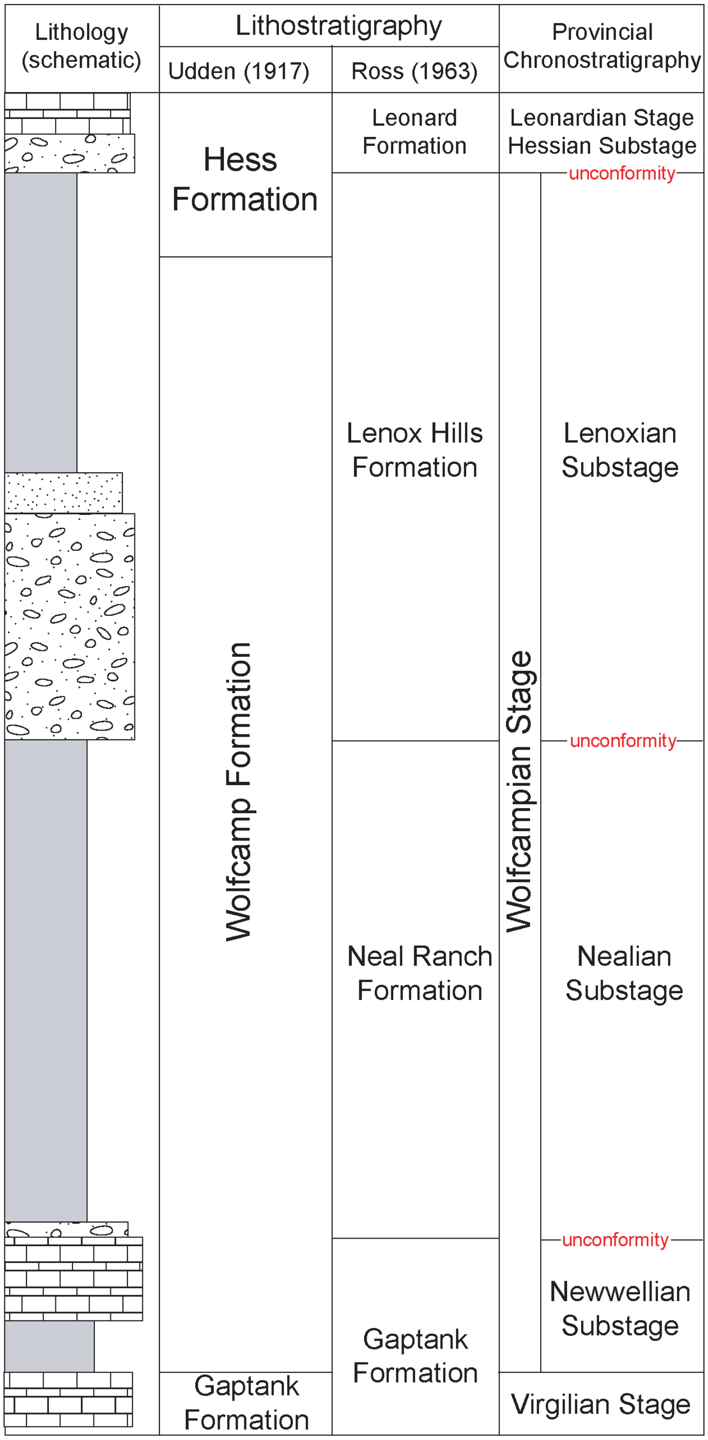

Fig. 2. Lithostratigraphy, biostratigraphy and provincial chronostratigraphy of the type Wolfcamp Formation (Udden, 1917) and adjacent strata in the Glass Mountains of Texas. Lithologic column is schematic and based on Ross (1963, fig. 10).

be extended beyond the areas in which they were originally described, and where other sets of names should be substituted for them" (King 1942, p. 667). He further noted (p. 667) that "whether on outcrop or in subsurface, it seems best to change from one set of names to another near the greatest change in facies, and where one group of deposits and marker horizons end and another begins." That said, King (p. 668) conceded that "in subsurface work outside of the Delaware basin, some departures from the ideal rules have been necessary, for the sake of convenience, and to harmonize with previous usage." King (1942, pl. 2) referred to Wolfcampian age strata in the Delaware basin as Hueco limestone and upper part of Magdalena group, and used informal terms for the Wolfcampian-age strata on the Central Basin platform ("limestone with *Pseudoschwagerina*") and in the Midland basin ("black shale" and "limestone with *Pseudoschwagerina*"). He used the name Wolfcamp Formation only for outcrops in the Glass Mountains. Nevertheless, subsequent workers, especially in the petroleum industry, misused the term Wolfcamp Formation, Shale or Group in the subsurface of the Permian basin.

Camp (2025) recently proposed that the term Wolfcamp Formation be "reinstated" and "redefined" to apply to the subsurface strata in the Delaware basin of southeastern New Mexico-West Texas that have long been referred to as "Wolfcamp" by petroleum geologists and on government maps (e.g., Lavery et al., 2024). Camp (2025, p. 866) argued that "reinstating" the Wolfcamp Formation is based on "following the rule of priority and to preserve well-established names," referring to Article 7c of the NACSN (North American Code of Stratigraphic Nomenclature). Nevertheless, Camp (2025, p. 865) noted that these "Wolfcamp" strata "range from platform carbonate to deep-water mudstone deposits" (also see Ruppel, 2019) and advocated the varied lithofacies be recognized as members of the Wolfcamp Formation. This "reinstated" Wolfcamp Formation is the interval between the Strawn and Bone Spring formations in the subsurface, which ranges in thickness from 245 m to more than 2200 m. Camp (2025, p. 875) concluded that "adoption of the proposed Wolfcamp Formation as outlined by this proposal will help to promote consistency for continued stratigraphic study in the Delaware basin."

The name Wolfcamp has been widely used informally as a lithostratigraphic term in the Delaware basin, leading to Camp advocating for the reinstatement of the name, NACSN Article 16a recommends that subsurface units be named after a type well. Camp (2025) noted that his type well of the subsurface "Wolfcamp Formation" is the Ross Draw 7 Well in Eddy County, New Mexico. Therefore, if the NACSN were followed, the unit called Wolfcamp Formation in the subsurface of the Delaware basin would be named the Ross Draw 7 Formation. Instead, what Camp (2025) proposed is to apply the name Wolfcamp to a unit that is lithologically and chronologically very different for the original Wolfcamp Formation, and that is difficult to reconcile with well-accepted lithostratigraphic practice. Indeed, the current NACSN guidelines do not explicitly address such an application. From a lithostratigraphic perspective, this approach is a "misappropriation" of the term Wolfcamp Formation (cf. Nelson et al., 2013), and what is needed is the development of a new, sound lithostratigraphic nomenclature to apply to the strata in the subsurface of the Delaware basin.

Wolfcamp is also used in a lithostratigraphic sense in the Midland basin for similar thick (up to about 732 m) and lithologically diverse strata that range in age from Missourian to Leonardian (e. g., Barrick and Wahlman, 2019; Fu et al., 2019). Indeed, in the Midland basin, the "Wolfcamp Shale" is divided into four informal units, A through D, the lower ones more siliciclastic, the upper ones more carbonate rich. As is the case in the Delaware basin, new lithostratigraphic nomenclature is needed for the rocks called Wolfcamp in the Midland basin.

Chronostratigraphic unit–Wolfcampian Series/Stage

Adams et al. (1939) introduced the term Wolfcampian Series as a chronostratigraphic term to refer to the lowest part of the Permian System in North America (also see Tomlinson et al., 1940). They stated that "it is characterized by the abrupt incursion of the fusulinid genera *Schwagerina* s. s., *Pseudoschwagerina* and *Paraschwagerina*, by the presence of the ammonoid genus *Properrinites*, the brachiopod genus *Parakeyserlingia*, and other distinctive Permian genera" (p. 1675). Adams et al. (1939) regarded the Wolfcampian base as the Permian base, placing the system boundary at an unconformity that reflected tectonism ("diastrophism"), as was generally done in the 1930s and earlier. They also noted (Adams et al., 1939, p. 1675) that "the great hiatus present at the base of the Wolfcamp Series in West Texas may be partly filled in regions removed from the Marathon disturbance by beds older than the type Wolfcamp. In that event the authors recommend that the base of the Wolfcamp series be drawn at the first important hiatus below strata characterized by the genera mentioned above." This opened the door to including strata older than the Wolfcamp Formation type section in the Wolfcampian Series (and thus in the Permian), and the fusulinid biostratigraphers did just that.

Schenck et al.'s (1941) critique of the Permian chrononostratigraphy of Adams et al. (1939) and Tomlinson et al. (1940) is often overlooked. They objected to equating the Wolfcampian base, an unconformity, with the Permian base, stating that this "is not a progressive move and is not likely to be a stable placement" (p. 2197). They thus noted that *Schwagerina* s.s. appears before *Pseudoschwagerina* s.s., so that placing the base at the lowest occurrence of *Pseudoschwagerina* in the Texas section equated it to that base in Russia, which to them was the Sakmarian base.

Thus, when Thompson (1954) published his classic monograph on American Wolfcampian fusulinids, he recognized a Wolfcampian fusulinid assemblage with *Triticites*, *Dunbarinella* and *Schwagerina* in the Bursum Formation of New Mexico as older than the type Wolfcampian. Note, however, that Dunbar et al (1960) equated the Bursum Formation to the Neal Ranch Formation, a mis-correlation. Much later, Wilde (1990) made a clear statement about a three-part Wolfcampian: (1) lower Wolfcampian, his zone PW-1 of *Schwagerina-Triticites*, later named Bursumian by Ross and Ross (1994), a name best replaced by Newwellian (Wilde, 2002, 2006); (2) middle Wolfcampian, his zone PW-2 or main zone of *Pseudoschwagerina*, the Nealian of Ross (1963) and (3) upper Wolfcampian, his zone PW-3 or zone of *Monodiexodina linearis*, the Lenoxian of Ross (1963).

As noted above, the unconformity at the base of the Wolfcamp Formation was a much-discussed issue, as was the age of the strata of the upper Gaptank Formation below that unconformity. After decades of discussion, agreement was reached on the position of that unconformity and the idea that the earliest Wolfcampian fusulinid zone was either missing in the Glass Mountains (Ross, 1963, 1965, 1975) or that the upper Gaptank included fusulinids of early Wolfcampian age (Bostwick, 1962; Wilde, 1971, 1984; Wahlman, 2019). Using conodonts, Wardlaw and Nestell (2019) equated the base of the Nealian to the Asselian base and identified conodonts from the upper Gaptank as correlative to the Foraker composite sequence in Kansas. Thus, Wardlaw and Nestell (2019) supported identification of at least part of the lower Wolfcampian in the upper Gaptank, and they identified the Gaptank-Neal Ranch hiatus as equivalent to one conodont zone, that of *Streptognathodus binodosus*.

According to conodont biostratigraphy, based on equating the lowest occurrence of *Streptognathodus isolatus* to the base of the Permian (but see Lucas, 2013), the early Wolfcampian is late Gzhelian, and the Nealian ranges from Asselian through early Sakmarian. The Lenox Hills Formation yields few conodonts, but is projected to encompass the Sakmarian through part of the Artinskian, and the base of the Leonardian is late Artinskian (Wardlaw and Nestell, 2014, 2019; Lucas et al., 2022).

I recommend continuing use of the term Wolfcampian as a North American provincial stage divided into three substages (ascending): Newwellian, Nealian and Lenoxian. But, the Wolfcampian Stage and its substages need better definition, which can be achieved in the Pedregosa basin of southwestern New Mexico where the section at New Well Peak contains fusulinid and conodont records in a conformable succession that encompasses the bases of the Wolfcampian (Newwellian), Nealian and Lenoxian (Wilde, 2002, 2006; Krainer et al., 2017; Lucas et al., 2017). The unconformity-bounded Wolfcampian sediment packages in the Glass Mountains are not an ideal section for such definition, though historically they were the basis for much of the Wolfcampian chronostratigraphy.

Conclusions

Based on the above, I offer the following recommendations:

1. The term Wolfcamp should no longer be used for a lithostratigraphic unit. It was abandoned more than 60 years ago and replaced by the names Neal Ranch and Lenox Hills formations (Ross, 1959, 1963).

2. Attempting to formalize use of Wolfcamp Formation for subsurface strata in the Delaware basin to which that name has been applied by petroleum geologists is to alter the concept of the original Wolfcamp Formation and apply it to a complex and thick set of lithofacies that are lithologically different from and encompass far more time than the type Wolfcamp Formation (Udden, 1917). Based on sound stratigraphic practice, the subsurface strata in the Delaware and Midland basins called Wolfcamp need new lithostratigraphic names that reflect their stratigraphic architecture.

3. Wolfcampian is a useful chronostratigraphic concept in North America and should serve as a provincial stage.

4. The Wolfcampian Stage can be divided into three substages based on fusulinid biostratigraphy (ascending): Newwellian (= "Bursumian"), Nealian and Lenoxian.

5. The base of the Permian is either at the base of the Wolfcampian or at about the Newwellian-Nealian boundary, depending on how the base of the Permian is defined.

References

Adams, J. E., Cheney, M. G., DeFord, R. K., Dickey, R. I., Dunbar, C. O., Hills, J. M., King, R. E., Lloyd, E. R., Miller, A. K. and Needham, C. E., 1929. Standard Permian section of North America. American Association of Petroleum Geologists Bulletin, v. 23, p. 1673–1681.

Barrick, J. E. and Wahlman, G P., 2019. Conodont and fusulinid biostratigraphy of the Strawn Group (Desmoinesian, Middle Pennsylvanian) and lower part of the "Wolfcamp Shale" (Missourian-Virgilian, Late Pennsylvanian) in the northern Midland Basin, West Texas. Stratigraphy, v. 16, p. 65–86.

Böse, E., 1917. The Permo-Carboniferous ammonoids of the Glass Mountains, West Texas and their stratigraphical significance. University of Texas, Bulletin 1762, p. 1–241.

Bostwick, D. A., 1962. Fusulinid stratigraphy of beds near the Gaptank-Wolfcamp boundary, Glass Mountains, Texas. Journal of Paleontology, v. 36, p. 1189–1200.

Camp, W. K., 2025. Proposal to reinstate the Wolfcamp Formation as a formal lithostratigraphic unit for the subsurface Delaware basin, New Mexico and Texas. AAPG Bulletin, v. 109, p. 863–877.

Dunbar, C. O., Baker, A. A., Cooper, G. A., King, P. B., McKee, E. D., Miller, A. K., Moore, R. C., Newell, N. D., Romer, A. S., Sellards, E. H., Skinner, J. W., Thomas, H. D., and Wheeler, H. E., 1960. Correlation of the Permian formations of North America. Geological Society of America Bulletin, v. 71, p. 1763–1806.

Fu, Q., Baumgardner, R. W., Jr. and Hamlin, H. S., 2019. Early Permian (Wolfcampian) succession in the Permian basin: Icehouse platform, slope carbonates, and basinal mudrocks. AAPG Memoir 118/ University of Texas at Austin BEG Report of Investigations, v. 285, p. 185–226.

Keyte, I. A., Blanchard, W. G., Jr. and Baldwin, H. L., Jr. 1927. Gaptank-Wolfcamp problem of the Glass Mountains, Texas. Journal of Paleontology, v. 1, p. 175–178.

King, P. B., 1931. The geology of the Glass Mountains, Texas, part 1: Descriptive geology. University of Texas, Bulletin, v. 3038, p. 1–167.

King, P. B., 1934. Permian stratigraphy of Trans-Pecos, Texas. Geological Society of America Bulletin, v. 45, p. 697–797.

King, P. B., 1937. Geology of the Marathon region, Texas. U. S. Geological Survey, Professional Paper, v. 187, p. 1–148.

King, P. B., 1942. Permian of West Texas and southeastern New Mexico. AAPG Bulletin, v. 26, p. 535–763.

Krainer, K., Vachard, D. and Lucas, S. G., 2017. Microfacies, microfossils and biostratigraphy of the Pennsylvanian-Permian Horquilla Formation, New Well Peak, Big Hatchet Mountains (Hidalgo County, southern New Mexico, USA). New Mexico Museum of Natural History and Science, Bulletin, v. 74, 1–163.

Lavery, D., Correa, M. R., Baca, A., Martin, L., and Attia, S., 2024. 3D Geologic Framework of the Delaware Basin, Eddy and Lea Counties, New Mexico. New Mexico Bureau of Geology and Mineral Resources, Open-file Geologic Map – 318, Scale 1:24,000. https://doi.org/10.58799/OF-GM-318.

Lucas, S. G., 2013. We need a new GSSP for the base of the Permian. Permophiles, n. 58, p. 8–13

Lucas, S. G., Krainer, K., Barrick, J. E., Vachard, D. and Ritter, S. M., 2017. Lithostratigraphy and microfossil biostratigraphy of the Pennsylvanian–lower Permian Horquilla Formation at New Well Peak, Big Hatchet Mountains, New Mexico, USA. Stratigraphy, v. 14, p. 223–246.

Lucas, S. G., Henderson, C., Barrick, J. E. and Krainer, K., 2022. Conodonts and the correlation of the lower Permian Yeso Group, New Mexico, USA. Stratigraphy, v. 19, p. 77–94.

Nelson, W. J., Hook, R. W and Elrick, S., 2013. Subsurface nomenclature in the Permian basin (Texas-New Mexico): Lithostratigraphic chaos or fixable problem? New Mexico Museum of Natural History and Science, Bulletin, v. 60, p. 312–313.

Ross, C. A., 1959, The Wolfcamp Series (Permian) and new species of fusulinids, Glass Mountains, Texas. Journal of the Washington Academy of Sciences, v. 49, p. 299–316.

Ross, C. A., 1963. Standard Wolfcampian Series (Permian), Glass Mountains, Texas. Geological Society of America, Memoir, v. 88, 1–205.

Ross, C. A., 1965. Late Pennsylvanian Fusulinidae from the Gaptank Formation, West Texas. Journal of Paleontology, v. 39, p. 1151–1176.

Ross, C. A., 1975. Base of the Permian System in the Glass Mountains. Texas. In Cys, J. M. and Toomey, D. F. (eds.), Permian Exploration, Boundaries, and Stratigraphy. Permian Basin Section SEPM, Publication 75-65, Midland, Texas, p. 43–50.

Ross, C. A. and Ross, J. P., 1994. The need for a Bursumian stage, uppermost Carboniferous, North America. Permophiles, n. 24, p. 3–6.

Ross, C. A. and Ross, J. P., 2003, Sequence evolution and sequence extinction: Fusulinid biostratigraphy and species-level recognition of depositional sequences, lower Permian, Glass Mountains, West Texas, U.S.A. SEPM Special Publication, v. 75, p. 317–359.

Ruppel, S., 2019. Anatomy of a Paleozoic basin: the Permian basin, USA: Introduction, overview, and evolution. AAPG Memoir 118/ University of Texas at Austin BEG Report of Investigations, v. 285, p. 1–27.

Schenck, H. G., Hedberg, H. D., Tomlinson, C. W., Eaton, J. E. and White, R. T., 1941. Stratigraphic nomenclature. American Association of Petroleum Geologists Bulletin, v. 25, p. 2195–2211.

Sellards, E. H., 1932 [1933]. The geology of Texas; vol. 1; the pre-Paleozoic and Paleozoic systems in Texas, part 1. University of Texas, Bulletin, n. 3232, p. 15–239.

Thompson, M. L., 1954. American Wolfcampian fusulinids. University of Kansas Paleontological Contributions, Protozoa Article, v. 5, 226 pp.

Tomlinson, C. W., Moore, R. C., Dott, R. H., Cheney, M. G., and Adams, J. E., 1940. Classification of Permian rocks. AAPG Bulletin, v. 24, p. 337–358.

Udden, J. A., 1917. Notes on the geology of the Glass Mountains, Texas. University of Texas, Bulletin, v. 93, p. 1–101.

Wahlman, G. P., 2019. Pennsylvanian and lower Permian fusulinid biostratigraphy of the Permian basin region, southwestern USA. AAPG Memoir/ University of Texas at

Austin BEG Report of Investigations 285, v. 118, p. 167–227.
Wardlaw, B. R. and Nestell, M. K., 2014. The first appearance of *Steptognathodus isolatus* in the Permian of Texas. Permophiles, n. 59, p. 17–20.
Wardlaw, B. R. and Nestell, M. K., 2019. Conodont biostratigraphy of lower Permian (Wolfcampian-Leonardian) stratotype section of the Glass and Del Norte mountains, West Texas, USA. AAPG Memoir 118/University of Texas at Austin BEG Report of Investigations, v. 285, p. 229–249.
Wilde, G. L., 1971. Phylogeny of *Pseudofusulinella* and its bearing on early Permian stratigraphy; in Dutro, J. T., Jr., (ed.), Paleozoic Perspectives: A Paleontological Tribute to G. Arthur Cooper. Smithsonian Contributions to Paleobiology, v. 3, p. 369–379.
Wilde, G. L., 1984. Systematics and the Carboniferous-Permian boundary. In Sutherland, P. K. and Manger, W. L., (eds.), Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère. Compte Rendus v. 2. Biostratigraphy. SIU Press, Carbondale and Edwardsville, p. 543–558.
Wilde, G. L., 1990. Practical fusulinid zonation---the species concept; with Permian basin emphasis. West Texas Geological Society Bulletin, v. 29, p. 5–33.
Wilde, G. L., 2002. The Newwellian Substage; rejection of the Bursumian Stage. Permophiles, v. 41, p. 53–62.
Wilde, G. L., 2006. Pennsylvanian-Permian fusulinaceans of the Big Hatchet Mountains, New Mexico: New Mexico. Museum of Natural History and Science, Bulletin, v. 38, 1–321.
Wilmarth, M. G., 1938, Lexicon of geological names of the United States. U.S. Geological Survey Bulletin, v. 896, 2396 pp.

What about the European Permian regional stages Autunian, Saxonian and Thuringian? − a new view on an old problem

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Schneider (2001) advised against focusing too much attention on the definition and delimitation of regional Western European Stages (WES) such as Autunian, Saxonian and Thuringian, and instead advocated linking the mainly continental regional European Permian profiles with their formations to the marine Standard Global Chronostratigraphic Scale (SGCS). The latter has been achieved since 2013 by the cooperation of numerous colleagues in the Nonmarine-Marine Correlation Working Group of the Subcommissions on Carboniferous, Permian and Triassic Stratigraphy (Schneider, 2020, 2023; Schneider et al., 2020; Fig. 1). Meanwhile, there is also growing awareness that, compared to other regions, such as North America, Russia, China, and South Africa in particular, it would make sense to continue the regional WES division, which previously ended with the Stephanian in the late Pennsylvanian, into the Permian, despite all the problems WES poses in the Carboniferous (e.g., Nelson and Lucas, 2021). However, these Permian WES would have to be defined at a point in a stratigraphic succession, and the biostratigraphic characteristics of that point investigated to allow the point to be correlated in accordance with the rules of the International Commission on Stratigraphy (Salvador, 2013; Lucas, 2018, 2020).

This would now be possible for the **Autunian**. It was initially described purely lithostratigraphically as a sequence of sandstones and bituminous black shales with its fossil content as ‘Autunin’ (Mayer-Aymar, 1881). Due to the rich flora and fauna published since the beginning of the 20th century, the Autunin changed its original meaning to a supposed biostratigraphic category, which henceforth found its way into literature as the Autunian (Chateauneuf and Pacaud, 1991; Broutin et al., 1999; but see Schneider, 2001). However, it was never declared as a formal chronostratigraphic stage at any of the International Congresses on the Carboniferous and Permian. If the Autunian is to become a stage according to international rules (Salvador, 2013; rules of the International Commission on Stratigraphy, https://stratigraphy.org/gssps/), then it must be defined at a point within a stratigraphic succession (for details, see Schneider, 2001). The decisive factor for the definition of an ‘Autunian stage’, i.e., a chronostratigraphic stage, is the determination of an isochronous lower boundary to the Stephanian. This cannot be correlated with either macro- or microflora – cf. Broutin et al. (1999, p. 28, originally in French): ‘The base of the Autunian cannot presently be correlated by the appearance of any “index species” for either macroflora or microflora.’ If one wanted to define the Autunian as a regional WES, its lower boundary could be set at a point in the stratigraphic succession which can be also marked and correlated by the First Appearance Date (FAD) of *Sysciophlebia balteata* in the Muse Oil Shales of the Muse Formation and the CA–ID–TIMS U–Pb zircon age of this level between 298.57±0.16 and 298.05±0.19 Ma (Pellenard et al., 2017). This point could possibly be correlated additionally by the occurrence of *Lioestheria paupera* (Fritsch, 1901). Its synonymous species is *Estheria (Lioestheria) lallyensis* Depéret and Mazeran, 1912, from the Lally Oil Shales of the basal Muse Formation, which were dated to 298.91±0.08 Ma CA–ID–TIMS U–Pb zircon age (Pellenard et al., 2017). However, the lowest known occurrence (LO) of this species is probably in the slightly older Ilmenau Formation of the Thuringian Forest Basin. The chronostratigraphic base of an Autunian defined by the FAD of *Sysciophlebia balteata* and radioisotope ages would lie approximately at the lithostratigraphic base of the Muse Formation in the Autun Basin, at the base of the Altenglan Formation in the Saar-Nahe Basin and at the base of the Manebach Formation in the Thuringian Forest Basin (Fig. 1). In relation to the marine SGCS, this would be roughly the base of the Asselian or Permian at 298.9±0.15 Ma (Figs. 1, 2).

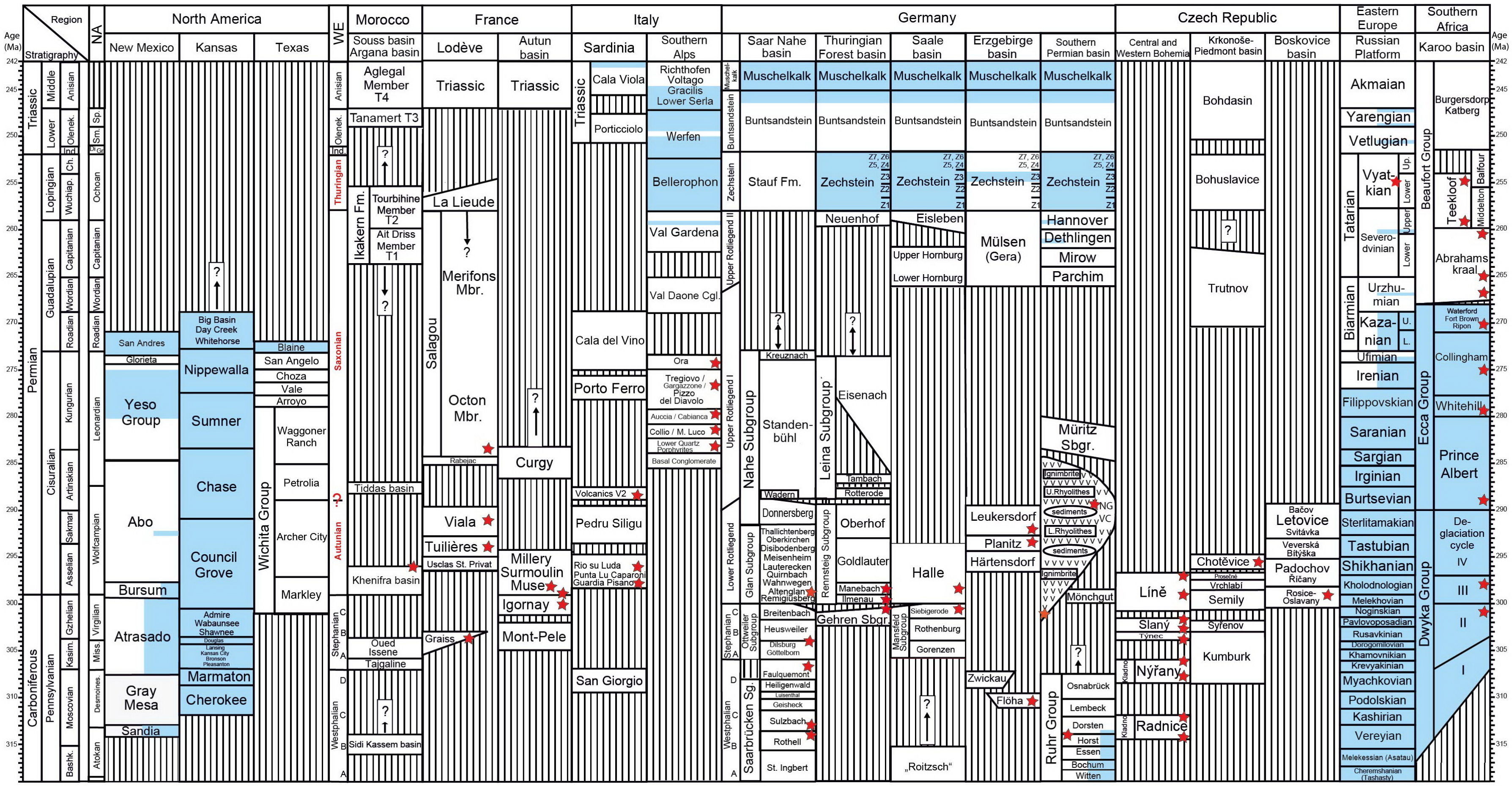

Fig. 1. Multistratigraphic correlation of the most important Euramerican basins with each other and with the profiles of the Russian Platform and South Africa. Marine deposits are marked in blue. Abbreviations: **NA** – regional North American Stages; **WE** – regional West European Stages; **Miss.** – Missourian; **Road.** – Roadian; **Gr.** – Griesbachian; **Di.** – Dienerian; **Sm.** – Smithian; **Sp.** – Spathian; **Cant.** – Cantabrian; **Graiss.** – Graissessac; **Cgl.** – Conglomerate; **Sg.** – Subgroup. Radioisotopic ages are marked with red stars: for Morocco from Youbi et al. (2018), for Lodève Basin Michel et al. (2015), for Autun Basin Pellenard et al. (2017), for Sardinia Gaggero et al. (2017) and Rossignol et al. (2025), for Southern Alps Marchetti et al. (2022), for Saar-Nahe Basin Pointon et al. (2012), Voigt et al. (2022) and Izart et al. (2025), for Thuringian Forest Basin Lützner et al. (2021), Trümper et al. (2023), Käßner et al. (2024), for Saale Basin Breitkreuz et al. (2009), Trümper et al. (2019); for Erzgebirge Basin Löcse et al. (2022); for Southern Permian Basin Breitkreuz et al. (2007); Luthardt et al. (2021) and for the Ruhr Group in the Variscan foreland Basin Pointon et al. (2012); Czech Republic basins Opluštil (2016a,b, 2017); for Russian Platform Davydov et al. (2020); for Southern Africa Day et al. (2015, 2022). Modified and completed after Schneider et al. (2020, fig. 2) and supplemented with new biostratigraphic and radioisotopic ages.

The ‘**Saxonin**’ was introduced by Munier-Chalmas and De Lapparent (1893, p. 454) as ‘Le faciès du grès rouge de Saxe dominant dans presque toute l'Europe’ (= the red sandstone facies of Saxony dominant throughout most of Europe). It refers to the red sediments above the “Autunin” and below the Zechstein, i.e., the classic “Rotliegend” in central Germany, whereby “Saxony” at the time of Munier-Chalmas and De Lapparent (1893) comprised the Kingdom of Saxony, the Prussian province of Saxony (parts of today's Saxony-Anhalt) and large parts of Thuringia, including the Thuringian Forest. The red sediments of the ‘Saxonin’ above the predominantly grey ‘Autunin’ in the sense of Munier-Chalmas and De Lapparent (1893) are only very incompletely preserved in Europe (Fig. 1). Nevertheless, it would make sense to pursue the idea of a regional chronostratigraphic stage encompassing the pure red continental sediment sequences of the European Permian. This is particularly true because chronostratigraphic units from the period down to the stage (should) always reflect processes in the history of the Earth, which are initially recognisable in striking changes of biota, biofacies and lithofacies, which are then defined chronostratigraphically.

Schneider (2001) proposed abandoning the Saxonian in favour of a Lodevian comprising the predominantly to exclusively red beds of Central Europe with the type section in the Lodève Basin in southern France. Exclusive red facies starts there with the Rabejac Formation (Körner et al., 2003; Schneider et al., 2006, 2020), which follows after a hiatus above the still alternating grey/red Viala Formation, which according to radioisotope dating (Michel et al., 2015) is still to be placed in the Autunian (Fig. 1). Based on tetrapod tracks (Fig. 2), the Rabejac Formation is younger than the totally red Tambach Formation (Voigt and Lucas, 2018; Schneider et al., 2020); it therefore does not mark the earliest onset of exclusive red bed facies in Central Europe, which should be defined chronostratigraphically as the base of a Saxonian. The idea of a Lodevian stage must therefore be abandoned.

If you look today for a **Saxonian** in what was in former times Saxony, you will find it in the Mülsen Formation of the Upper Rotliegend II in the Chemnitz Basin (Fig. 1), just below the Zechstein (Schneider et al., 2012). In Saxony-Anhalt, these would be the Hornburg and Eisleben formations of the Upper Rotliegend II, which follow the Halle Formation of the Lower Rotliegend with a hiatus of approx. 28 million years (Fig. 1). Both the Mülsen and Hornburg/Eisleben formations are therefore completely unsuitable for the definition of a Saxonian. In the former Saxon part of Thuringia, it would be the exclusively red Rotterode Formation of the Upper Rotliegend I, which follows the still alternating grey-red Oberhof Formation with a hiatus (Fig. 1). In the equally relatively continuous profile of the Saar-Nahe Basin, this would be the Standenbühl Formation (Fig. 1). The fossil content of the Rotterode and Standenbühl formations should be examined to see whether index fossils could be found at their base that would be suitable for at least a European-wide bio- or chronostratigraphic definition of the base of a Saxonian. As it is generally the case in the Permian continental red bed sediments of Europe, conchostracans would be best suited for this purpose (Fig. 2). In order to remain in the type region of a Saxonian, the fossil content of the Rotterode Formation would be suitable for defining the base of a Saxonian (Schneider et al., 2024b). According to conchostracans, the Rotterode Formation, together with the Tambach and Eisenach formations, belongs to the *Lioestheria andreevi–Pseudestheria* Form Wilhelmsthal-Assemblage Zone (Fig. 2) (Schneider and Scholze, 2018). Of these two species, *Lioestheria andreevi* appears to be restricted to the Rotterode and Tambach formations. If the occurrence of this species in the upper Oberhof Formation could be ruled out (Schneider and Scholze, 2018; Schneider et al., 2024b), this species would be very suitable for defining the base of the Saxonian, especially since it also appears to occur in the Sobernheim Horizon of the lower Standenbühl Formation of the Saar-Nahe Basin. With regard to continental trace fossils, the early Saxonian is indicated by an increase in the frequency of *Hyloidichnus* (captorhinid tracks of variable size) as well as by the first appearance of *Erpetopus* (small parareptilian track) and *Sphaerapus* (specialized hexapod burrow), as exemplified in the upper third of the Abo Formation in New Mexico, the Hermit Formation in Arizona, the Rabejac Formation of the Lodève Basin, and the Tiddas and Koudiat El Hamra-Haiane basins in Morocco (Lucas et al., 2013; Voigt and Lucas, 2017, 2018; Zouicha et al., 2021; Marchetti et al., 2025).

The new U–Pb CA–ID–TIMS zircon ages for the Thuringian Forest Basin (Lützner et al., 2021; Käßner et al., 2024; Fig. 3, inset) partly contradict biostratigraphic and lithostratigraphic correlations, raising questions about the absolute age of the Autunian/Saxonian boundary. According to the ages of Lützner et al. (2021) and Käßner et al. (2024), the 1,600 to 1,900 m thick discontinuous sequence from the upper Goldlauter Formation to the top of the Rotterode Formation covers the time interval 298.5 Ma to 296 Ma. This time interval corresponds approximately to the *Sysciophlebia balteata* form H zone in terms of insect biostratigraphy (Schneider et al., 2020; Belahmira et al., 2024), but is several insect biozones “too old” for the discussed part of the lithostratigraphic section (Figs. 1, 2). The *Sysciophlebia balteata* Form H zone is fixed with marine fossils in North America and with CA–ID–TIMS U-Pb zircon ages in the Autun and Boskovice basins in the time period 298.5 to 296.5 Ma in several independent profiles (Pellenard et al., 2017; Opluštil et al., 2017; Schneider et al., 2020). Insect biostratigraphy suggests a post-Sakmarian age for the Rotterode Formation, which contradicts the postulated radioisotopic age of 295.8 ± 0.4 Ma (Lützner et al., 2021; Käßner et al., 2024). The climate stratigraphy does not look much better: if we follow the radioisotopic age, the completely red Rotterode Formation would mean that sedimentation in pure red facies in the Thuringian Forest began much earlier than in almost all other non-maritime-influenced Carboniferous-Permian basins (e.g., Lodève Basin, mixed grey/red facies up to the top of the Viala Formation with a CA-ID-TIMS U-Pb zircon age of 290.96 ± 0.19 Ma (Michel et al. 2015) (Fig. 3).

There is no doubt about the high precision of the ages determined by Lützner et al. (2021) and Käßner et al. (2024), but the question is whether they really indicate eruption ages or older crystallization processes in the magma chamber. A detailed discussion of this issue can be found in Schneider et al. (2024b).

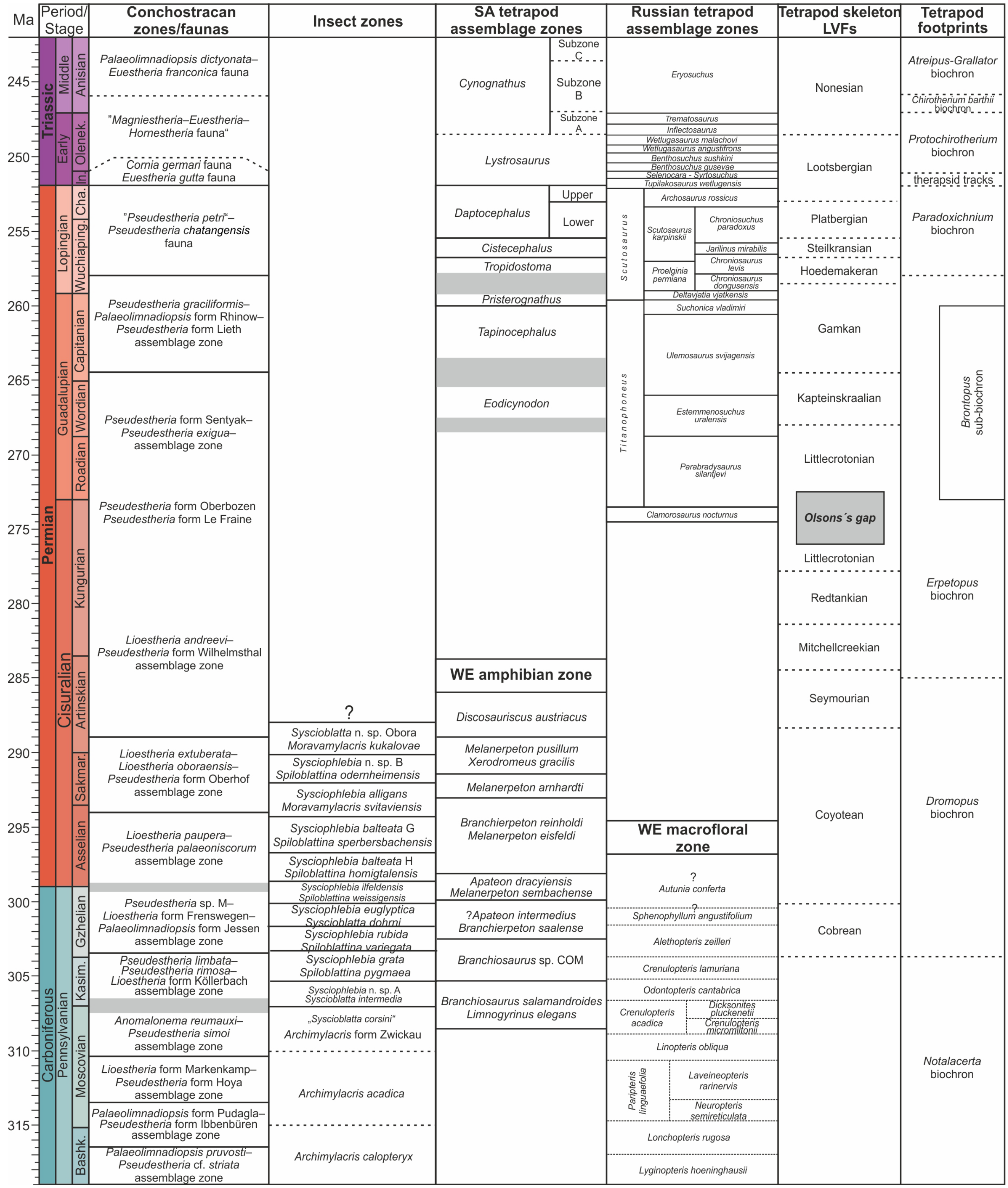

Fig. 2. Synthesis of biostratigraphic methods used here for basin correlations. Most of the zones are calibrated to each other by co-occurrences of zone species in the same horizon or stratigraphic level; for the calibration with the SGCS by radioisotopic ages see Fig. 1 and for co-occurrences of nonmarine and marine zone fossils see the discussion and references in the text. Levels of uncertainty are marked in gray. Abbreviations: **SA** – South African, **WE** – West European, **LVF** – land vertebrate faunachrons. From Schneider et al. (2020) modified with new biostratigraphic and radioisotopic age data.

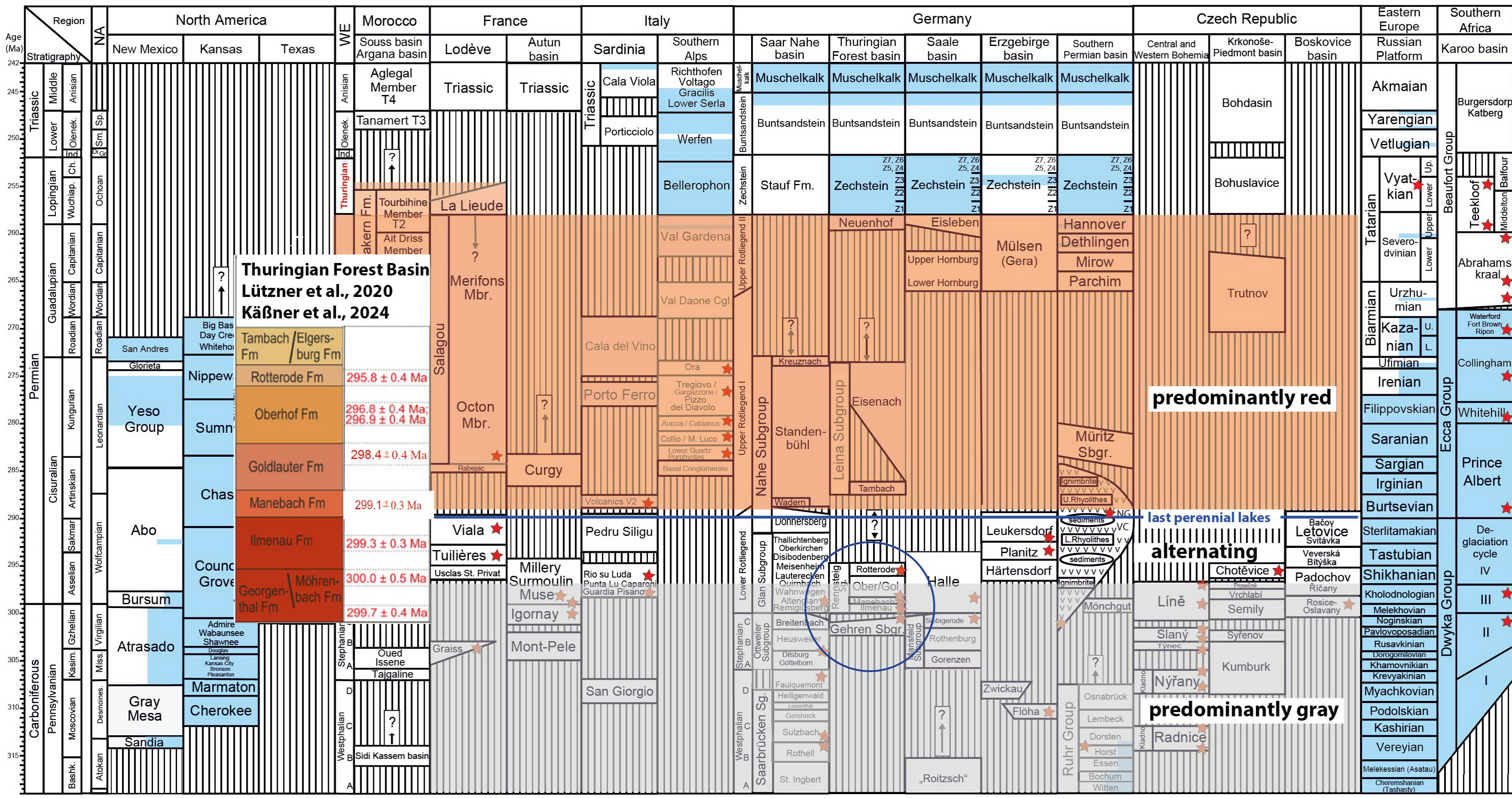

Fig. 3. Multistratigraphic correlation of the most important Euramerican basins with each other and with the profiles of the Russian Platform and South Africa as in Fig. 1. Inset show the radioisotopic ages for the Thuringian Forest Basin after Lützner et al. (2021) and Käßner et al. (2024). Based on these ages, the correlation of the formations in this basin has been adapted to the SGCS (blue circle). Climate depending changes from predominantly grey (marked in grey) with last intense coal formation around 300 Ma to alternating grey/red facies with the last perennial lake horizons by about 290 Ma and following predominantly wet to increasingly dry red bed facies (marked in red; exceptions discussed in the text). The position of the completely red Rotterode Formation contrasts not only to biostratigraphic data, as discussed in the text, but also to the general distribution of predominantly red beds in the Permian of Europe and North Africa.

The term '**Thuringian**' was introduced by Renevier (1874) to replace the term "Zechstein", which could not be translated into French. Like the 'Saxonian', it is primarily a lithostratigraphic category, even though it is sometimes treated as a regional WES in the literature (e.g., Henderson et al., 2020). Nevertheless, the Thuringian has the best chance of being accepted as a regional WES, as its base as a point in a given rock succession could be defined chronostratigraphically with conodonts (*Mesogondolella britannica*, *Merrillina divergens*). These conodonts from the English Marl Slate and the Kupferschiefer (Copper Slate) of Central Europe and their equivalents allow correlation with the early Wuchiapingian of the marine SGCS (Mei and Henderson, 2001; Legler and Schneider, 2013). Skeletons of the reptile *Protorosaurus speneri* and the tetrapod track *Paradoxichnium problematicum* most likely produced by this animal (Voigt, 2012, 2024; Voigt and Lucas, 2018; Marchetti et al., 2017), as well as possibly the macro- and microflora (Kerp et al., 2022), could contribute to the correlation with terrestrial equivalents of the initially marine Thuringian (Fig. 4). The upper boundary of the Thuringian is marked by the lowest occurrence of the *Euestheria gutta* conchostracan-zone species in the upper half of Zechstein cycle 7, the upper Fulda Formation, which marks the base of the Induan or the Triassic respectively in continental deposits (Scholze et al., 2017; 2020) (Fig. 2).

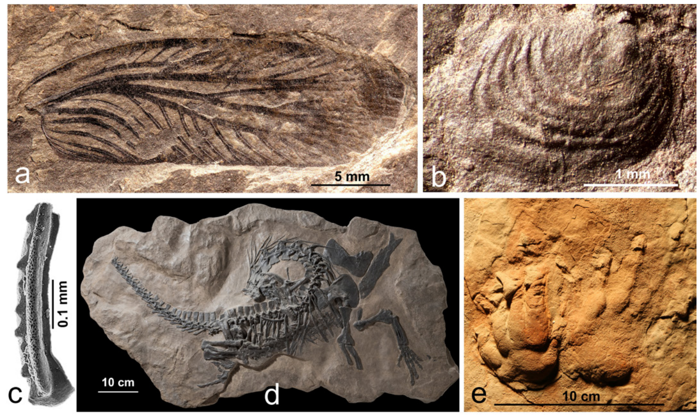

Fig. 4. Potential index fossils for Autunian, Saxonian and Thuringian. **a** – for base Autunian the insect biostratigraphy zone fossil *Sysciophlebia balteata* form H, lower Goldlauter Formation, Sperbersbach locality, Thuringian Forest Basin; Natural History Museum Schleusingen, collection number WP 7939. **b** – for base Saxonian the conchostracan biostratigraphy zone fossil *Lioestheria andreevi*, Tambach Formation, Bromacker locality, Thuringian Forest Basin, which also occurs in the Rotterode Formation; Natural History Museum Schleusingen, collection number NHMS-Am13096-1. **c** – for base Thuringian conodont zone species *Mesogondolella britannica*, basal Zechstein Kupferschiefer equivalent of well Nordsee C1, from Legler and Schneider (2008, fig. 4). **d** – for base Thuringian the reptile *Protorosaurus speneri*, basal Zechstein Kupferschiefer, Ibbenbüren, LWL Museum of Natural History Münster. **e** – tetrapod track *Paradoxichnium problematicum* made by *Protorosaurus*, terrestrial lower Zechstein of Thuringia (Ronneburg, Z2); holotype, Palaeontological collection Technical University Bergakademie Freiberg, collection number FG 20/1.

Conclusion

When the terms Autunian, Saxonian and Thuringian are used in current and future publications, even if they have not yet been formally confirmed as regional Western European Stages by the International Commission on Stratigraphy, this should be done in the sense as proposed here. This will help to avoid misunderstandings and will support the eventually future confirmation of these regional Western European Stages in common discussions.

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References

Breitkreuz, C., Ehling, B.C. and Sergeev, S., 2009. Chronological evolution of an intrusive/extrusive system: the late Paleozoic Halle Volcanic Complex in the northeastern Saale Basin (Germany). Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, v. 160, p. 173–190.

Breitkreuz, C., Kennedy, A., Geissler, M., Ehling, B.C., Kopp, J., Muszynski, A., Protas, A. and Stouge, S., 2007. Far Eastern Avalonia: its chronostratigraphic structure revealed by SHRIMP zircon ages from Upper Carboniferous to Lower Permian volcanic rocks (drill cores from Germany, Poland and Denmark). Geological Society of America Special Papers, v. 423, p. 173–190.

Broutin, J., Chateauneuf, J., Galtier, J. and Ronchi, A., 1999. L'Autunien d'Autun reste-t-il une référence pour les dépôts continentaux du Permien inférieur d'Europe? Apport des données paléobotaniques. Géologie de la France, v. 2, p. 17–31.

Chateauneuf, J.J. and Pacaud, G., 1991. The Autun Permian Basin The Autun Stratotype. Guidebook French Association for Permian Geology, 10 pp.

Day, M.O., Ramezani, J., Bowring, S.A., Sadler, P.M., Erwin, D.H., Abdala, F. and Rubidge, B.S., 2015. When and how did the terrestrial mid-Permian mass extinction occur? Evidence from the tetrapod record of the Karoo Basin, South Africa. The Royal Society Proceedings: ser. B, Biological Sciences, v. 282, 20150834. https://doi.org/10.1098/rspb.2015.0834.

Day, M.O., Ramezani, J.F., Ryan, E. and Rubidge, B.S. 2022. U-Pb zircon age constraints on the vertebrate assemblages and palaeomagnetic record of the Guadalupian Abrahamskraal Formation, Karoo Basin, South Africa. Journal of African Earth Sciences, v. 186, 104435. https://doi.org/10.1016/j.jafrearsci.2021.104435.

Davydov, V.I., Arefiev, M.P., Golubev, V.K., Karasev, E.V., Naumcheva, M.A., Schmitz, M.D., Silantiev, V.V. and Zharinova, V.V., 2020. Radioisotopic and biostratigraphic constraints on the classical Middle–Upper Permian succession and tetrapod fauna of the Moscow syneclise, Russia. Geology, v. 48, n. 7, p. 742–747. https://doi.org/10.1130/G47172.1.

Depéret, C. and Mazeran, P., 1912. Les Estheria du Permien d'Autun. Bulletin de la Société d'Histoire Naturelle d'Autun, v. 25, p. 165–174.

Fritsch, A., 1901. Fauna der Gaskohle und der Kalksteine der Permformation Böhmens. Selbstverlag, Prag, v. 4, n. 3, p. 65–101.

Gaggero, L., Gretter, N., Langone, A. and Ronchi, A., 2017. U–Pb geochronology and geochemistry of late Palaeozoic volcanism in Sardinia (southern Variscides). Geoscience Frontiers, v. 8, p. 1263–1284. https://doi.org/10.1016/j.gsf.2016.11.015.

Henderson, C.M., Shen, S.Z., Gradstein, F.M. and Agterberg, F.P., 2020. The Permian Period. In Gradstein, F.M., Ogg, J.G., Schmitz, M.D. and Ogg, G.M. (eds.), The geologic time scale 2020. Elsevier, Amsterdam, p. 875–902. https://doi.org/10.1016/C2020-1-02369-3.

Käßner, A., Tichomirowa, T., Rößler, R. and Görz, I., 2024. Zircon U–Pb CA–ID–TIMS constraints on the chronology of the Late Carboniferous–early Permian continental Döhlen Basin and its correlation with the Thuringian Forest Basin (Central and Eastern Germany). International Journal of Earth Sciences, v. 113, p. 1599–1618. https://doi.org/10.1007/s00531-024-02464-0.

Kerp, H., Bödige, H., Bomfleur, B. and Schneider, J.W., 2022. First records of the conifers Majonica and Ortiseia from the German Zechstein (upper Permian) of east Thuringia and west Saxony, Germany. Botany Letters, p. 1–19. https://doi.org/10.1080/23818107.2022.2122555.

Körner, F., Schneider, J.W., Hoernes, S., Gand, G. and Kleeberg, R., 2003. Climate and continental sedimentation in the Permian of the Lodève basin (Southern France). Bollettino della Società Geologica Italiana, Volume speciale, n. 2, p. 185–191.

Kustatscher, E., Bernardi, M., Fabio Massimo Petti, F.M., Franz, M., van Konijnenburg-van Cittert, J.H.A. and Kerp, H., 2017. Sea-level changes in the Lopingian (late Permian) of the northwestern Tethys and their effects on the terrestrial palaeoenvironments, biota and fossil preservation. Global and Planetary Change, v. 148, p. 166–180. https://doi.org/10.1016/j.gloplacha.2016.12.006.

Legler, B. and Schneider, J.W., 2013. High-frequency cyclicity preserved in nonmarine and marine deposits (Permian, Germany and North Sea). In Lucas, S.G., DiMichele, W.A., Barrick, J.E., Schneider, J.W. and Spielmann, J.A. (eds.), 2013. The Carboniferous-Permian Transition. New Mexico Museum of Natural History and Science, Bulletin, v. 60, p. 200–211.

Löcse, F., Schneider, G., Härtel, B., Linnemann, U. and Rößler, R., 2022. Schwierigkeiten mit dem Alter - U-Pb LA-ICPMS-Datierungen von Grüna-Tuff und Planitz-Ignimbrit (Planitz-Formation, Chemnitz-Becken, frühes Perm). Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, v. 174, n. 3, p. 521–544.

Lucas, S.G., 2018. The GSSP method of chronostratigraphy: A critical review. Frontiers in Earth Science, v. 6: 191, p 1–19. https://doi.org/10.3389/feart.2018.00191.

Lucas, S.G., 2020. GSSP-based Chronostratigraphy: Should Boundaries Be Defined by Arbitrarily Chosen Non-Events? Permophiles, n. 68, p. 9–11.

Lucas, S.G., Voigt, S., Lerner, A.J. and Rainforth, E.C., 2013. *Sphaerapus*, a poorly known invertebrate trace fossil from nonmarine Permian and Jurassic strata of North America. Ichnos, v. 20, p. 142–152. https://doi.org/10.1080/10420940.2013.817406.

Luthardt, L., Breitkreuz, C., Schneider, J.W., Gaitzsch, B., Brink, J., Stanek, K.P., Linnemann, U., Hofmann, M. and Ehling, B.C., 2021. An andesitic sill complex in the Southern Permian Basin: volcanogenetic model and stratigraphic implications. International Journal of Earth Sciences, v. 109, n. 7, p. 2447–2466. https://doi.org/10.1007/s00531-020-01911-y.

Lützner, H., Tichomirowa, M., Käßner, A. and Gaupp, R., 2021. Latest Carboniferous to early Permian volcanostratigraphic evolution in Central Europe – U–Pb CA-ID-TIMS ages of volcanic rocks in the Thuringian Forest Basin (Germany). International Journal of Earth Sciences, v. 110, p. 377–398. https://doi.org/10.1007/s00531-020-01957-y.

Marchetti, L., Voigt, S. and Klein, H., 2017. Revision of Late Permian tetrapod tracks from the Dolomites (Trentino-Alto Adige, Italy). Historical Biology, v. 31, p. 748–783. http://doi.org/10.1080/08912963.2017.1391806.

Marchetti, L., Forte, G., Kustatscher, E., DiMichele, W.A., Lucas, S.G., Roghi, G., Juncal, M.A., Hartkopf-Fröder, C., Krainer, K., Morelli, C. and Ronchi, A., 2022. The Artinskian Warming Event: an Euramerican change in climate and the terrestrial biota during the early Permian. Earth-Science Reviews, v. 226, 103922. https://doi.org/10.1016/j.earscirev.2022.103922.

Marchetti, L., Mujal, E., Logghe, A., Buchwitz, M., Klein, H. and Lucas, S.G., 2025. Permian vertebrate tracks. In Lucas S.G., Hunt A.P. and Klein H. (eds.), Vertebrate Ichnology. Chapter 4, p. 87–178. https://doi.org/10.1016/B978-0-443-13837-9.00007-X.

Mayer-Eymar, C., 1881. Classification internationale, naturelle, uniforme, homomorphe et pratique des terrains de sediments. unpublished manuscript, Archiv Bibliothek Polytechnicum ETH Zürich, 15 pp.

Mei, S.L. and Henderson, C.M., 2001. Evolution of Permian conodont provincialism and its significance in global correlation and paleoclimate implication. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 170, p. 237–260. https://doi.org/10.1016/S0031-0182(01)00258-9.

Michel, L.A., Tabor, N.J., Montañez, I.P., Schmitz, M.D. and Davydov, V.I., 2015. Chronostratigraphy and paleoclimatology of the Lodève Basin, France: Evidence for a pan-tropical aridification event across the Carboniferous–Permian boundary. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 430, p. 118–131. https://doi.org/10.1016/j.palaeo.2015.03.020.

Munier-Chalmas, E. and De Lapparent, A., 1893. Note sur la nomenclature des terrains sédimentaires. Bulletin de la Société Géologique de France, v. 3, n. 21, p. 454.

Nelson, W.J. and Lucas, S.G., 2021. The Cantabrian and Barruelian substages (Stephanian Stage, Carboniferous) were never properly defined and should be dropped from formal usage. New Mexico Museum of Natural History and Science Bulletin, v. 82, p. 285–296.

Opluštil, S., Schmitz, M., Cleal, C.J. and Martínek, K., 2016a. A review of the Middle–Late Pennsylvanian west European regional substages and floral biozones, and their correlation to the geological time scale based on new U–Pb ages. Earth-Science Reviews, v. 154, p. 301–335. https://doi.org/10.1016/j.earscirev.2016.01.004.

Opluštil, S., Schmitz, M., Kachlík, V. and Stamberg, S., 2016b. Re-assessment of lithostratigraphy, biostratigraphy, and volcanic activity of the late Paleozoic Intra- Sudetic, Krkonoše-Piedmont and Mnichovo Hradiště basins (Czech Republic) based on new U-Pb CA-ID-TIMS ages. Bulletin of Geosciences, v. 91, n. 2, p. 399–432.

Opluštil, S., Jirásek, J., Schmitz, M. and Matýsek, D., 2017. Biotic changes around the radioisotopically constrained Carboniferous–Permian boundary in the Boskovice Basin (Czech Republic). Bulletin of Geosciences, v. 92, n. 1, p. 95–122. https://doi.org/10.3140/bull.geosci.1638.

Pellenard, P., Gand, G., Schmitz, M., Galtier, J., Broutin, B. and Stéyer, J.S., 2017. High-precision U-Pb zircon ages for explosive volcanism calibrating the NW European continental Autunian stratotype. Gondwana Research, v. 51, p. 118–136. https://doi.org/10.1016/j.gr.2017.07.014.

Pointon, M.A., Schew, D.M., Ovtcharova, M., Sevastopulo, G.D. and Crowley, Q.G., 2012. New High-precision U-Pb dates from western European Carboniferous tuffs; implications for time-scale calibration, the periodicity of Late Carboniferous cycles and stratigraphical correlation. Geological Society of London, v. 169, p. 713–721. https://doi.org/10.1144/jgs2011-092.

Renevier, E., 1874. Tableau des terrains sédimentaires formés pendant les époques de la phase organique du globe terrestre. Bulletin de la Societé Vaudoise des Sciences Naturelles, v. 12, n. 70, p. 218–252.

Rossignol, C., Logghe, A., Luccisano, V., Shi, X., Cogné, N., Poujol, M., Pradel, A., Bourquin, S., Pillola, G.L., Botella, H., Cocco, F., Loi, A., Fois, D., Stara, P. and Sanciu, L., 2025. New age constraints for the Perdasdefogu Basin, Italy: implications for vertebrate paleobiogeography during the early Permian. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 675, 113085. https://doi.org/10.1016/j.palaeo.2025.113085.

Salvador, A., 2013 (ed.). International stratigraphic guide: a guide to stratigraphic classification, terminology and procedure. International Union of Geological Sciences. International Subcommission on Stratigraphic Classification, Second Edition; https://doi.org/10.1130/9780813774022.

Schneider, J., 2001. Rotliegendstratigraphie – Prinzipien und Probleme. Beiträge zur Geologie von Thüringen, N.F., v. 8, p. 7–42.

Schneider, J.W., 2020. Summary report of the Nonmarine-Marine Correlation Working Group and notes from the former Vice-Chair of the SPS. Permophiles, n. 69, p. 37–40.

Schneider, J.W., 2023. Permophiles 2007 – 2023: looking back and looking forward on the tasks and results of the Nonmarine-Marine Late Carboniferous – Permian – Early Triassic Correlation Working Group. Permophiles, n. 75, p. 26–31.

Schneider, J.W. and Scholze, F., 2018. Late Pennsylvanian–Early Triassic conchostracan biostratigraphy: A preliminary approach. In Lucas, S.G. and Shen, S.Z. (eds.), The Permian Timescale. Geological Society of London, Special Publications, v. 450, p. 365–386. https://doi.org/10.1144/SP450.6.

Schneider, J.W., Körner, F., Roscher, M. and Kroner, U., 2006. Permian climate development in the northern peri-Tethys area — the Lodève basin, French Massif Central, compared in a European and global context. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 240, p. 161–183. https://doi.org/10.1016/j.palaeo.2006.03.057.

Schneider, J., Rößler, R. and Fischer, F., 2012. Rotliegend des Chemnitz-Beckens (syn. Erzgebirge-Becken). In Deutsche Stratigraphische Kommission: Stratigraphie von Deutschland X. Rotliegend. Teil I: Innervariscische Becken. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, v. 61, p. 530–588.

Schneider, J.W., Lucas, S.G., Scholze, F., Voigt, S., Marchetti, L., Klein, H., Opluštil, S., Werneburg, R., Golubev, V.K., Barrick, J.E., Nemyrovska, T., Ronchi, A., Day, M.O., Silantiev, V.V., Rößler, R., Saber, H., Linnemann, U., Zharinova, V. and Shen, S.Z., 2020. Late Paleozoic–early Mesozoic continental biostratigraphy - Links to the Standard Global Chronostratigraphic Scale. Palaeoworld, v. 29, n. 2, p. 186–238. https://doi.org/10.1016/j.palwor.2019.09.001.

Schneider, J.W., Werneburg, R., Trümper, S., Voigt, S., Rößler, R., Spindler, F., Scholze, F., Luthardt, L., Fischer, J. and Gaitzsch, B., 2024a. Palökologie im Karbon und Perm des Thüringer-Wald-Beckens. In Werneburg, R. and Schneider, J.W. (eds.), Rotliegend-Fauna des Thüringer Waldes. Semana, Sonderveröffentlichung, Kap. 18, p. 199–256.

Schneider, J.W., Werneburg, R., Voigt, S., Rößler, R., Spindler, F., Scholze, F. and Roscher, M., 2024b. Karbon und Perm im Thüringer-Wald-Becken – ein euramerisches Referenzprofil für regionale und globale Prozesse. In Werneburg, R. and Schneider, J.W. (eds.), Rotliegend-Fauna des Thüringer Waldes: Semana, Sonderveröffentlichung, Kap. 19, p. 257–268.

Scholze, F., Wang, X., Kirscher, U., Kraft, J., Schneider, J.W., Götz, A.E., Joachimski, M.M. and Bachtadse, V., 2017. A multistratigraphic approach to pinpoint the Permian-Triassic boundary in continental deposits - The Zechstein–Lower Buntsandstein transition in Germany. Global and Planetary Change, v. 152, p. 129–151. https://doi.org/10.1016/j.gloplacha.2017.03.004.

Scholze, F., Shen, S.Z., Backer, M., Wei, H.B., Hübner, M., Cui, Y.Y., Feng, Z. and Schneider, J.W., 2020. Reinvestigation of conchostracans (Crustacea: Branchiopoda) from the Permian–Triassic transition in Southwest China. Palaeoworld, v. 29, n. 2, p. 368–390. https://doi.org/10.1016/j.palwor.2019.04.007.

Trümper, S., Gaitzsch, B., Schneider, J.W., Ehling, B.C. and Rößler, R., 2019. Die versteinerten Bäume des Kyffhäusers (Oberkarbon, Thüringen): Forschungshistorie, Ablagerungsraum und Alter. Veröffentlichungen Museum für Naturkunde Chemnitz, v. 42, p. 5–44.

Trümper, S., Vogel, B., Germann, S., Werneburg, R., Schneider, J.W., Hellwig, A., Linnemann, U., Hofmann, M. and Rößler, R., 2023. Decoding the drivers of deep-time wetland biodiversity: insights from an early Permian tropical lake ecosystem. Palaeontology, v. 66, n. 3, e12652. https://doi.org/10.1111/pala.12652.

Voigt, S., 2012. Tetrapodenfährten. In Deutsche Stratigraphische Kommission (ed.), Stratigraphie von Deutschland X. Rotliegend. Teil I. Innervariscische Becken. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, v. 61, p. 92–106.

Voigt, S., 2024. Tetrapodenfährten. In Werneburg, R. and Schneider, J.W. (eds.), Rotliegend-Fauna des Thüringer Waldes. Semana, Sonderveröffentlichung, Kap. 17, p. 184–196.

Voigt, S. and Lucas, S.G., 2017. Early Permian tetrapod footprints from central New Mexico. New Mexico Museum of Natural History and Science Bulletin, v. 77, p. 333–352.

Voigt, S. and Lucas, S.G., 2018. Outline of a Permian tetrapod footprint ichnostratigraphy. In Lucas, S.G. and Shen, S.Z. (eds.), The Permian Timescale. Geological Society of London, Special Publications, v. 450, p. 387–404. https://doi.org/10.1144/SP450.10.

Voigt, S., Schindler, T., Tichomirowa, M., Käßner, A., Schneider, J.W. and Linnemann, U., 2022. First high-precision U–Pb age from the Pennsylvanian-Permian of the continental Saar–Nahe Basin, SW Germany. International Journal of Earth Sciences, v. 111, p. 2129–2147. https://doi.org/10.1007/s00531-022-02222-0.

Werneburg, R., Ronchi, A. and Schneider, J.W., 2007. The Lower Permian Branchiosaurids (Amphibia) of Sardinia (Italy): Systematic Palaeontology, Palecology, Biostratigraphy and Palaeobiogeographic Problems. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 252, p. 383–404. https://doi.org/10.1016/j.palaeo.2007.03.048.

Youbi, N., Gaggero, L., Assafar, H., Hadimi. I., Boumehdi, M.A., Bensalah, M.Kh., Linnemann, U., Gärtner, A., Mata, J., Doblas, M., Cabanis, B., Chalot-Prat, F., Cailleux, Y., Ben Abbou, M., Zouita, F. and Khounch, H., 2018. U-Pb Zircon Geochronological and Petrologic Constraints on the Post- Collisional Variscan Volcanism of the Khenifra Basin (Western Meseta, Morocco). Stratigraphic and Petrogenetic Implications. – 2nd International Congress on Permian and Triassic, Casablanca 25th-27th April 2018, Abstract Book, p. 53–54.

Zouicha, A., Voigt, S., Saber, H., Marchetti, L., Hminna, A., El Attari, A., Ronchi, A. and Schneider, J.W., 2021. First record of Permian continental trace fossils in the Jebilet Massif, Morocco. Journal of African Earth Sciences, v. 173, 104015. https://doi.org/10.1016/j.jafrearsci.2020.104015.

The Umm Irna Formation in the Dead Sea Region (Jordan) is Permian, not Triassic!

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In a recent paper by Ahmad et al. (2024) it was suggested that the age of the terrestrial Umm Irna Formation would be Triassic instead of Permian as had been stated before. A correct age constraint of the formation is crucial because it has yielded a very rich and diverse flora with several "typical Mesozoic" taxa, e.g., *Dicroidium*, occurring together with typical Permian elements. Moreover, the flora comprises a mixture of taxa from different floral provinces, i.e., Gondwana, Cathaysia and Euramerica.

The age assessment by Ahmed et al. (2024) was based on a palynological study. However, the Umm Irna Fm. is not exposed where they took the samples according to their locality map; moreover, the text even indicates another locality. Several of the illustrated palynomorphs are very poorly preserved and unidentifiable, while others are clearly misidentified. Hence, their claim that the Umm Irna Formation would be Triassic is not justified. The age of the Umm Irna Fm. is firmly established, based on detailed palynological studies, e.g., Stephenson et al. (2024) and Stephenson (2025), including correlations with borehole data from the partly marine developed succession in Israel. For more arguments, a detailed discussion and further references please refer to Kerp et al. (2025); a pdf of this latter paper is available on request from: kerp@uni-muenster.de.

References

Ahmad, T., Tahoun, S. S., Makhlouf, I., Al-Kahtany, K., Ibrahim, M. and Zaky, A. S., 2024. Triassic sporomorph data for the Umm Irna Formation: Age constraints from the northwestern part of Jordan. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 310, n. 3, p. 239–250.

Kerp, H., Abu Hamad, A., Stephenson, M.H., Jardine, P.E., Blomenkemper, P. and Bomfleur, B., 2025. The Late Permian (Changhsingian) age of the Umm Irna Formation, Dead Sea region, Jordan. Comment on: Triassic sporomorph data for the Umm Irna Formation: Age constraints from the northwestern part of Jordan by F. Ahmad, S. S. Tahoun, I. Makhlouf, K. Al-Kahtany, M. Ibrahim and A. S. Zaky (Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 310/3, 239–250). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 314, n. 3, p. 277–287.

Stephenson, M. H., 2025. A tentative upper Guadalupian–Lopingian (Middle–Upper Permian) palynozonation for the Arabian Peninsula and Levant. Petroleum Geoscience, v. 31, petgeo2025-011.

Stephenson, M. H., Bomfleur, B., Jardine, P., Kerp, H., Blomenkemper, P., Bäumer, R., Abu Hamad, A. and Schneider, J. W., 2024. Palynological variability within the Permian (Changhsingian) Umm Irna Formation (Jordan): implications for biostratigraphy and fluid-flow character in alluvial formations. Palynology, v. 48, n. 4, 2388134.

Large language models for palynomorph and brachiopod identification

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In light of recent advances in AI technology in science, we considered it a useful exercise to investigate whether a large language model (LLM) could provide a reliable and accurate aid to identifications in branches of palaeontology. We chose to develop pilot LLM-augmented taxonomic keys (LATKs) to support researchers in the identification of palynomorphs and brachiopods– both common fossils in Permian successions.

Identification keys are not new. The first identification key was developed by Lamarck (1778) who included several in his book 'Flore Françoise'. This used dichotomous keys, which are classification tools that allow the user to choose between opposing pairs of morphological characters. The use of artificial intelligence in palaeontological identification keys is rare, being mostly limited to commercial systems that use images as prompts to identification rather than formal descriptions of taxa.

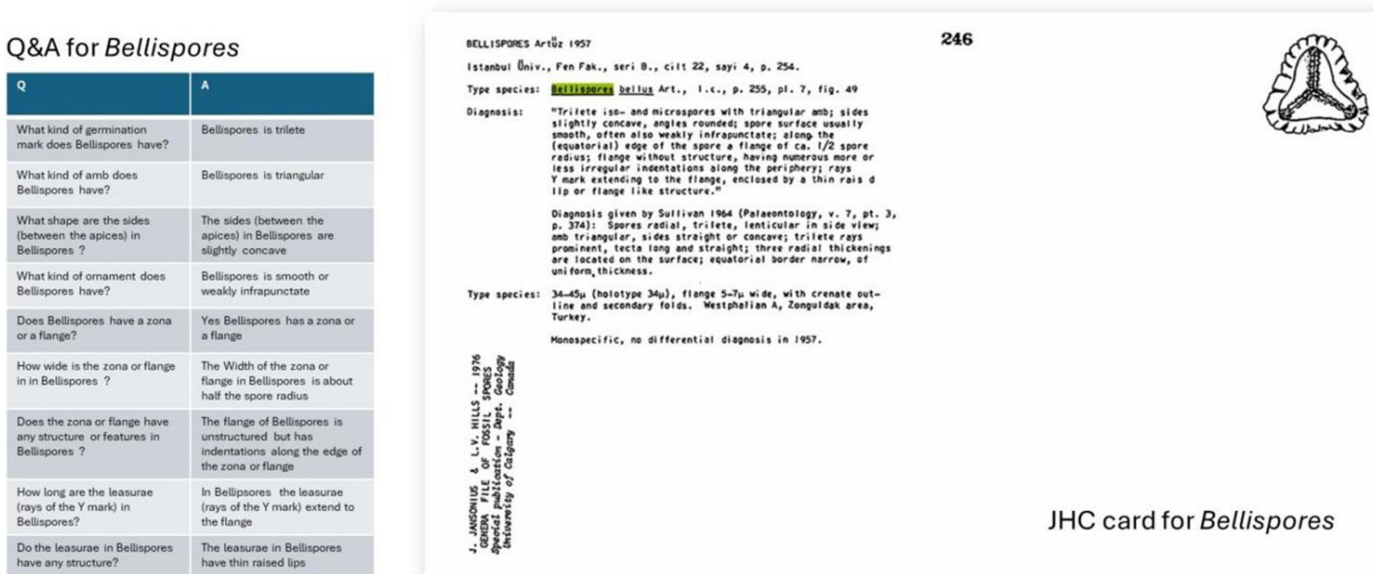
An LLM, being text based, is the ideal form of AI to work in palaeontology because taxonomic palaeontology is based on the primacy of text (diagnoses/descriptions) in published papers. An LLM is essentially a sophisticated pattern-recognition system that processes text data to generate coherent, contextually relevant responses. LLMs learn from extensive text datasets, including books, articles, and websites. This helps them recognize patterns in language, grammar, meaning, and context. LLMs use deep learning architectures, particularly transformers, to process and generate text.

We set out to see if very large text databases of fossils could be used to develop LLMs that can guide a palaeontologist through the stages of identification, allowing for the palaeontologist to make the best judgements on determination with the best supporting information and guidance. This article is about two of these datasets and the challenge of making them suitable for LLM development.

Palynology LATK Taxonomy Assistant 2.2

The database in question for palynology is the Jansonius and Hills Catalogue (JHC; 1976 and subsequent updates) of fossil spore and pollen genera. The JHC was originally created as a series of cards - originally one card per genus – and contains around 4500 spore (fungi, plants and algae) and pollen genera from the Phanerozoic. This monumental database by Calgary palynologists J Jansonius and L V Hills provides descriptions and diagnoses for these genera, the source publications and authors, descriptions of genus type species, and often subsequent genus descriptions, including formal emendations. Taken as a whole, the catalogue is an enormously useful resource which has no other equivalent in palynology.

An LLM augmented taxonomic key (LATK) has already been developed for a much smaller dataset (around 70 spore species from the Carboniferous–Permian of the Arabian Plate) where 'chain of thought' logical steps are embedded in the


Q&A for *Bellispores*

Q	A
What kind of germination mark does Bellispores have?	Bellispores is trilete
What kind of amb does Bellispores have?	Bellispores is triangular
What shape are the sides (between the apices) in Bellispores ?	The sides (between the apices) in Bellispores are slightly concave
What kind of ornament does Bellispores have?	Bellispores is smooth or weakly infrapunctate
Does Bellispores have a zona or a flange?	Yes Bellispores has a zona or a flange
How wide is the zona or flange in in Bellispores ?	The Width of the zona or flange in Bellispores is about half the spore radius
Does the zona or flange have any structure or features in Bellispores ?	The flange of Bellispores is unstructured but has indentations along the edge of the zona or flange
How long are the leasurae (rays of the Y mark) in Bellispores?	In Bellispores the leasurae (rays of the Y mark) extend to the flange
Do the leasurae in Bellispores have any structure?	The leasurae in Bellispores have thin raised lips

BELLISPORES Artüz 1957 246

Istanbul Üniv., Fen Fak., seri B., cilt 22, sayi 4, p. 254.

Type species: Bellispores bellus Art., l.c., p. 255, pl. 7, fig. 49

Diagnosis: "Trilete iso- and microspores with triangular amb; sides slightly concave, angles rounded; spore surface usually smooth, often also weakly infrapunctate; along the (equatorial) edge of the spore a flange of ca. 1/2 spore radius; flange without structure, having numerous more or less irregular indentations along the periphery; rays Y mark extending to the flange, enclosed by a thin rais d lip or flange like structure."

Diagnosis given by Sullivan 1964 (Palaeontology, v. 7, pt. 3, p. 374): Spores radial, trilete, lenticular in side view; amb triangular, sides straight or concave; trilete rays prominent, tecta long and straight; three radial thickenings are located on the surface; equatorial border narrow, of uniform thickness.

Type species: 34–45μ (holotype 34μ), flange 5–7μ wide, with crenate outline and secondary folds. Westphalian A, Zonguldak area, Turkey.

Monospecific, no differential diagnosis in 1957.

J. JANSONIUS & L.V. HILLS -- 1976
GENERA FILE OF FOSSIL SPORES
Special publication - Dept. Geology
University of Calgary -- Canada

JHC card for *Bellispores*

Fig. 1. A series of QA pairs for the spore genus *Bellispores*. Q&A pairs on the left; JHC card on the right.(https://ddeworld.org/blog/detail/320)

system (Stephenson et al., 2025) through careful structuring of the learning material (for example in providing hierarchical stages in the process). This functions relatively well. However, the decision was made to develop a taxonomic key for the JHC mainly because its comprehensive and authoritative coverage would be of interest to a wider group of palynologists. Because of the difficulties of pre-structuring such a large dataset (as was done with the Carboniferous–Permian LATK), it was agreed to proceed on the basis of a Retrieval-Augmented Generation (RAG) technique to search for the best matches based on users' descriptions.

The first stage was to gain permission to use the database for LLM training. The JHC is open-access as an online, searchable PDF in the digital collection of the Library of the University of Calgary. Permission was sought from the library which instead referred the team to the descendants of J Jansonius (sadly deceased). Following correspondence, the Jansonius family readily agreed to allow the team to develop the JHC as learning material for AI applications.

This was perhaps the easiest part. Careful study of the database revealed many problems affecting the usability of the dataset.

The first is the quality of the PDF. The text was originally manually typed onto cards in the 1970s and 80s and some of the typed letters are not clear; for example the computing system often mistakes Os for 0s, with the result that the names of genera and their characteristics are sometimes obscured. Similar mistakes occur with non-standard symbols and letters, or letters with umlauts, for example.

The quality of descriptions and diagnoses of genera is very variable. There are some excellent comprehensive descriptions and diagnoses of genera erected in the later years of the rapid expansion of palynology in the 1960s and 1970s, particularly when the science was being taken up by the oil industry. However, many early genus descriptions and diagnoses are very short and sketchy, partly because at the time of their composition, palynology was a young science and few other genera had been recognised so low levels of detail in descriptions was the norm. Jansonius and Hills correctly recognised also that some genera have been invalidly published (e.g., Gravendyck et al., 2021), so some names appearing in the JHC are superfluous. Jansonius and Hills often dealt with descriptions and diagnoses in foreign languages by translating them (many are translated from Russian).

Inconsistent use of terminology is another problem. This inconsistency occurs in several forms, for example synonyms for the same ornament element type (verrucae/warts), or more commonly multiple slightly different versions of descriptive terms (spines or spinae; bacula or baculae). Palynological terminology has also developed near parallel systems (e.g., exoexine/intexine, nexine/sexine; cavate/camerate) often due to different usage in the different international 'schools' of palynology, and different terminology developed for different time periods (e.g., the Palaeozoic and Cenozoic).

The most important part of the training that deals with many of these problems is the creation of 'question-and-answer pairs' because they help the LLM to learn how to generate relevant, structured, and context-aware responses. For the JHC, two kinds of question-and-answer pairs were developed. The first are structured QA pairs directly anchored in the JHC text; in other words the answers to the questions can be found directly within the text of JHC. A set of Q&A pairs for the spore genus *Bellispores* is shown in Fig. 1. Most questions are simple: 'Question; What kind of germination mark does *Bellispores* have?', 'Answer; *Bellispores* has a trilete mark'; and the answers can be found directly in the corresponding card (Fig. 1). The QA pairs also had to include similarly anchored compound questions (requiring integration of multiple information), and counterintuitive questions (testing the model's error-correction ability, e.g. 'Is *Bellispores* monolete?'). The simple, compound and counterintuitive QA pairs are used to 'supervised fine tune' the embedding model to expand the word lists for the genera. When users type in descriptions similar to those of the QA pairs, the RAG system recognizes these descriptions and gives certain genera higher scores when recommending potential candidates.

The second type of QA pairs are known as 'incorporate'; these cover areas of palynology outside the immediate learning materials, i.e. outside the JHC. They include questions like 'What are the characteristics of zonate spores?' and 'Describe all the features of monolete spores'. The incorporate QA pairs are similarly used to supervised-fine tune the LLM in the broader knowledge of palynology.

Hundreds of QA pairs were generated for the JHC, partly by specialists (authors MHS and AC). Synthetic QA pairs were also be generated by the LLM based on the QA pairs generated by the specialists. Many of these preparations are complete and the LATK is now in advanced development and will be ready for testing soon.

In many ways this is a good example of data and knowledge that although very important to a developing science, is currently accessible in only an unsophisticated form. Many palynologists will know of the JHC and will have used it. But it isn't easy to use and there are many trends in the data which are hidden from view because in its unprocessed form it cannot easily by assimilated into any artificial intelligence platform.

The conversion of the JHC into a LATK is typical of the challenges of making complex data suitable for AI development.

Taxonomy assistant for brachiopod identification

Given the promising results obtained with the JHC Taxonomy Assistant for palynology, we thought it would be useful to expand the development of taxonomy assistants to other fields of palaeontology, in particular to that of invertebrate palaeontology. An almost complete database of invertebrate fossil genera exists in the form of the Treatise of Invertebrate Paleontology, published from 1953 by the Geological Society of America and the University of Kansas, consisting of 55 volumes, written by more than 300 palaeontologists, and subdivided in a number of sections each dealing with a different invertebrate animal phylum.

Permission to work with the descriptions of genera from the Treatise was gained from the University of Kansas, whereas the data were provided by Prof Jim Ogg's team at Purdue University, which was already working on the digitalisation of the Treatise in collaboration with the Zhejiang Lab, Hangzhou.

Developing a TA based on genera descriptions in the Treatise provided different challenges to those encountered during the development of TA2.2: nomenclature is mostly consistent in all sections of the Treatise, as well as the format of genera diagnoses. PDFs are mostly of high quality, and the extraction of texts was performed without problems.

However there were difficulties in dealing with the Treatise in that some sections are quite old and do not contain some genera described in the second half of the 20th century (e.g., Mollusca section). A second difficulty is that the Treatise includes only short diagnoses for each invertebrate genus, not complete descriptions.

To overcome the first problem, the Treatise Section Part H BRACHIOPODA (Revised) was selected (Williams et al., 1997, 2000, 2002, 2006, 2007). This is the revised version of the original Brachiopod volumes (Williams et al., 1965), one of the most complete and recently updated sections of the Treatise.

A first version of the Brachiopod TA has been then developed based on data extracted from Part H (Revised) volumes, obtaining a TA capable of guiding the user through the identification of around four thousand genera (Fig. 2). First tests of the Brachiopod TA provided mildly satisfactory results, given the shortness and incompleteness of the diagnoses. In order to increase the efficacy of the TA, the inclusion in the genus diagnosis of the information provided for the corresponding higher hierarchy taxa (family, superfamily, order), and possibly the integration of QA pairs will be attempted in the near future, obtaining a Brachiopod TA 2.0 which will be available for open testing alongside TA 2.2 in the GeoGPT Agent Store (https://geogpt.zero2x.org/).

LLM-augmented taxonomic keys into the future

The two LLM-augmented taxonomic keys (LATKs) presented in this contribution represent the first of their kind. Though they might present numerous shortcomings either reflecting the imperfection of the learning materials (Jansonius and Hills database, Treatise of Invertebrate Paleontology) and the numerous problems encountered during their implementation, they also show the potential of further future development of such AI-powered tools. LATKs could become part of the basic set of tools used by systematic palaeontologists, assisting them in their identification work and speeding up their workflow, speeding up the process of information retrieval on taxa and selection of a genus/species-group suitable for the specimens under study. Furthermore, LATKs will probably prove also valuable tools to revise the science of taxonomy, by investigating the similarity between thousands of taxa descriptions, revealing previously unrecognised synonyms and helping in the building of more objective supra-genus classification schemes.

Our group is now working on the implementation of a new palynology TA for modern pollen in collaboration with the Smithsonian Institution, and further TAs for invertebrate fossils based on other Treatise sections. These TAs will work also at the genus level. To develop species-level taxonomy assistants will require access to diagnoses and descriptions many of which are behind paywalls and thus unavailable as learning material for LLMs.

What might AI tell us about palaeontological taxonomy?

We set out to see if very large text databases of fossils could be used to develop LLMs that can guide a palaeontologist

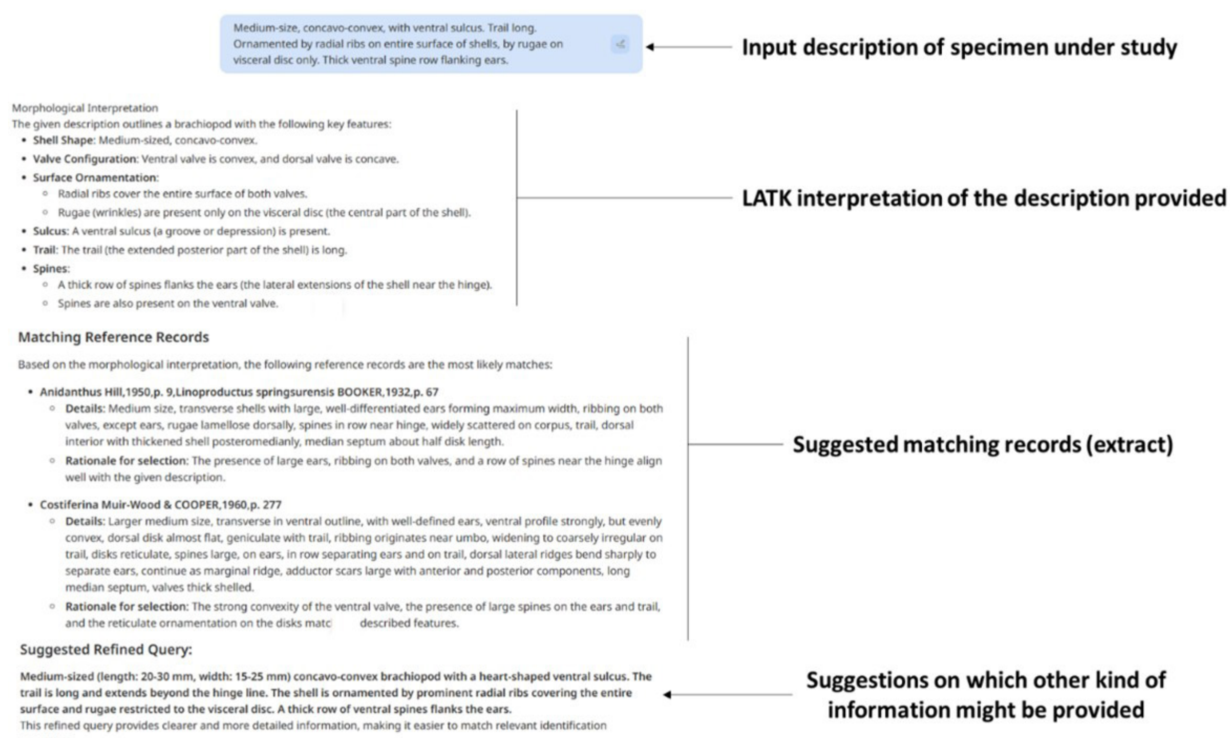


Fig. 2. An overview of the Brachiopod TA. The LATK interprets the input description of the specimen under study and then provides a series of possible matching records, discussing why they might fit the provided description. The LATK does not provide one answer only, but instead a series of matching possibilities, supporting the work process of the systematic palaeontologist as an assistant.

through the stages of identification, allowing for the palaeontologist to make the best judgements on determination with the best supporting information and guidance. However we also began to realise that LLMs with this kind of information and 'understanding' of large areas of palaeontology could be used to understand taxonomy more fully.

A simple example is the occurrence of synonyms in palaeontology. Although palaeontologists try hard to avoid giving a fossil organism a name when it already has one, sometimes these 'redundant' names slip through. This is usually because later palaeontologists don't know that a particular fossil organism has already been named. It can be a problem because it can create the illusion of differences between groups of fossil organisms in separate continents for example, encouraging the idea of provinciality when none exists. Although it is designed to help palaeontologists identify fossil spore or pollen genera, Taxonomy Assistant 2.2 is theoretically very capable of detecting synonyms and indicating priority.

Another interesting angle for a taxonomy LLM to investigate is the equality of distribution of genera (or taxa) in 'morphological space'. If we think of the possible shapes and sizes and features of a particular fossil group (like the brachiopods or the spores) they could be seen as occurring in multidimensional space (illustrated here in only two dimensions; Fig. 3).

The system has a conception of these thousands of genera and how similar they are to each other. One thing that is clear from the use of Taxonomy Assistant 2.2 is that some genera are very similar and appear in groups or dense clusters; others are more rarefied (Fig. 3). What does this 'inequality of morphological distribution' mean? Are some groups of genera, that are very close morphologically, simply better re-instituted as a single genus? Should we be aiming for more equal distribution of the units of morphology?

Some of the things that AI could be used for in the future!

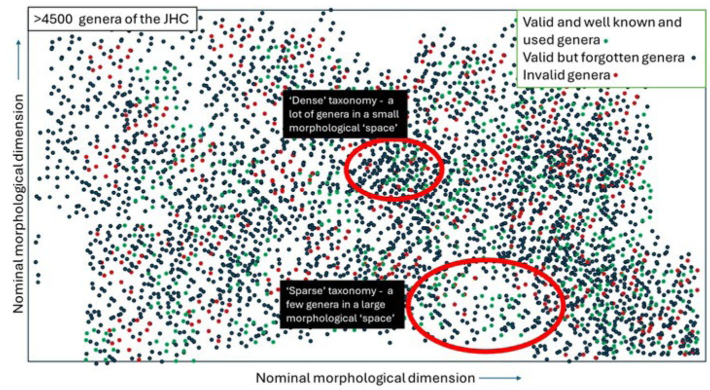


Fig. 3. Idealized morphological variation amongst JHC genera.

References

Gravendyck, J., Fensome, R. A., Head, M. J., Herendeen, P. S., Riding, J. B., Bachelier, J. B. and Turland, N. J., 2021. Taxonomy and nomenclature in palaeopalynology: basic principles, current challenges and future perspectives. Palynology, v. 45, n. 4, p. 717–743.

Jansonius, J. and Hills, V., 1976. Genera file of fossil spores and pollen. Canada: Special Publication, Department of Geology, University of Calgary.

Lamarck, J.B., 1778. Flore françoise ou description succincte de toutes les plantes qui croissent naturellement en France [French flora or brief description of all plants growing naturally in France]. Imprimerie Royale, Paris.

Stephenson, M. H., Shen, C., Shen, S., Carniti, A. P., Fan, J., Yang, J. and Ye, J., 2025. Large Language Models in palynological taxonomy: a pilot study. Palynology, 2547645. https://doi.org/10.1080/01916122.2025.2547645.

Williams, A., Rowell, A.J., Muir-Wood, H.M., Pitrat, C.W., Schmidt, H., Stehli, F.G., Ager, D.V., Wright, A.D., Elliott, G.F., Amsden, T.W., Rudwick, M.J.S., Hatai, K., Biernat, G., McLaren, D.J., Boucot, A.J., Johnson, J.G., Staton, R.D., Grant, R.E. and Jope, H.M., 1965. Treatise on invertebrate paleontology, Part H: Brachiopoda. Volumes 1 and 2. The Geological Society of America, Boulder and University of Kansas, Lawrence.927pp.

Williams, A., James, M. A., Emig, C. C., Mackay, S., Rhodes, M. C., Cohen, B. L., Gawthrop, A. B., Peck, L. S., Curry, G. B., Ansell, A. D., Cusack, M., Walton, D., Brunton, C. H. C., MacKinnon, D. I. and Richardson, J. J., 1997. Treatise on Invertebrate Paleontology. Part H: Brachiopoda. Revised. Volume 1: Introduction. The Geological Society of America, Boulder and University of Kansas, Lawrence.

Williams, A., Carlson, S. J., Brunton, C. H. C., Holmer, L. E., Popov, L. E., Mergl, M., Laurie, J.R., Bassett, M. G., Cocks, L. R. M., Rong, J., Lazarev, S. S., Grant, R. E., Racheboeuf, P. R., Jin, Y., Wardlaw, B. R., Harper, D. A. T., Wright, A. D. and Rubel, M., 2000. Treatise on Invertebrate Paleontology. Part H: Brachiopoda. Revised. Volumes 2 and 3: Linguliformea, Craniiformea, and Rhynchonelliformea (part). The Geological Society of America, Boulder and University of Kansas, Lawrence. 539pp.

Williams, A., Brunton, C. H. C., Carlson, S. J., Alvarez, F., Blodgett, R. B., Boucot, A. J., Copper, P., Dagys, A. S., Grant, R. E., Jin, Y., MacKinnon, D. I., Mancenido, M. O., Owen, E. F., Rong, J., Savage, N. M. and Sun D., 2002. Part H: Brachiopoda. Revised. Volume 4: Rhynchonelliformea (part). The Geological Society of America, Boulder and University of Kansas, Lawrence.

Williams, A., Brunton, C. H. C., Carlson, S. J., Baker, P. G., Carter, J. L., Curry, G. B., Dagys, A. S., Gourvennec, R., Hou, H., Jin, Y., Johnson, J. G., Lee, D. E., MacKinnon, D. I., Racheboeuf, P. R., Smirnova, T. N. and Sun D., 2006. Treatise on invertebrate paleontology, Part H: Brachiopoda. Volume 5: Rhynchonelliformea (part). The Geological Society of America, Boulder and University of Kansas, Lawrence. p. 921–1688

Williams, A., Brunton, C. H. C., Carlson, S. J., Alvarez, F., Baker, P. G., Bassett, M. G., Boucout, A. J., Carter, J. L., Cocks, L. R. M., Cohen, B. L., Curry, G. B., Cusack, M., Emig, C. C., Gourvennec, R., Harper, D. A. T., Holmer, L. E., Lee, D. E., Logan, A., Lüter, C., MacKinnon, D. I., Manceńido, M. O., Mergl, M., Popov, L. E., Racheboeuf, P. R., Rubel, M., Savage, N. M., Smirnova, T. N., Sun, D. and Wright, A. D., 2007. Treatise on Invertebrate Paleontology. Part H: Brachiopoda. Revised. Volume 6: Supplement. The Geological Society of America, Boulder and University of Kansas. 906pp.

High-Resolution calibration of Cisuralian volcanic-sedimentary deposits in the Southern Alps: advances from CALDERA project in 2025

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Introduction

The CALDERA (CALibrating a Deglaciation ERA) project focuses on the Cisuralian climate transition by developing a high-resolution chronostratigraphical framework for the volcano-sedimentary sequences in the Southern Alps (Italy). This period marks the decline of the Late Paleozoic Ice Age, involving a shift from icehouse to greenhouse conditions and profound reorganization of continental ecosystems. However, continental deposits with these characteristics are commonly difficult to correlate and often lack absolute age controls. The Kungurian deposits of the Southern Alps provide an exceptionally preserved fossil record in sedimentary intervals interbedded with volcanic units. The Caldera project brings together high-precision U–Pb zircon geochronology, a calibration of the temporal ranges of key palynostratigraphical markers of the Permian, and a study of the paleoecological changes associated to volcanic environments, all these through a collaboration between ETH Zurich and the Museum of Nature South Tyrol. Within this project we link ecological and sedimentological signals to precise and accurate radiometric dating and refine the timing and expression of Cisuralian climate change in tropical areas of Pangea. In this context, the CALDERA project made substantial progress during 2025.

Scientific publications

Research published during 2025 focused on palynology as a tool for regional correlation. New palynostratigraphic data from the Southern Alps (Guncina Formation; Spina et al., 2025), together with a taxonomic and chronostratigraphic review of key Permian palynomorphs (Barreiro et al., 2025a; 2025b) and comparative studies from other European basins (Barreiro et al., 2025c; Juncal et al., 2025), all contributed to update the temporal resolution of Cisuralian palynofloras. Collectively, these studies improved the consistency of biostratigraphic correlations across the Euramerican phytoprovince (i.e., mainly western and central Europe).

Another line of research focused on the temporal calibration of volcanic systems through high-precision U–Pb geochronology and zircon-based petrochronological approaches, which have been used to constrain processes of magma generation and differentiation pathways. In this context, Nathwani et al. (2025) addressed the processes controlling zircon age distributions in volcanic, subvolcanic, and plutonic lithologies, providing methodological and interpretative advances directly relevant to the complex magmatic systems of the Southern Alps.

Finally, publications in 2025 also explored the relationship between volcanism, sedimentary processes, and terrestrial ecosystems. Studies of volcano–sedimentary environments associated with the Athesian Volcanic District highlighted how disturbance regimes linked to volcanic activity can influence habitat structure and biodiversity patterns (Baucon et al., 2025).

Another highlight, although unpublished to date, is the Bachelor's thesis by Bianca Müller at the University of Padova ("Life on the edge of a supervolcano: study of lower Permian bioturbations at Sesto"), which received the award for Best Bachelor's Thesis from the Società Italiana di Paleontologia. Also unpublished is the Master's thesis by Matias Delfosse-Allain at Sorbonne University, entitled "Mesofossils from the Kungurian (early Permian) locality of Gorl (Southern Alps, northern Italy)".

Conference contributions

In 2025, CALDERA results were presented at several international and regional meetings, including the XXV Paleodays (Italian Paleontological Society; Catania, Italy; 3–5 June), *the Congrès de l'Association Paléontologique Française* (Lille, France; 5–7 May), GeoTolosa 2025 (University of Toulouse; 24–27 June), the IAVCEI Scientific Assembly 2025 (Geneva, Switzerland; 29 June–4 July), the 9th Meeting of Agora Paleobotanica (2–5 July), Geo4Göttingen 2025 (Göttingen, Germany; 14–18 September), the *Congresso congiunto SIMP–SGI 2025* (Italian Geological Society and Italian Mineralogy and Petrology Society; Padova, Italy; 16–18 September), and the *XL Jornadas SEP* (Spanish Paleontological Society; Aracena, Spain; 7–10 October). Among these meetings, GeoTolosa 2025 was particularly significant for CALDERA dissemination, as it is specifically designed to bring together research communities working on Devonian–Carboniferous–Permian Earth-system evolution. Its strategic relevance is further underscored by the presence of major Paleozoic-focused research groups and by meetings such as the business meeting of the Subcommission on Permian Stratigraphy.

CALDERA contributions at GeoTolosa 2025 showcased the project's integrative approach through a combination of poster and oral presentations. Results on the temporal evolution of post-Variscan magmatism across the Southern Alps were presented in posters focusing on high-precision zircon petrochronology (Marroquín et al., 2025a) and the taxonomic–chronostratigraphic synthesis of key Permian prepollen *Nuskoisporites* (Barreiro et al., 2025d). Additional poster contributions addressed paleobotanical and paleoecological aspects of Cisuralian ecosystems in the Southern Alps (Kustatscher et al., 2025a). Oral presentations emphasized the integration of biostratigraphy, paleobotany, and sedimentology (Barreiro et al., 2025e; Delfosse-Allain et al., 2025a). In particular, the oral presentation "Side by side with a volcano: a Cisuralian deltaic to lacustrine basin under the effect of volcanic activity" highlighted the tight coupling between volcanism, basin evolution, and terrestrial ecosystems (Fig. 1A; Kustatscher et al., 2025b) and was awarded Best Oral Presentation.

The IAVCEI Scientific Assembly also provided an effective platform to present ongoing work focused on understanding the build-up of what it seems to be the largest supereruption in the Athesian Volcanic District, which formed the Gargazzone Ignimbrite (Marroquín et al., 2025b). This conference brought together more than one thousand international delegates working on volcanology and geochemistry of the Earth interior and generated insightful discussions. The poster presentation attracted particular interest from early-career researchers working on analogous large silicic systems worldwide.

At the remaining conferences, mainly preliminary paleontological results (i.e. paleobotany and ichnology) from the AVD were presented, including at the *Congrès de l'Association Paléontologique Française* (Delfosse-Allain et al., 2025b), Geo4Göttingen 2025 (Kustatscher et al., 2025c), the 9th Meeting of Agora Paleobotanica (Delfosse-Allain et al., 2025c), the *Congresso congiunto SIMP–SGI 2025* (Barreiro et al., 2025f), the *XL Jornadas SEP* (Barreiro et al., 2025g), and the *XXV Paleodays – Edizione delle Giornate di Paleontologia* (Barreiro et al., 2025h, 2025i; Kustatscher et al., 2025d; Müller et al., 2025).

Fieldwork

Field activities carried out in 2025 aimed to expand the high-precision geochronological record of magmatism in the Southern Alps, focusing on the poorly studied Lugano–Valganna magmatic centre. This work was conducted between 20 and 21 March by a group of four project members and collaborators (ETH Zürich). During this short campaign, four samples were collected from both volcanic (two samples) and intrusive (two samples) units, with the objective of extending the temporal record of magmatism between the Sesia Magmatic System and the Orobic Alps.

Additional fieldwork focused on expanding the palynostratigraphic framework beyond the Athesian Volcanic District through a new palynological sampling campaign in the Orobic Alps, near Monte Cabianca. This campaign was carried out between 22 and 24 August by a group of five project members and collaborators (ETH Zürich, Museum of Nature South Tyrol, and University of Milano). Sampling targeted relevant sedimentary units of the area (the Pizzo del Diavolo Formation and sedimentary beds within the Cabianca Unit) resulting in the collection of a total of 66 samples (Fig. 1B–D). Although these deposits are slightly older than those of the Athesian Volcanic District, they are possibly linked to a related volcanic system, falling within the upper Artinskian. The sampling strategy was designed to support regional-scale correlations and to evaluate palaeoenvironmental signals from a different region of the Permian volcanic complex of the Southern Alps. The resulting dataset will represent a step toward extending the temporal and spatial resolution of the palynofloras studied within the CALDERA project and will form the basis for forthcoming palynostratigraphic and regional correlation studies.

Fig. 1. **A.** Oral presentation of "Side by side with a volcano: a Cisuralian deltaic to lacustrine basin under the effect of volcanic activity" by Evelyn Kustatscher during GeoTolosa 2025; **B.** Work planning during the fieldwork in the Orobic Alps; **C.** Sample collection in the Cabianca Unit, above Lago Cernello; **D.** Sampling for palynological and geochronological analyses in the Pizzo del Diavolo Formation, in proximity of Lago d'Aviasco.

Future perspectives

Based on the advances achieved during 2025, the next phase of the CALDERA project will focus on consolidating and integrating the new datasets into a time-calibrated framework for Cisuralian continental environments. A key priority will be the publication of a comprehensive palynostratigraphic scheme for the Athesian Volcanic District, providing a substantial biostratigraphic background for regional correlation with other areas. This will be complemented by obtaining new high-precision U–Pb zircon ages, aimed at refining the temporal constraints on volcanic activity and basin evolution within the Athesian Volcanic District and other neighboring districts (e.g., Orobic Alps and Lugano-Valganna).

Further work will target the upper Kungurian alluvial–lacustrine succession of the Gorl section, combining detailed sedimentological analysis with palaeobotanical data, including the publication of its mesoflora. Together, these studies are expected to clarify the relationships between volcanism, sedimentation, and ecosystem dynamics during a critical interval of climatic transition such as the end of the Cisuralian. In parallel, palynostratigraphic results from the Orobic Alps and geochronological results from the Lugano-Valganna district will extend CALDERA's regional coverage, allow independent testing of correlations and enhance the spatial resolution of continental records. Collectively, these expected outputs will strengthen the project's capacity to resolve the timing, expression, and ecological consequences of Cisuralian climate change in central Pangea.

References

Barreiro, I. R., Diez, J. B., Fijałkowska-Mader, A., Schneebeli-Hermann, E., Spina, A. and Kustatscher, E., 2025a. Reassessment of the chronostratigraphic and paleogeographic distribution of the Permian prepollen genus Nuskoisporites. Review of Palaeobotany and Palynology, v. 343, 105425.

Barreiro, I. R., Diez, J. B., Fijałkowska-Mader, A., Schneebeli-Hermann, E., Spina, A. and Kustatscher, E., 2025b. The genus Nuskoisporites revisited: a refined framework for Permian palynostratigraphy. Permophiles, n. 79, p. 32–34.

Barreiro, I. R., Juncal, M. A., de la Horra, R., López-Gómez, J., Barrenechea, J. F. and Diez, J. B., 2025c. Chronostratigraphic significance of the "Thüringian" palynological record from the Permian of Iberia and the Balearic Islands: Implications for correlations across Western Europe. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 680. 113324.

Barreiro, I. R., Diez, J. B., Fijałkowska-Mader, A., Schneebeli-Hermann, E., Spina, A. and Kustatscher, E., 2025d. The Permian prepollen Nuskoisporites: A taxonomic and chronostratigraphic review. GeoTolosa 2025, 23rd–26th June 2025, Toulouse (France). Poster.

Barreiro, I. R., Spina, A., Degl'Innocenti, N., Morelli, C. and Kustatscher, E., 2025e. Palynostratigraphy of the Permian Athesian Volcanic District (Southern Alps, Italy). GeoTolosa 2025, 23rd–26th June 2025, Toulouse (France). Oral communication.

Barreiro, I. R., Spina, A., Degl'Innocenti, N., Morelli, C. and Kustatscher, E., 2025f. The Athesian Volcanic District (upper Cisuralian, Southern Alps): palynostratigraphical implications. Congresso congiunto SIMP-SGI 2025, 16th-18th September 2025, Padova (Italy). Oral communication

Barreiro, I. R., Spina, A., Degl'Innocenti, N., Morelli, C. and Kustatscher, E., 2025g. Viviendo con el supervolcán: palinofloras del Complejo Volcánico Atesino (Alpes Meridionales, Italia) y sus implicaciones bioestratigráficas en el Pérmico inferior. XL Jornadas SEP, 7th-10th October 2025, Aracena (Spain). Oral communication.

Barreiro, I. R., Spina, A., Degl'Innocenti, N., Morelli, C. and Kustatscher, E., 2025h. Permian Palynostratigraphy of the Athesian Volcanic District in the Southern Alps. XXV Paleodays - XXV Edizione delle Giornate di Paleontologia, 4th-6th June 2025, Catania (Italy). Oral communication

Barreiro, I. R., Diez, J. B., Fijalkowska-Mader, A., Schneebeli-Hermann, E., Spina, A. and Kustatscher, E., 2025i. Chronostratigraphic and paleogeographical distribution of Permian prepollen Nuskoisporites. XXV Paleodays - XXV Edizione delle Giornate di Paleontologia, 4th-6th June 2025, Catania (Italy). Poster

Baucon, A., Trümper, S., Morelli, C., de Carvalho, C. N. and Kustatscher, E., 2025. Can habitat disturbance promote biodiversity? Disturbance ecology of an alluvial fan deposited in the caldera of the Bolzano supervolcano (Gocciadoro: Trento, Italy). Palaeogeography, Palaeoclimatology, Palaeoecology, v. 664, 112785.

Delfosse-Allain, M., Branz, R., Barreiro, I. R. and Kustastcher, E., 2025a. The mesoflora of the Kungurian site Gorl from the Southern Alps (Northern Italy). GeoTolosa 2025, 23rd–26th June 2025, Toulouse (France). Oral communication.

Delfosse-Allain, M., Branz, R., Barreiro, I. R. and Kustatscher, E., 2025b. Une mésoflore flore Kungurian dans les Alpes du Sud (Sud-Tyrol, Italie). Congrès de l'Association Paléontologique Française, 05th–07th May 2025, Lille (France). Poster

Delfosse-Allain, M., Branz, R., Barreiro, I. R. and Kustatscher, E., 2025c. Plant mesofossils from the Kungurian of the Southern Alps (Northern Italy). 9th meeting Agora Paleobotanica, 2th-5th July 2025, Paris (France) abstract book, p. 12. Oral communication.

Juncal, M. A., Barreiro, I. R., Galtier, J., Broutin, J., Pellenard, P., Steyer, J. S., Diez, J. B. and Gand, G.. 2025. The Asselian palynoflora from the Autunian series (Muse oil-shale beds, Autun Basin, France): new insights on early Permian equatorial palaeoflora and palaeoenvironments. Comptes Rendus. Géoscience, v. 357, n. G1, p. 245–263.

Kustatscher, E., Forte, G., Vallé F., Rodríguez-Barreiro, I. and Branz, R., 2025a. The evolution of the Kungurian (Cisuralian) flora in the paleotropics (Southern Alps, Northern Italy). GeoTolosa 2025, 23rd–26th June 2025, Toulouse (France). Poster.

Kustatscher, E., Trümper, S., Preto, N., Dinelli, E., Forte, G., Vallé, F., Branz, R., Lanthaler, B. and Morelli, C., 2025b. Side by side with a volcano: a Cisuralian deltaic to lacustrine basin under the effect of volcanic activity. GeoTolosa 2025, 23rd–26th June 2025, Toulouse (France). Oral communication.

Kustatscher, E., Felderer, R., Schweigkofler, M. and Morelli, C., 2025c. Caldera Connections: Engaging the Public with the Story of South Tyrol's Supervolcano. Geo4Göttingen 2025, 14-18.09.2025, Göttingen, Germany, abstract book, p. 305. Poster

Kustatscher, E., Forte, G., Barreiro, I. R. and Branz, R., 2025d. The Kungurian (Cisuralian) flora of the Southern Alps (Northern Italy). XXV Paleodays - XXV Edizione delle Giornate di Paleontologia, 4th-6th June 2025, Catania (Italy). Poster

Marroquín Gómez, M.P., Szymanowski, D., Tavazzani, L., Morelli, C., Forni, F., Brack, P. and Kustatscher, E., 2025a. Post-Variscan magmatism in the Southern Alps: Insights from high-precision zircon petrochronology in the Athesian Volcanic District. GeoTolosa 2025, 23rd–26th June 2025, Toulouse (France). Poster.

Marroquín Gómez, M.P., Szymanowski, D., Tavazzani, L., Morelli, C., Forni, F., Brack, P. and Kustatscher, E., 2025b. Insights into the build-up to the early Permian Gargazzone super-eruption (Southern Alps) from high-precision zircon petrochronology. IAVCEI 2025, 29th June–4th July 2025, Geneva (Switzerland). Poster.

Müller, B., Kustatscher, E., Fornaciari, E., Baucon, A. and Morelli, C., 2025. Life on the edge of a supervolcano: study of lower Permian bioturbations at Sesto. XXV Paleodays - XXV Edizione delle Giornate di Paleontologia, 4th-6th June 2025, Catania (Italy). Oral communication

Nathwani, C., Szymanowski, D., Tavazzani, L., Markovic, S., Virmond, A. L. and Chelle-Michou, C., 2025. Controls on zircon age distributions in volcanic, porphyry and plutonic rocks. Geochronology, v. 7, n. 1, p. 15–33.

Spina, A., Marchetti, L., Diez, J. B., Capezzuoli, E., Saleh, H., Barreiro, I. R., Kustatscher, E. and Ronchi, A., 2025. New palynostratigraphic data from the Kungurian (Cisuralian) Guncina Formation, Athesian District (Southern Alps, northern Italy) with regional-global correlation. Journal of Iberian Geology, p. 1–25.https://doi.org/10.1007/s41513-025-00300-1.

Report of paleontological fieldwork in the Permian units of Mongolia, September 2025

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In the first half of September 2025, a joint team of researchers and students from the Nanjing Institute of Geology and Palaeontology CAS, Nanjing University, and the Institute of Paleontology, Mongolian Academy of Sciences, visited several Permian localities of paleontological interest in Mongolia. Stratigraphic and paleoclimatic studies of the Permian in Mongolia are crucial for understanding the tectonic and climate evolution of the Late Paleozoic, as Mongolia is located in the center of the Central Asian Orogenic Belt (CAOB), mainly corresponding geographically with the Altaids. These formed from the collision of various terranes and microcratons during the closure of the Paleo-Asian Ocean in the middle to late Paleozoic (Bardach et al., 2002; Safonova et al., 2017). Despite its significance, knowledge of the stratigraphic record of Mongolia's Permian and its fossil content remains incomplete (Shen et al., 2006), primarily due to the logistical challenges of accessing remote regions of the country.

The main aims of the joint fieldwork were the collection of palynological and geochemical samples from continental and marginal P/T sections, to improve the classification and correlation between Permian units in Mongolia and extract paleoclimatic data with possible regional to global implications. Furthermore, a number of localities possibly bearing Permian brachiopod faunas were inspected (Figs. 1, 2).

Here follows the detailed report on the work in each visited locality:

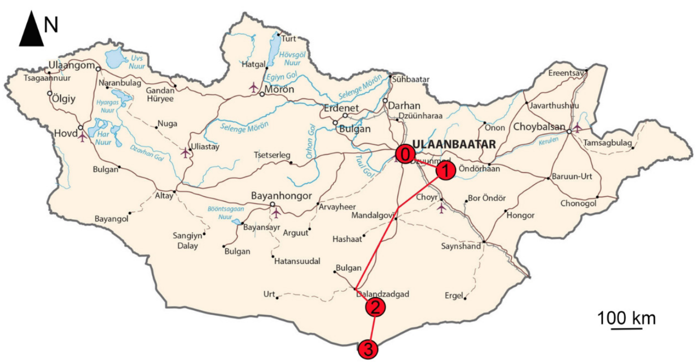

Fig. 1. Location of the study sites in Mongolia. **0.** Institute of Paleontology, Ulaanbaatar; **1.** Shanaga area; **2.** Tsagaan Tolgoi Section; **3.** Bulgan Uul area. Base map after www.gisgeography.com.

Fig. 2. The joint research group on the Tsagaan Tolgoi Section.

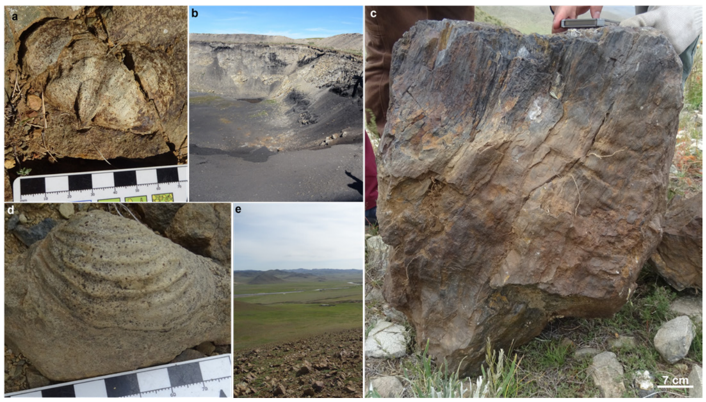

Fig. 3. Stop 1, Shanaga area. **a**. *Spiriferella* sp. at the top of unit P2cn2, Tsenkher Gol Formation; **b**. the open-pit coal mine in unit P2cn3; **c**. fossil stem collected from locality Shiree-Nuruu; **d**. infaunal bivalve of the Anomalodesmata from locality Shiree-Nuruu. **e**. the valley of the Kherlen River.

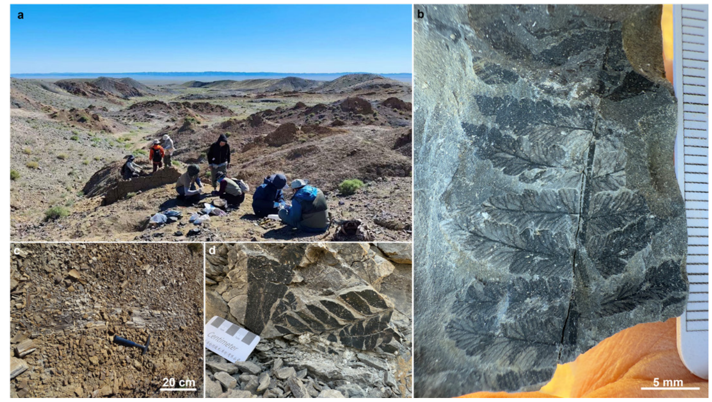

Fig. 4. Tsagaan Tolgoi Section, Nomgon. **a.** the research group on the Tsagaan Tolgoi Section; **b, d.** fossil plants from Tsagaan Tolgoi Section; **c.** fossil stem in the Tsagaan Tolgoi Section.

Stop 1: Shanaga area

After meeting at the Institute of Paleontology building in Ulaanbaatar on 2 September, 2025, the joint research group, along with three local drivers and one cook, traveled in three vehicles south to the Shanaga area. There, Camp 1 was set up in the prairies near the P/T Shanaga Section, in the Bayanjargalan District of Tôv Province, Mongolia. The area is of significant scientific and economic interest due to its abundance of Lopingian coal deposits (Michaelsen, 2016).

The next day (3 September, 2025), the group visited the Shanaga Section, where the Lopingian interval of the Tsenkher Gol Formation, unit $P2cn^2$ of Michaelsen (2016) and Michaelsen and Storetvedt (2023), is exposed. The lithology consists of fine to coarse sandstone. Inspection of the section revealed several fragments of plant fossils and sparse bivalves, although poorly preserved, indicating a proximal shallow marine environment. A single horizon at the top of the lower part of the section yielded a few brachiopods, spiriferides (*Spiriferella* sp.), and productides (*Spinomarginifera* sp.), along with bryozoans (Fig. 3a); this bed probably corresponds to the "shellbed horizon" of Michaelsen (2016) at the base of unit $P2cn^3$.

Above the brachiopod-bearing bed, unit $P2cn^3$ was mostly not exposed. The research group thus focused on a succession of coal, volcanic ash, and chert beds exposed in a disused open-pit coal mine near the base of the unit (Fig. 3b), collecting samples for palynology, radiometric dating, and fossil stems. The mine probably corresponds to the DH10 coal outcrop of Michaelsen (2016). The attempt to find other coal outcrops indicated by Michaelsen (2016: fig. 2) in the area was unsuccessful.

Finally, the group visited the top of the section, where rare ammonoids, infaunal bivalves, and fossil plants were collected from the basal Triassic unit T1A of the Tsenkher Gol Formation.

The following day (4 September, 2025), the research group focused on visiting several fossil-bearing localities reported by geological maps on the western bank of the Kherlen River: the hills of Berkhiin-Ovoo, Kholboo Ondor-Uuuls, and Shiree-Nuruu, also in the Lopingian sandstone of the Tsenkher Gol Formation (Fig. 3c-e). The last locality yielded some excellent fossil stems and shale units from which palynological samples were collected. Findings of marine invertebrates were scarce across all three localities, with very few, poorly preserved productide brachiopods (?*Kutorginella* sp.), bivalves (possibly infaunal bivalves of the Anomalodesmata; Fig. 3d), large archeogastropods, and sporadically found trace fossils.

Stop 2: Tsagaan Tolgoi Section, Nomgon

After two days' drive from Camp 1, the group arrived on 6 September, 2025 in the South Gobi Province and camped near the Tsagaan Tolgoi Section (Camp 2, Fig. 1) in the Nomgon District. The area features a P/T sequence of coal, mudstone, and sandstone beds deposited in an alluvial plain environment (Johnson et al., 2008; Cai et al., 2022). The succession contains several horizons with fossil tree stumps, which are essential for understanding the Late Paleozoic Angara flora and for reconstructing continental paleoclimatic conditions on the eastern part of Laurasia. Recently, two new conifer stem species, *Ductoagathoxylon tsaaganensis* Cai et al., 2022, and *Secrospiroxylon tolgoyensis* Cai et al., 2023, were established based on materials from this section.

The research group worked on the section for two days (7-8 September, 2025), collecting several samples for $\delta^{13}C_{org}$ analysis, palynology, and fossil wood (Fig. 4a, c). In addition, four ash beds were sampled for radiometric dating, and exceptionally-preserved fossils of ferns and pteridosperms were collected from some Lopingian horizons (Fig. 4b, d).

Stop 3: Bulgan Uul area

After a stop in Dalanzadgad, the capital of South Gobi Province, to obtain permits from authorities to visit the southernmost part of the region, the research group embarked on a two-day drive to reach the Bulgan Uul area, near the southern border with China, where Camp 3 was established (Fig. 1).

The southern part of the Gobi lies immediately north of the Tien Shan – Yin Shan suture (sensu Heumann et al., 2012), formed in the Late Paleozoic due to the collision between the Altaids terranes to the north and the North China Block to the south at the closure of the Paleo-Asian Ocean (Johnson et al., 2008). Understanding the timing of transitions in depositional environments and ecological shifts is therefore essential for reconstructing the timing, polarity, and modes of subduction and

Fig. 5. Bulgan Uul area. **a.** panorama on the southernmost part of the Bulgan Uul area; **b.** conglomerates at the top of the succession in the Bulgan Uul area; **c.** roaming camels; **d.** the site of the brachiopod collection by Pavlova et al. (1991).

collision along the suture zone, but the area remains understudied, and its stratigraphy is not fully understood.

Heumann et al. (2012) investigated the sequence in the area, which consists of Cisuralian to Triassic fluvial-alluvial clastic units with interbedded carbonates, and they provided a general stratigraphic scheme, sandstone provenance data, and radiometric ages. However, biostratigraphy data are scarce from the sequence, leaving its age poorly constrained. Therefore, the research team collected several samples for palynology and conodonts over three days of work (10-12 September, 2025) (Fig. 5).

A site bearing Permian brachiopods was reported by Pavlova et al. (1991) in the upper part of the Bulgan Uul sequence. The site was successfully relocated (Fig. 5d), but only a few spiriferides (*Spiriferella* sp.) and productides (Echinoconchidae gen. et sp. indet.) of Lopingian affinity, along with fenestellid bryozoans, were found in loose cobble-sized limestone blocks of reefal character, mixed with cobbles of various other lithologies (volcanics, metamorphic rocks, and sandstones). The cobbles probably originate from weathered conglomerate beds similar to those outcropping around the site (Fig. 5b), possibly corresponding to the uppermost Permian–Lower Triassic conglomerates reported by Heumann et al. (2012) at the top of the sequence. Similar cobbles with abundant crinoids were observed in comparable conglomerate beds further west.

After finishing the work on the Bulgan Uul area, the research group drove back to Ulanbaataar, where the samples were packed in order to be processed and studied in Nanjing.

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References

Bardach, G., Cunnigham, W.D. and Windley, B.F., 2002. A new terrane subdivision for Mongolia: implications for Phanerozoic crustal growth in Central Asia. Journal of Asian Earth Sciences, v. 21, p. 87–110.

Cai, Y., Zhang, H., Feng Z., Gou, X., Byambajav, U., Zhang, Y., Yuan, D., Qie, W., Xu, H., Cao, C., Yarinphil, A. and Shen, S., 2022. A new conifer stem, *Ductoagathoxylon tsaaganensis*, from the Upper Permian of the South Gobi Basin, Mongolia and its palaeoclimatic and palaeoecological implications. Review of Palaeobotany and Palynology, v. 304, 104719.

Cai, Y., Zhang, H., Feng, Z., Zhang, Y., Yuan, D.X., Xu, H., Byambajav, U., Yarinpuil, A. and Shen, S., 2023. *Secrospiroxylon tolgoyensis* gen. nov. et sp. nov., a unique coniferous stem from the uppermost Permian of the South Gobi Basin, Mongolia, and its palaeoclimatic, palaeoecophysiological, and palaeoecological implications. Palaeontographica Abteilung B, v. 305, p. 93–119.

Heumann, M., Johnson, C.L., Webb, L.E., Taylor, J.P., Jalbaa, U. and Minjin C., 2012. Paleogeographic reconstruction of a late Paleozoic arc collision zone, southern Mongolia. GSA Bulletin, v. 124, p. 1514–1534.

Johnson, C.L., Amory, J.A., Zinniker, D., Lamb, M.A., Graham, S.A., Affolter, M. and Badarch, G., 2008. Sedimentary response to arc-continent collision, Permian, southern Mongolia. In: Draut, A., Clift, P.D. and Scholl D.W. (eds.), Formation and Applications of the Sedimentary Record in Arc Collision Zones. Geological Society of America Special Papers, v. 436, 363–390.

Michaelsen, P., 2016. Late Permian coal formation under boreal conditions along the shores of the Mongol-Transbaikalian seaway. New Concepts in Global Tectonics Journal, v. 4, p. 615–636.

Michaelsen, P. and Storetvedt, K.M., 2023. Tectonic evolution of a sequence of related late Permian transtensive coal-bearing sub-basins, Mongolia: A global wrench tectonics portrait. Mongolian Geoscientist, v. 28, n. 57, p. 1–53.

Pavlova, E.E., Manakov, I.N., Morozova, I.P., Solovjeva, M.N., Suetenko, O.D. and Bogoslovskaya, M.F., 1991. Permian invertebrates of Southern Mongolia. Наука, Тр.ССМПЭ - Nauka, Sovmestnaya Sovetsko-Mongol'skaya Paleontologicheskaya Ekspeditsiya Trudy, v. 40, p. 1–172.

Safonova, I., Kotlyarov, A., Krivonogov, S. and Xiao, W., 2017. Intra-oceanic arcs of the Paleo-Asian Ocean. Gondwana Research, v. 50, p. 167–194.

Shen, S., Zhang, H., Shang, Q.H. and Li, W.Z., 2006. Permian stratigraphy and correlation of northeast China: A review. Journal of Asian Earth Sciences, v. 26, p. 304–326.

Shi, G.R., 2006. The marine Permian of east and northeast Asia: An overview of biostratigraphy, paleobiogeography and palaeogeographical implications. Journal of Asian Earth Sciences, v. 26, p. 175–206.

STRATI 2026 (5th International Congress on Stratigraphy)
Suzhou, China | June 28-July 3, 2026

The Organizing Committee are excited to invite the global stratigraphy community to STRATI 2026 – Exploring the Depths: Bridging Tradition and Innovation in Stratigraphy, taking place from June 28 to July 3, 2026, at the Suzhou DDE Center in Jiangsu Province, China.

Important dates: Opening registration (January 31st, 2026); Abstract submission Deadline (March 15th, 2026).

Conference website: https://strati2026.org/

Call for Applications – SPS Travel Grants to STRATI 2026 (China)

The Subcommission on Permian Stratigraphy (SPS) Executive invites applications for travel support grants to attend the upcoming STRATI 2026 Congress in Suzhou, China between the 28 June to 3 July. These grants are intended to facilitate the participation of members of the Permian research community, with particular attention to early career researchers and colleagues from the Global South. A maximum of **USD 500** per award will be granted to each successful applicant, to be used toward registration fees and travel expenses.

Grant Categories

Two categories of applicants are eligible:

· Early Career Researchers (ECRs) (within 10 years post PhD – allowing for research breaks)

· Global South SPS members (Africa, Central and South America, the Pacific Island Nations, South and South-East Asia, and the Middle East).

Application Requirements

Applicants must submit the following materials:

1.The same abstract that has been submitted to the STRATI 2026 Congress – this will not be published in *Permophiles*).

2.A short communication intended for publication in *Permophiles*, Issue 81 (this contribution does not need to be related to the STRATI abstract).

Submission Details

Deadline for applications: **1 April 2026** to yczhang@nigpas.ac.cn (Prof. Yichun Zhang, SPS secretary).

Selection Criteria

Applications will be evaluated according to the following weighted criteria:

50% – Scientific quality of the abstract submitted to STRATI

50% – Scientific quality of the communication submitted to Permophiles

Announcement of Results

Successful applicants will be notified around **15 April 2026**.

The SPS strongly encourages eligible members of the Permian community to apply and looks forward to supporting broad and inclusive participation at STRATI 2026!

SUBMISSION GUIDELINES FOR ISSUE 81

It is best to submit manuscripts as attachments to E-mail messages. Please send messages and manuscripts to Yichun Zhang's E-mail address. Hard copies by regular mail do not need to be sent unless requested. To format the manuscript, please follow the TEMPLATE that you can find on the SPS webpage at http://permian.stratigraphy.org/.

Please submit figures files at high resolution (600dpi) separately from text one. Please provide your E-mail addresses in your affiliation. All manuscripts will be edited for consistent use of English only.

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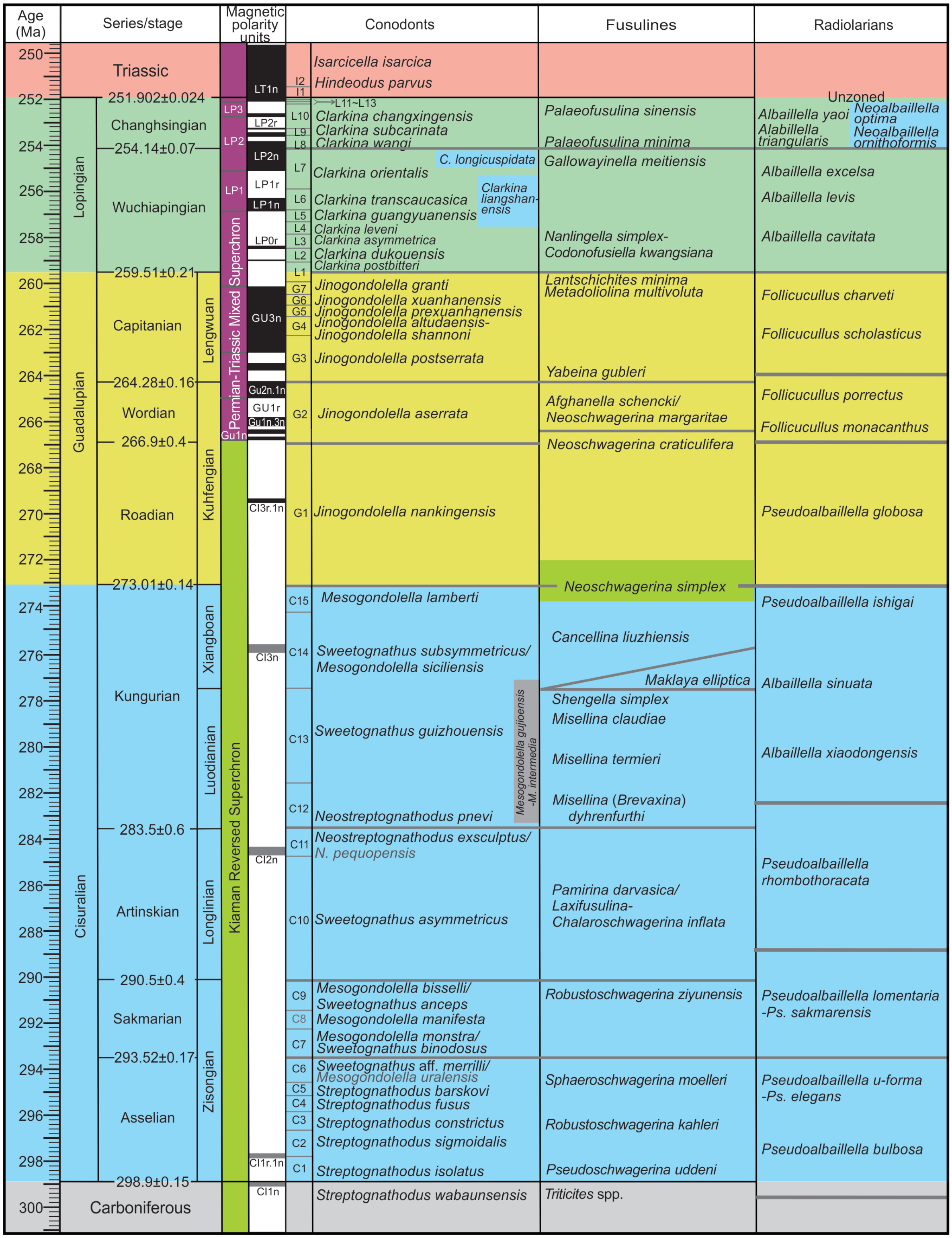
The deadline for submission to Issue 81 is July 31, 2026



High-resolution integrative Permian stratigraphic framework (after Shen et al., 2019. Permian integrative stratigraphy and timescale of China. Science China Earth Sciences 62(1): 154–188. Guadalupian ages modified after (1) Shen et al., 2020. Progress, problems and prospects: An overview of the Guadalupian Series of South China and North America. Earth-Science Reviews, 211: 103412 and (2) Wu et al., 2020, High-precision U-Pb zircon age constraints on the Guadalupian in West Texas, USA. Palaeogeography, Palaeoclimatology, Palaeoecology, 548: 109668. Lopingian ages modified after Yang et al., 2018, Early Wuchiapingian cooling linked to Emeishan basaltic weathering? Earth and Planetary Science Letters, 492: 102–111. Base-Artinskian age modified after Henderson and Shen, 2020. Chapter 24-The Permian Period. In Gradstein F.M., Ogg, J.G., Schmitz M.D., and Ogg, G.M. (eds.), The Geologic Time Scale 2020, Elsevier, v. 2, p. 875–902. The position of the beginning of the Illawarra Reversal is not indicated in the table because it is still controversial, having been placed in the earliest Wordian (Hounslow and Balabanov, 2018), in the middle Wordian (Jin et al., 1999; Steiner, 2006; Henderson et al., 2012; Lanci et al., 2013; Shen et al., 2013a, 2019b; Henderson and Shen, 2020), slightly below the base of the Capitanian (Shen et al. 2022) or in the earliest Capitanian (Menning, 2000; Isozaki, 2009). For references see Shen et al., 2020. Progress, problems and prospects: An overview of the Guadalupian Series of South China and North America. Earth-Science Reviews, 211: 103412; Shen et al., 2022. The Global Stratotype Section and Point (GSSP) for the base of the Capitanian Stage (Guadalupian, Middle Permian). Episodes, 45, 3: 309–331.