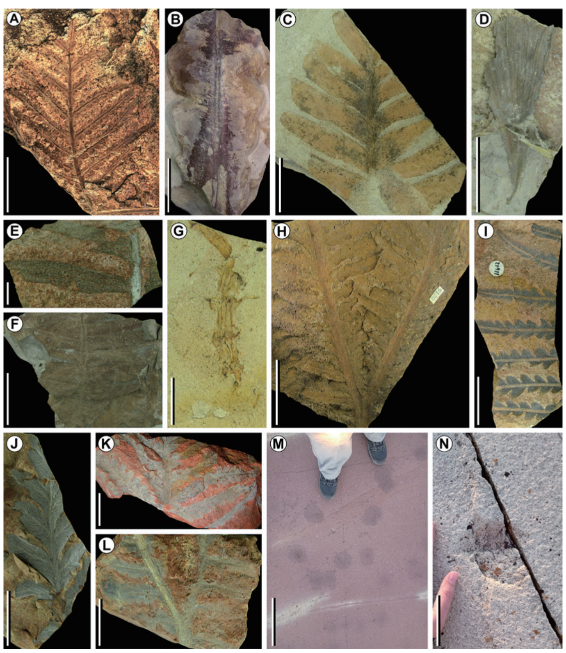
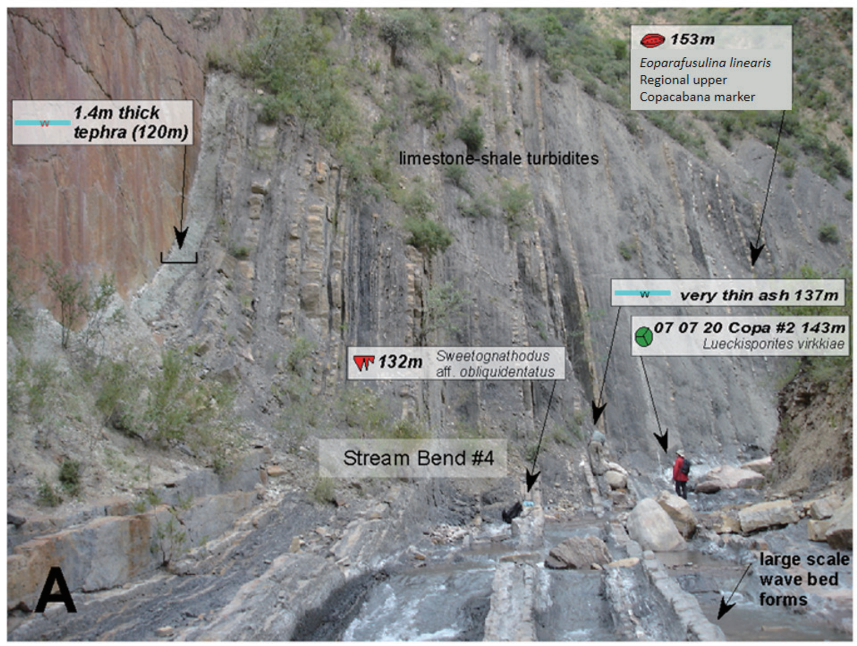
Permophiles

International Commission on Stratigraphy





Newsletter of the
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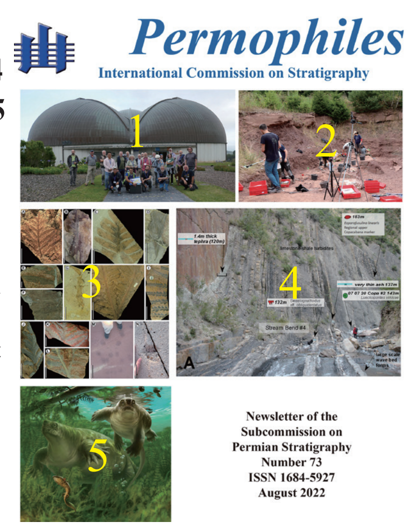

Fig. 1. Workshop participants visit MUJA(Jurassic of Asturias Museum), López-Gómez and Heredia, this issue.
Fig. 2. 2022 excavation at Bromacker in the Tambach Formation of the Thuringian Forest basin, Germany, Schneider et al., this issue.
Fig. 3. Fossiliferous content of the Los Menucos Group, Falco et al., this issue.
Fig. 4. Apillapampa outcrop at Quebrada Chullpanimayo, Cisterna et al., this issue.
Fig. 5. Life restoration of *Lalieudorhynchus gandi* Werneburg et al., 2022, Schneider et al., this issue.

Notes from the SPS secretary
Yichun Zhang

Introduction and thanks

At the end of July, I received many submissions to this issue of *Permophiles* when I was in northern Tibet for fieldwork. I realize that it is the right time to edit this issue of Permophiles.

During the past several months, we faced more serious situations such as long-standing Covid-19 pandemic and unexpected Russian-Ukraine war. Despite all these tensions around the world, enthusiasm and collaborations are prevalent in our Permian community. On April 12, 2022, an online webinar by Prof. Mike Simmons about the Sequence stratigraphy was organized by SPS. In addition, a new working group chaired by Prof. Mike Stephenson was established by SPS to study the "Gondwana to Euramerica correlations", with two online meetings on 17 May and 17 June respectively. Thanks to Profs. Lucia Angiolini and Mike Stephenson for their great work. During the last month, we were happy to see the renewal of the voting members of SPS. Welcome to the new voting members: Annette Goetz, Sam Lee, Ana Karina Scomazzon, Elisabeth Weldon, and Dongxun Yuan. Also, many thanks to past voting members of SPS, Prof. Nestor Cuneo, Prof. Guang Shi and Prof. Yue Wang for their great contributions to the Permian community in past years.

Many thanks to the contributors of this issue: Charles M. Henderson, Gabriela A. Cisterna and co-authors, Spencer G. Lucas and Stephen J. Reynolds, Micha Horacek, Frank Scholze, Manfred Menning, Juan I. Falco and co-authors, Joerg W.Schneider and co-authors, José López-Gómez and Nemesio Heredia.

Finally, I would like to keep drawing your attention to the new SPS website https://permian.stratigraphy.org/, where you can find all issues of Permophiles, updated Permian Timescales, presentation videos and news about the Permian Subcommission.

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This issue of *Permophiles* contains valuable contributions covering comments, research articles, new finding and meeting news. As usual, *Permophiles* is always an open platform for free discussions related to the Permian studies.

This issue starts with the tenth harangue by Charles M. Henderson. He pleas for cooperative and collaboration actions on the base-Kungurian sections in Nevada, USA because of the inconvenience at the Mechetlino section in Russia due to Russian-Ukraine war.

Gabriela A. Cisterna and her colleagues introduce the tasks and research objectives of the new wording group "Gondwana to Euramerica correlations". Two key sections in Bolivia and Argentina were considered to be studied in detail.

Spencer G. Lucas and Stephen J. Reynolds describe the Upper Paleozoic lithostratigraphy at the Mogollon Rim in Arizona, USA based on three outcrop areas. This review will facilitate the further correlations of lithostratigraphy between these regions.

Micha Horacek continues to comment on the Sakmarian-Artinskian Boundary GSSP by Chernykh et al. He questioned the correlations between Dal'ny Tulkas section and trench as well as the potential significance of *Sweetognathus asymmetricus*. A short editors note is attached following his comment.

Frank Scholze introduces the application of digital photograph collection of sedimentary structures from the Bromacker, Germany and reports an interesting scratch circle, which is explained to result from the plant axis moved by wind currents.

Manfred Menning reports latest dating work on Rotliegend succession in Germany. A significant stratigraphic gap was recognized in Central Europe.

Juan I. Falco and his colleagues reports the Permian-Triassic boundary in the Los Menucos Basin in Northern Patagonia, Argentina. They highlight the presence of PTB in the Los Menucos Group based on the plant fossils and as well as dating on volcanic rocks.

Yi-chun Zhang and his colleagues report a new section in the South Qiangtang Block, which contains both conodonts and fusulines. The coexistence of both taxa indicates the correlation of base Mugarbian stage of Tethyan scale with Upper Kungurian of the Global scale.

Joerg W. Schneider and his colleagues introduce the activities and work of "Carboniferous-Permian-Triassic Nonmarine-Marine Correlation Group" for 2021 and 2022, with several new publications being summarized.

José López-Gómez and Nemesio Heredia report the Permian-Triassic workshop held in the Cantabrian mountains, northern Spain.

Finally, three symposiums/meetings are announced, respectively the XVII Argentinian Paleobotany and Palynology Symposium, the 6th INTERNATIONAL PALAEONTOLOGICAL CONGRESS in Thailand and STRATI 2023 in France.

Future issues of Permophiles

The next issue of *Permophiles* will be the 74th 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 74 is **31 December 2022**.

Manuscripts and figures can be submitted via email address (yczhang@nigpas.ac.cn) as attachment.

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

Notes from the SPS Chair
Lucia Angiolini

The difficulties our scientific community had to face over the last two years seem never ending. Besides the covid pandemic, we had to face the problems related to the Russian invasion of the Ukraine, geopolitical tensions around the world and, very recently, a heatwave due to the current climate change. Notwithstanding all the problems of direct collaboration, travel abroad and sometimes even access to the laboratories, Permian research has progressed a lot, as shown by this rich issue of *Permophiles*, and SPS has been active, and renewed.

SPS is following the IUGS statement of March 18, 2022 in reaction to the invasion of Ukraine by the Russian Federation, but no action is personally directed towards our Russian colleagues, which we deeply respect and value. The sanctions mean that the decision on the manuscript on the base-Artinskian GSSP submitted to *Episodes* and reviewed is at the moment suspended, even if the **base-Artinskian GSSP has been ratified** by IUGS on February 1, 2022. The sanctions will have consequences also for the research we have to undertake on the next (and the last!) GSSP for the Permian, the base-Kungurian GSSP.

In *Permophiles* 56, two GSSP candidates are proposed for defining the base-Kungurian: the Mechetlino section, Urals, Russia (Chernykh et al., 2012) and the Rockland section, Nevada, USA (Henderson et al., 2012), both siting the point at the FAD of the conodont *Neostreptognathodus pnevi*. Table 1 in Henderson et al. (2012) shows the comparison between the main features of the two sections, with Rockland having the merit of recording a longer time interval (all Artinskian and Kungurian), a much more expanded boundary interval in carbonate facies, and a richer benthic fossil content, also allowing correlation with the Tethyan sections. On the other hand, conodonts are much better preserved in Mechetlino allowing strontium isotopic analyses and Mechetlino is within the historical type area. Additional work at the Mechetlino section was further described in *Permophiles* 69 by Chernykh (2020). However, the geopolitical situation and the necessity to have permanent free access to a GSSP section suggest that we focus our efforts on the Rockland section as the base-Kungurian GSSP candidate. Please read Charles Henderson's harangue in this issue to know about our future plans on the Kungurian.

As said above, SPS has been active and also renewed. I am very happy to announce that five new voting members have been selected based on their extensive experience in Permian stratigraphy. They are: Annette Goetz, Landesamt für Bergbau, Energie und Geologie, Hannover, Germany; Sam Lee, School of Earth, Atmospheric and Life Sciences

University of Wollongong, Australia; Ana Karina Scomazzon, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil; Elisabeth Weldon, School of Life and Environmental Sciences, Deakin University, Australia; Dongxun Yuan, School of Resources and Geosciences China University of Mining and Technology, Jiangsu China.

I warmly welcome the new voting members, as they will solicit and provide contributions and comments to the Permian Community in *Permophiles* issues, help us to establish GSSPs, and participate in webinars and in the discussion on all aspects of the Permian.

In the meantime, I know that all the Permian Community will want to join with me in conveying what a great honour it has been to work with the members that are standing down as voting members: Nestor Cuneo, Guang Shi, and Yue Wang. The successes of SPS reflect their hard work and commitment in the last years. I hope they will continue to take an interest in SPS and send us comments and contributions.

To continue our good practice to organize webinars on Permian topics and promote discussion, on April 12, 2022, the webinar "Joining the Dots: Sequence Stratigraphy-Based Regional Geology" by Prof. Mike Simmons of Halliburton was organized live online through Zoom:

https://permian.stratigraphy.org/Interests/Simmons

A new webinar is scheduled for November 2, 2022. This webinar, by one of the Past SPS Chairs Prof. Charles Henderson, will be about the principal tools of Permian biostratigraphy: "The Science of Permian Conodonts". I welcome all the Permian community to attend this webinar.

Another important piece of information concerns the already established Lopingian-base GSSP at the Penglaitan section in Guangxi, South China, which has been permanently flooded due to a dam. Shuzhong Shen and his research group have decided to keep the GSSP at the Penglaitan section, as a trench has been excavated by the local government to expose an outcrop beneath the river bank very close to the GSSP section, which will be flooded for half a year only, thus not permanently. Another section, the Fengshan section, will represent an auxiliary section. More information will be provided in the next *Permophiles* issue by Shuzhong Shen.

I conclude my notes thanking the voting members who are indefatigable in their contribution to the discussion on Permian topics and to *Permophiles*, and who really move Permian studies forward: Charles Henderson, Spencer Lucas, Joerg Schneider, Shuzhong Shen, Mike Stephenson, and Yichun Zhang. Without Yichun, the publication of *Permophiles* would not be possible. Thank you!

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2) Correlation between marine and continental Guadalupian Working Group; Chair-Charles Henderson.

3) Carboniferous-Permian-Triassic Nonmarine-Marine Correlation Working Group; Chair-Joerg Schneider.

4) Gondwana to Euramerica correlations Working Group; Chair-Mike Stephenson.

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Henderson's Harangue #10

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It is time to 'finish' the Permian by defining the Kungurian - revisited!

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

In my last harangue I talked about the base-Artinskian GSSP – it had been ratified by IUGS on February 1, 2022 and a revised manuscript was sent a few weeks later to Episodes to publish the result. The review of the manuscript had just begun when IUGS decided on March 1 to establish scientific sanctions against Russians for the invasion of the Ukraine. The result of these sanctions is that the GSSP manuscript sits in limbo. The path forward is not clear, but possibly greater emphasis on the comparison with a section at Carlin Canyon, Nevada might provide clarity. The path forward for the base-Kungurian GSSP seems to be clear. Until further notice, IUGS has advised that "active involvement of scientists from Russian institutions in IUGS groups and activities should cease". Fortunately there is an alternative section at Rockland, Nevada, USA (see *Permophiles* 56; p. 8-21). In this harangue I wish to highlight some plans for the Kungurian as well as discuss the process of 'doing' science in this crazy world.

This really is a crazy world with the covid pandemic, political instability, climate change, human migrations, runaway inflation, and military invasions. Tensions are rising and I do wonder about the fate of these negative trends, but hope that calmer minds prevail. Many of us are trying to find our own little bit of normal and science is one place where we often look. The pandemic has changed the way we do science – it has changed the way we work in our offices and laboratories and it has changed the way we collaborate and communicate. As geologists we understand that change is normal and some change can be very positive. It is much more restrictive, difficult and costly to travel to other countries, but we can talk to each other easily and often via Zoom at no cost. It means we can continue to make geoscientific progress at least until the samples, currently collecting dust in our laboratories, have been fully studied. Is there a geologist who doesn't have extra samples lying around?

SPS has previously determined that two GSSP candidates have priority for defining the base-Kungurian; see two articles in *Permophiles* 56 (Chernykh et al., 2012; Henderson et al., 2012). The first is at the Mechetlino section in Russia and the second is at the Rockland section in Nevada USA. Those two articles, highlighting results from two distant regions, prove the wide correlation potential of the chosen point (*ie*. the FAD of *Neostreptognathodus pnevi*). Numerous additional correlation tools are discussed in these articles, including strontium isotopes. One of the key characteristics of any GSSP is the open and free access to the site for scientific study. The Russian-Ukraine war has negatively impacted the open and free access to the Mechetlino section for the moment and, in all likelihood, for some time to come after the war has ended. Therefore, SPS is directing and concentrating its effort to define the GSSP at the Rockland section in Nevada. What do we need to do? One limitation was the Sr isotopic excursion noted in figure 8 (p. 15 of *Permophiles* 56) was only extrapolated to the GSSP level. This excellent research was part of the PhD dissertation of Kate Tierney. Fortunately, Kate has some samples stored at the University of Iowa and has agreed, with some support from SPS, to start drilling those samples to complete the curve through the GSSP level. We also need to consider access and protection of the site. The site is on Bureau of Land Management forestry land and is therefore freely accessible. In addition, a recent ruling by the BLM means that conodont samples can be collected free of permit. The site is accessible by a gravel road 38 km south of the I-80 highway, followed by a 2.3 km hike with elevation gain of 580 metres (starting at 5750 feet and ending at 7650 feet elevation). In other words some effort and reasonable level of fitness is required to get to this site in the Basin and Range province of Nevada. The potential GSSP location is at 40.77904°N and 114.60604°W and is illustrated in *Permophiles* 56; you can check out the location on Google Earth. Some effort will need to be made to improve the site, including signage. I have contacted some American colleagues and hope to contact BLM officials and the mining industry; I will continue to make this effort in advance of a SPS field workshop, currently planned for May, 2023. I appreciate any advice on this matter.

There is one other area in northern Nevada that is pertinent to the base-Artinskian and likely the base-Kungurian – this area is Carlin Canyon, near the town of Carlin. Gold deposits referred to as Carlin-type gold are mined nearby. For me, Carlin Canyon became a site of our University of Calgary senior-level field school in 2010. Through the efforts of field school students, two BSc theses, and a MSc thesis, my colleague Benoit Beauchamp and I have mapped and sampled a 4X5 km area extensively. This research followed earlier detailed work by Walter Snyder (Emeritus Boise State) and the late James H. Trexler Jr. The history of this research and new results are detailed in Beauchamp et al. (coming soon in 2022). Some results at Carlin Canyon have been compared to recent GSSP proposals (base-Sakmarian and base-Artinskian). Carlin Canyon could also be a location for the base-Kungurian, but to date we have only sampled as high as near the Artinskian-Kungurian boundary. Benoit Beauchamp, Lucia Angiolini, at least two students, and myself plan to visit and sample in mid-October.

In conclusion, this is not so much a harangue, but rather a plea for cooperative and collaborative action. By completing the last of our Permian GSSPs we set a defined template for important work that considers correlation into continental successions and other regions like Gondwana (see elsewhere in this issue). Can we do this in 2023 or early 2024? Say "yes".

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Subcommission on Permian Stratigraphy Working Group: Gondwana to Euramerica correlations

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The Subcommission on Permian Stratigraphy (SPS) has always had very active working groups that consider challenges and opportunities that the Permian community thinks are important. At present there are three working groups in SPS. The Artinskian-base and Kungurian-base GSSP Working Group,

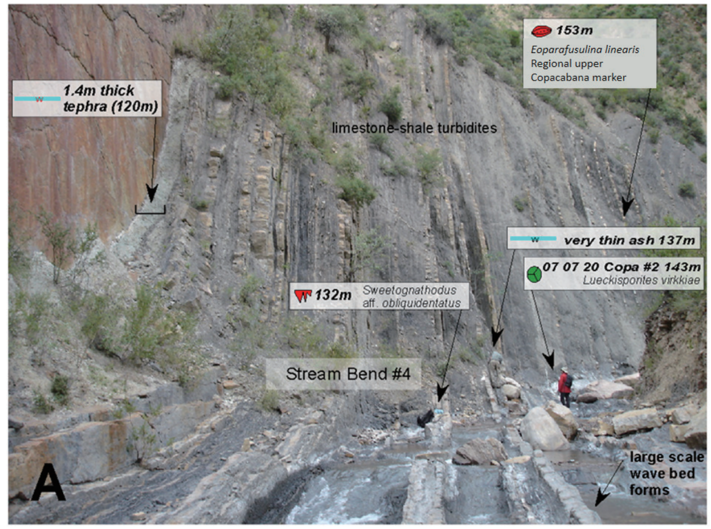

Fig. 1. Apillapampa outcrop at Quebrada Chullpanimayo. Chullpanimayo stream bend #4 showing highly fossiliferous limestone and shale (see Table 1 for references), vertically bedded Copacabana Formation turbidites in the basal Pc5 Sequence (shaley marine ramp lithozone). View is to the south; up-section is to the right; Charles Henderson and Vladimir Davydov for scale. Photograph taken during medium water level, March 2007. A thick ignimbrite marks the end of deposition of coaly and carbonate rocks and the beginning of deposition of sandstones and cherty mudstone of the Vitiacua Formation (from di Pasquo et al. 2015).

the Carboniferous-Permian-Early Triassic Nonmarine-Marine Correlation Working Group and the Correlation between marine and continental Guadalupian Working Group.

At recent meetings of the SPS, it was considered that a challenge for Permian science is the difficulty of correlating between Gondwana and Euramerica. This is particularly acute when important Gondwana successions are to be correlated with the 'standard sections' (including GSSPs) in Russia, the US and China. The SPS Executive therefore recommended that a Working Group be set up and a list of possible members was suggested. The Working Group was first convened on 17th May with most of the suggested members present. A second meeting was held on 17 June when all members were present. The group has agreed to have meetings around every two months or so to begin with, but also encourages meetings of sub-groups, for example, of palynologists, conodont specialists or brachiopodologists. The group has tried to maintain a good balance of men and women and representation of the main Gondwana and Euramerica continents.

So far, the meetings of the group have settled on three main aims for the WG:

1. To work on key sections for correlation where rock successions contain combinations of fossils that are particularly useful for correlating between Gondwana and Euramerica. Field visits and joint sampling may be part of this work.

2. To work on the taxonomy of some key species for Gondwana to Euramerica correlations, for example so-called 'bridge taxa' that occur between or throughout different Permian provinces

3. Share knowledge through digital means, for example galleries of photographs and taxonomic notes (example the BGS Taxonomy online galleries: https://www.bgs.ac.uk/information-

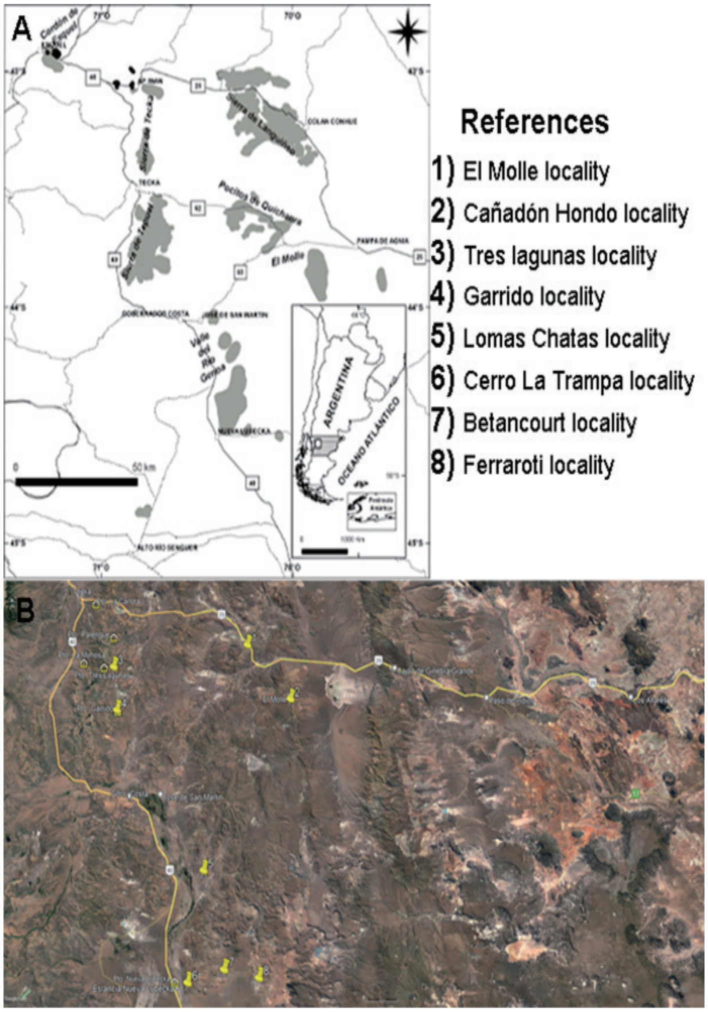

Fig. 2. Tepuel-Genoa Basin. **A**, location map; **B**, satellite image showing the key localities of Permian outcrops.

hub/data-collections/fossil-taxonomy/)

To decide on which key species and sections to work on, the WG has devised a proposal system whereby a member of the group proposes a key taxon or section through a short written proposal, which will be circulated before a meeting. This will help us choose the best sections and taxa.

So, the group is already quite active. We even have a WhatsApp account!

So far, the group has only considered (1) above in detail. Two key sections have been proposed, the Apillapampa section in Bolivia (Fig. 1) and sections in the Tepuel Group, Argentina (Fig. 2, 3). Some details of these proposed key sections are shown in Table 1.

The WG will continue to work on its aims and review its membership, and will report its progress regularly in Permophiles.

The members of the group are as follows (Table 2).

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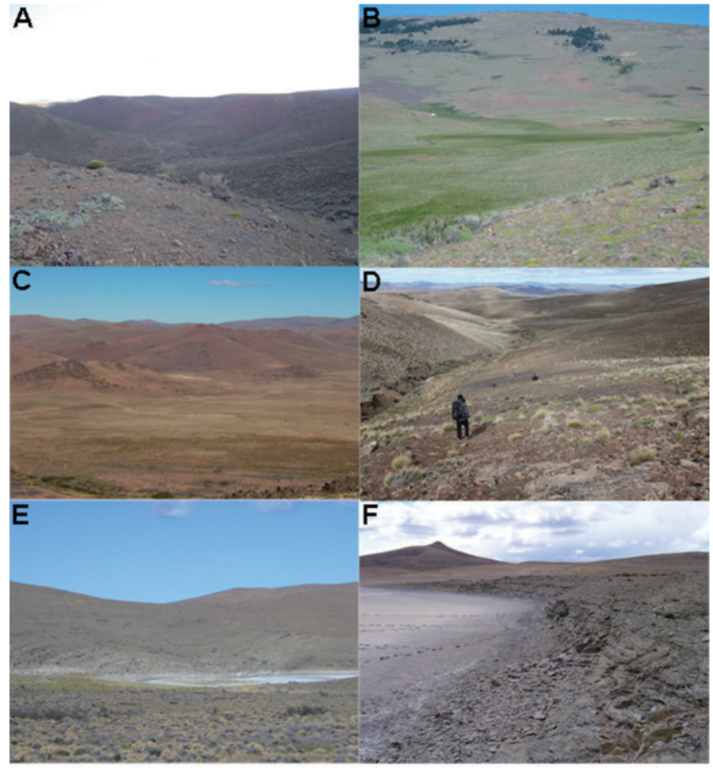

Fig. 3. **A**, general view of El Molle outcrops; **B–C**, general view of Tres Lagunas outcrops, B, lower levels, C, middle and upper levels; **D**, general view of Arroyo Garrido outcrops; **E**, general view of Betancort outcrops; **F**, general view of Ferraroti outcrops.

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Table 1. Key sections for correlation proposed by the Working Group: Gondwana to Euramerica correlations.

Name of Section	**Why is it important that this section is considered by the Working group, or a subsection of the group**	**Key papers that discuss the section (max 5 papers) with links if possible**	**Precise location of section**
Apillapampa	Correlation between the paleo-equatorial province in which the Permian Stage GSSPs are based and Gondwana has been historically difficult mainly because the conodonts on which Permian Stage GSSPs are based (Henderson, 2018) are largely absent from Gondwana basins (Mouro et al., 2020; Scomazzon et al., 2013, Stephenson 2016). The Apillapampa section (Copacabana Formation) near Cochabamba, central Bolivia, is key to correlation between paleo-equatorial province and Gondwana because it contains conodonts, fusulinids and dated ash beds. Di Pasquo et al. (2015) quoted radiometric dates from six volcanic ash beds within the section; these dates were first cited by Henderson et al. (2009) based on analyses performed at Boise State University by Jim Crowley and Mark Schmitz. The six dates (cited as preliminary in Permian ICS Newsletter Permophiles, 53, Supplement 1) are 298 (40 m), 295.2 (120 m), 293.3 Ma (154 m), 293 Ma (185 m), 291.6 Ma (242 m) and 290.1 Ma (262 m) (Fig. 1). These dates are CA-ID-TIMS dates, but the precision has not been published yet. These zircons should be reanalysed using current tracers and statistical protocols. The dates fix the upper Coal Member of the Copacabana Formation as late Sakmarian to early Artinskian. The presence of the conodont *Sweetognathus* cf. *obliquidentatus* corroborates this correlation. *Sweetognathus whitei* and *Sw.* aff. *behnkeni* and the fusulinid *Eoparafusulina linearis* occur lower in the section; these taxa are typical of the late Asselian and early Sakmarian (Henderson, 2018; Petryshen et al., 2020; Chernykh et al., 2022 in *Permophiles* 72). Among the invertebrates, the high-diversity	Grader et al. (2008), Henderson et al. (2009), di Pasquo and Grader (2012), di Pasquo et al. (2015) (and previous references in those works) Base of section is located at 3043 m elevation with latitude 17.86669°S and longitude 066.24495°W.	17°30’00’’S – 66°W, central Bolivia

	brachiopod fauna mentioned from the lower limestone of the Apillapampa section (Chamot, 1965), includes *Gypospirifer condor*, *Linoproductus cora*, *Waagenoconcha humboldti*, *Kozlowskia capaci* and *Rhipidomella cora*, which are key species for biostratigraphic correlations in South America, i.e. Bolivia, Perú and north-central Chile (Cisterna & Sterren, 2022), and which would also have been recorded from the northern hemisphere. The marine member of the Copacabana Formation displays cyclicity that may correlate with a long eccentricity signal. Our proposal suggests re-visiting and re-studying the fossiliferous groups present in the Cisuralian Copacabana Fm such as conodonts, fusulinids and plants and microfloras and invertebrates including common brachiopods along with isotopically-dated ash beds that can also be re-sampled. However, since only the palynology was fully revised, the brachiopods as the other groups would need further detailed study from new sample-collections. Current collections of conodonts (Henderson) and fusulinids (Davydov) need to be described and illustrated.		
Tepuel Group (Pampa de Tepuel Fm., Mojon de Hierro Fm. and Río Genoa Fm)	The Tepuel-Genoa Basin (Patagonia, southern Argentina) was infilled by nearly 7000 m of a continuous succession, from the Early Carboniferous (late Tournaisian) to the Early Permian (Artinskian). Lowermost Permian faunas were recognised in the upper part of the Pampa de Tepuel Formation and in the overlying Mojón de Hierro and Río Genoa Formation. The Permian exhibits an abundant and diverse record of fossil groups, being brachiopods, bivalves, bryozoans and gastropods the most representatives, together with subordinate occurrences of cnidarians, echinoderms, cephalopods, hyolithids, trilobites, ostracods, scaphopods and polyplacophors, but no conodonts. Absence of warm-water fossils coupled with several glacial-influenced horizons	Taboada (2008) Pagani & Taboada (2010) Taboada & Pagani (2010) Pagani & Taboada (2011) Taboada *et al.*, 2016 Taboada *et al.*, 2022	In central-west Patagonia, Late Paleozoic rocks extend over extensive areas between 43°–44° 20′S and 69° 30′–71°W, and are distributed from north–northwest to south–southeast for approximately 250 km.

	characterize the Tepuel Group, suggesting its faunal development in cold- to cool-water seas within high paleolatitudes (~70° S) and recording the most complete polar view of the Late Paleozoic Ice Age. The taxonomic composition of the Permian sequence in Patagonia suggests strong, but temporally varied faunal links with western Australia and the Cimmerian regions in south and southeast Asia, as well as moderate, but significant links with the Siberian Arctic region and, to a lesser extent, with eastern Australia. The key taxon are *Languigneotus dammanorum* Taboada *et al.* 2018; *Verchojania archboldi* Taboada, 2008; *Cimmeriella willi* Taboada & Pagani, 2010; *Costatumulus* sp.1; *Costatumulus* sp.2; *Costatumulus* sp.3; *Kochiproductus* sp.; *Tivertonia* sp.; *Jakutorpoductus sabattiniae* taboada & Pagani, 2010; *Jakutoproductus australis* Simanauskas & Archbold, 2002; *Piatnitzkya borreloi* Taboada, 1993 and *Magniplicatina* sp. The most important disadvantage of the Patagonia sequence is its paleogeographic position at high latitudes and the absence of warm-water fossils. However, the Permian sequence in Patagonia can be correlated with other sections in Gondwana, northeast Asia and the Arctic to establish global correlations. The bipolar or antitropical brachiopods provide a potential correlation to the Canadian Arctic (Bamber and Waterhouse, 1971), but these ages should be reevaluated based on new data and revisions to the Permian Time Scale. In this sense, the Tepuel–Genoa Basin in Patagonia is best positioned to serve as a possible reference area for Late Paleozoic Gondwana biostratigraphy as it possesses an excellently exposed and continuous succession containing diverse marine faunas and, in places, floras.		

Table 2 Members of the Working Group: Gondwana to Euramerica correlations.

Name	Location	Expertise
Gabriela A. Cisterna	CONICET-Instituto Superior de Correlación Geológica (INSUGEO), Tucumán, Argentina	Carboniferous and Permian brachiopods
Mercedes di Pasquo	CICYTTP - Centro de Investigaciones Científicas y transferencia Tecnológica a la Producción	Carboniferous and Permian palynology and paleobotany
Charles Henderson	University of Calgary	Permian conodonts
Pauline Kavali	Birbal Sahni Institute of Palaeosciences, India	Permian palynology
Alejandra Pagani	Museo Paleontologico Egidio Feruglio, Trelew Argentina - CONICET	Permian molluscs, brachiopods and bryozoa
Ana Karina Scomazzon	Universidade Federal do Rio Grande do Sul, Brazil	Permian and Carboniferous conodonts
Mike Stephenson (Chair)	British Geological Survey/Stephenson Geoscience Consulting Ltd	Permian and Carboniferous palynology
Liz Weldon	Deakin University Australia	Brachiopods, stratigraphy and palaeontology
Yi-chun Zhang	State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology	Fusulinida

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Preliminary observations on Permian lithostratigraphy on the Mogollon Rim, Arizona, USA

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Introduction

Permian strata deposited on the western part of the Arizona shelf (a structural feature of the ancestral Rocky Mountains) are best exposed along the Mogollon Rim, the western edge of the Colorado Plateau in central Arizona (Fig. 1). Most of these strata are a thick (up to 550 m), red-bed-dominated section of the Supai Group (Formation) (e.g., Peirce et al., 1977, 1989; Blakey, 1979, 1990). Marine strata of the Naco Formation below

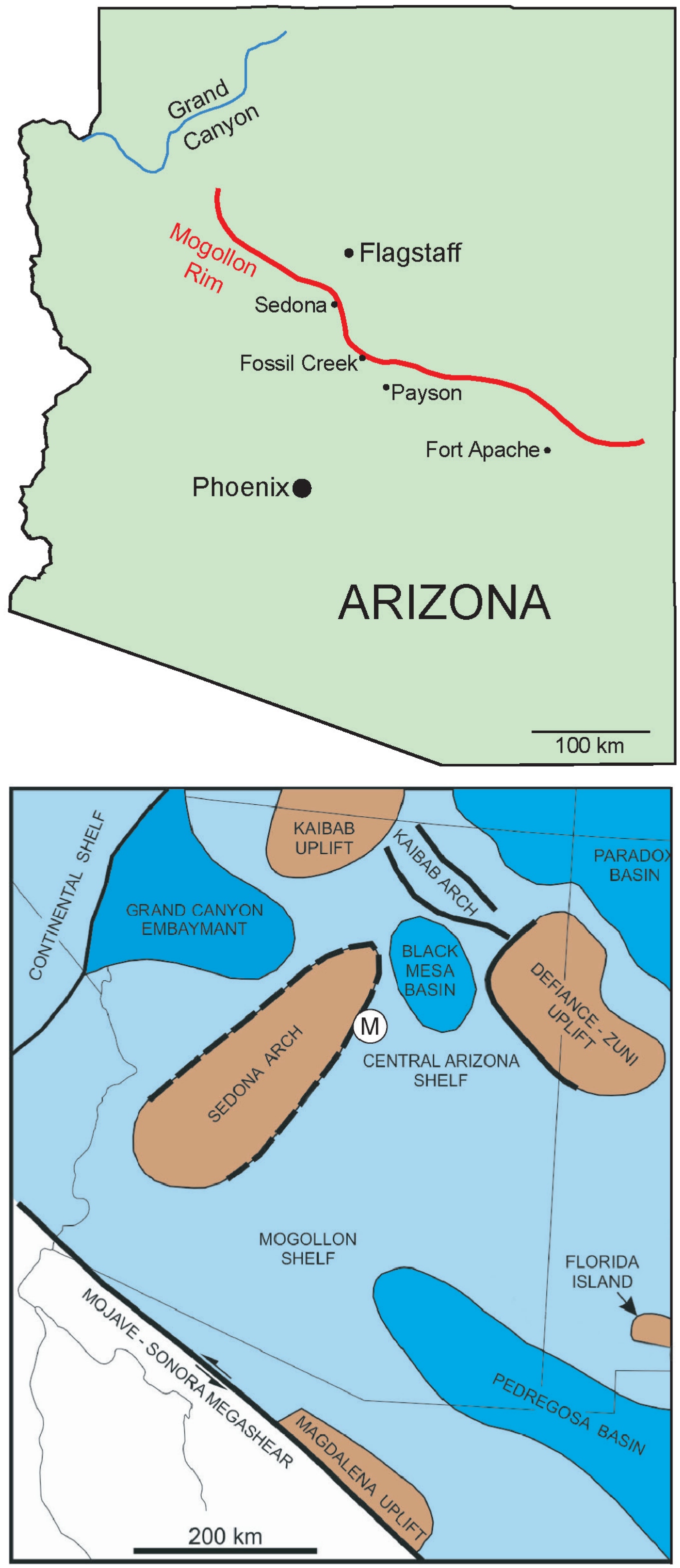

Fig. 1. Map of Arizona, USA, showing location of Mogollon Rim (above) and late Paleozoic paleo-tectonic map of Arizona; M = Mogollon Rim (below).

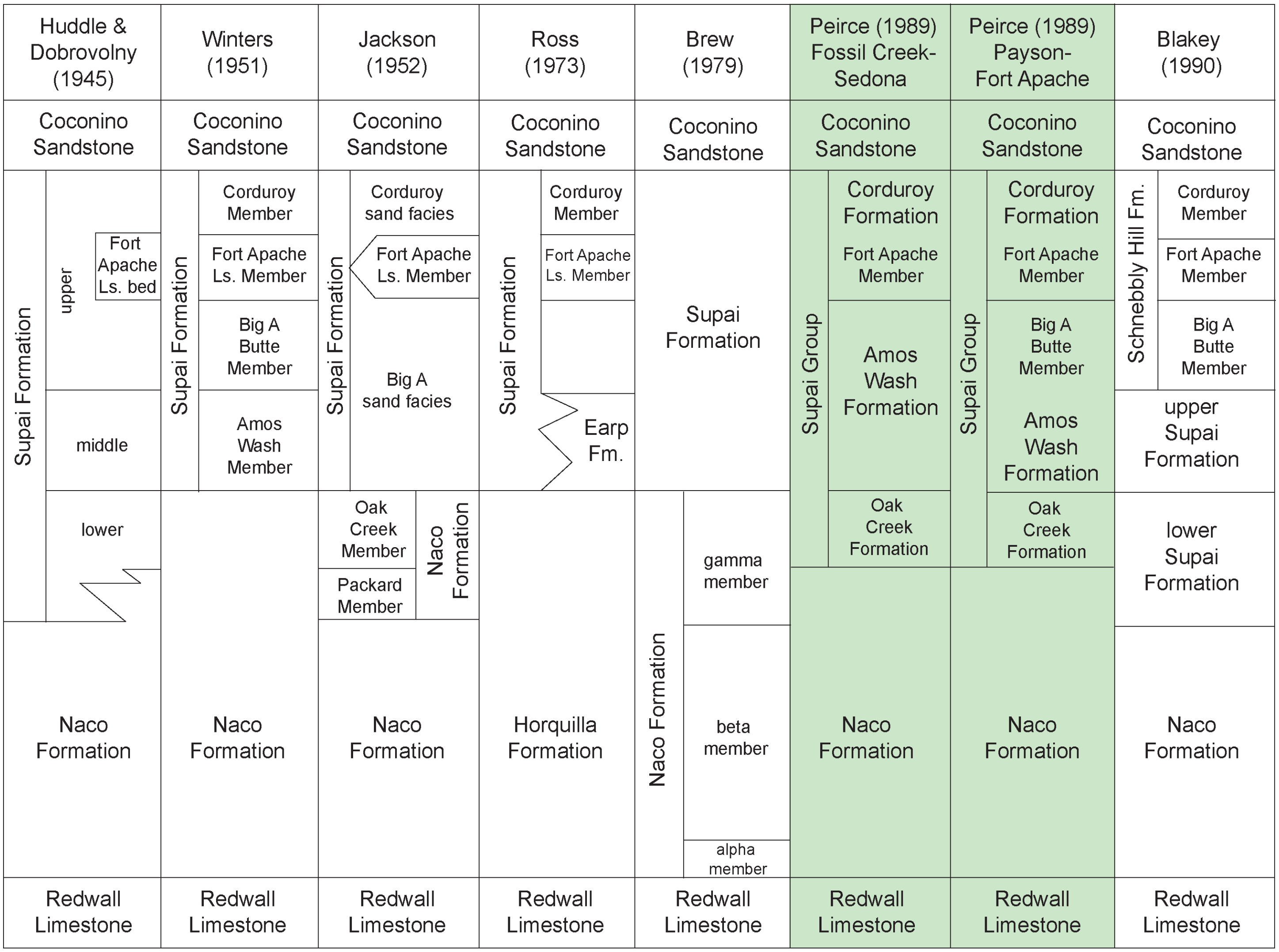

Fig. 2. Some previous lithostratigraphic nomenclature of the Pennsylvanian-Permian section on the Mogollon Rim in Arizona. The nomenclature of Peirce (1989) is advocated here.

Supai Group red beds yield fusulinids and macroinvertebrates (primarily brachiopods) that indicate an age range of Middle-Late Pennsylvanian (Desmoinesian-Virgilian) (e. g., Huddle and Dobrovolny, 1945; Brew, 1965, 1970, 1979).

We are currently restudying the lithostratigraphy, paleontology and biostratigraphy of the Pennsylvanian-Permian strata exposed along the Mogollon Rim. A complex lithostratigraphic nomenclature exists for these strata that reflect different workers naming and renaming units and diverse ideas about correlations and facies changes (Fig. 2). The need for some simplification of this nomenclature is obvious, and some names need to be created and others replaced to arrive at a lithostratigraphic nomenclature that most accurately reflects the lithologies and stratigraphic architecture of the succession.

Here, we offer a brief review of initial conclusions about the lithostratigraphy of upper Paleozoic strata exposed on the Mogollon Rim. In this review we make an important distinction between three outcrop areas of upper Paleozoic strata along the Mogollon Rim: (1) southeast of Payson, including the Fort Apache Indian Reservation; (2) Fossil Creek and vicinity north and west of Payson; and (3) the Sedona-Oak Creek Canyon area to the northwest (Fig. 1). Another important point is that there have been three approaches to the upper Paleozoic lithostratigraphy on the Mogollon Rim: (1) correlate and bring lithostratigraphic nomenclature in from the Grand Canyon; (2) create local nomenclature specific to all or parts of the Rim outcrops; or (3) bring lithostratigraphic nomenclature in from the late Paleozoic Pedregosa basin to the southeast (Fig. 2).

Naco Formation

On the Mogollon Rim, strata between the Mississippian Redwall Limestone and strata called Supai Formation (or group) have long been given the name Naco Formation, following the first use of that name on the Rim by Huddle and Dobrovolny (1945) (Fig. 2). The Naco consists of 122-244 m of limestone, mudrock and sandstone that form a ledge and slope topography. Naco strata rest with profound unconformity on the Mississippian Redwall Limestone, and there is a paleosol and breccia-dominated karst fill at the contact. The top of the Naco is generally placed at the highest marine limestone below Supai red beds, but the extent to which the red beds interfinger with the Naco strata is not agreed on.

Brew (1965, 1970, 1979) divided the Naco Formation into three informal members (ascending): alpha, beta and gamma (Fig. 2). The alpha member is the basal 13-27 m and is the karst fill on top of the Redwall Limestone—reddish brown siliciclastic strata and chert-- and yields early Desmoinesian fusulinids. The beta member is 256 m of interbedded limestone and shale and is the main, characteristic part of the Naco. The gamma member is 21-97 m of reddish brown clastics interbedded with limestones. Brew (1979, fig. 106) indicated (based primarily on fusulinids) that the gamma member is Desmoinesian along Fossil Creek but as young as Virgilian on the Fort Apache Indian Reservation to the southeast. Thus, he posited extensive intertonguing of the Naco and Supai lithosomes, a conclusion that has found little support from other workers

The original Naco Group is a thick succession of mostly marine carbonate-dominated strata of Pennsylvanian-Early Permian age exposed in the Pedregosa basin of southeastern Arizona and adjacent areas. For Naco strata along the Rim, Ross (1973) identified to two formations of the Naco Group; he assigned most of the strata to the Horquilla Formation and assigned the interval of interbedded carbonate and red-bed clastics (the gamma member of Brew's later usage) to the Earp Formation (Fig. 2). However, we find no lithostratigraphic basis for applying those formation names to strata along the Rim, as Horquilla and Earp strata in the Pedregosa basin differ significantly from the strata on the Rim to which Ross (1973) applied those names.

The name Naco Formation is being used on the Mogollon Rim for a much thinner and much more clastic interval of Pennsylvanian strata than the Pennsylvanian-Permian strata of the Naco Group in the Pedregosa basin. We thus regard Naco Formation as a "placeholder" name that should be replaced with a new local formation name. The three informal members of the Naco Formation recognized by Brew also merit new, formal nomenclature.

Supai Group

Along the Mogollon Rim and elsewhere in Arizona, we favor using Supai as a unit of group rank, as its major subdivisions are readily mapped and thus should be recognized as formations. One approach is to advocate inclusion of "Naco Formation" strata on the Rim in the Supai Group, as was done by Darton (1910), who named the Supai Formation for the red-bed dominated section between the Mississippian Redwall Limestone and the Permian Coconino Sandstone in the Grand Canyon. Noble (1922) removed the upper, siltstone-dominated part of the Supai and named it the Hermit Shale. As redefined by McKee (1975, 1982), the Supai Group in the Grand Canyon is mostly Pennsylvanian-lowermost Permian strata that are not equivalent to most of the Supai strata on the Mogollon Rim. We favor abandoning Noble and McKee's redefinitions to include the Hermit Formation in the Supai Group and thus a return to Darton's original definition of the Supai, a strategy also recommended by Peirce (1989).

Huddle and Dobrovolny (1945) published a series of stratigraphic sections of Paleozoic rocks exposed along the Rim, using the name Naco Formation for the Pennsylvanian strata and Supai Formation informally divided into lower, middle and upper for the Permian strata (Fig. 2). Their lower Supai is 61-165 m of sandstone, shale and some limestone (this is the gamma member of the Naco Formation of Brew); the middle Supai is 76-122 m of mostly sandstone, siltstone and shale with uneven bedding; and the upper is 335-488 m of even bedded sandstone and siltstone, including the Fort Apache Limestone.

Winters (1951, 1963), working primarily in the Fort Apache area, proposed the first formal, local nomenclature for subdivisions of the Supai strata along the Mogollon Rim. He thus divided the Supai into four members (ascending): (1) Amos Wash Member, 100 m of reddish brown, very fine grained noncalcareous sandstone and siltstone; (2) Big "A" Member, 145 m of slope-forming reddish brown calcareous mudstone with some intercalated beds of gypsum and limestone; (3) the Fort Apache Limestone, 29-36 m of limestone-dominated strata; and 4) Corduroy Member, 114 m of alternating slope-forming reddish brown calcareous mudstone and siltstone with some interbeds of limestone and gypsum. Finnell (1966a, b) renamed the Amos Wash Member the Cibecue Member, so Finnell's name can be abandoned. We follow Peirce et al. (1977) in using Winter's stratigraphic nomenclature of the Supai strata along much of the Mogollon Rim.

The work of Jackson (1952) indicated that the Supai red beds along the Rim become sandier to the northwest (Fig. 3). The critical change in facies northwestward is well seen at Fossil Creek north of Payson, where Jackson recognized two lower units of the Supai, his Packard member and (overlying) Oak Creek member, that are equivalent to the upper part of the Naco Formation. He also considered the Amos Wash and Big A Butte units to the south to merge northward to a "Big A" sand facies and regarded the Corduroy unit to the south as equivalent to the north to a "Corduroy sand facies" on Fossil Creek. Jackson's (1952) subdivisions of the Supai can be recognized to the north, in the Sedona-Oak Creek area.

Blakey (1979, 1990) presented two contrasting lithostratigraphies of the upper Paleozoic strata along the Rim. First (1979), he brought Supai Group nomenclature used in the Grand Canyon into the Mogollon Rim. Blakey (1979) thus assigned the Naco Formation section and its northern equivalents to Supai Group formations from the Grand Canyon, including (ascending) the Watahomigi, Manakacha, Wescogame and Esplanade formations. He proposed that these units were overlain by the Hermit Shale and capped by the informally named Schnebly Hill Formation, a new local unit proposed for the red rocks of Sedona (traditionally, these rocks were called Supai). However, these correlations lack a strong lithostratigraphic basis and are at least in part refuted by biostratigraphy. For example, fusulinids indicate Morrowan and Atokan ages for the Watahomigi and Manakach formations in the Grand Canyon, whereas fusulinids indicate the oldest age of Naco strata along the Mogollon Rim is Desmoinesian.

Blakey (1990) largely rejected his earlier lithostratigraphy of the upper Paleozoic section on the Mogollon Rim and formally introduced the Schnebly Hill Formation, which encompasses the Big A-Corduroy interval of Winters' lithostratigraphy. In doing so, Blakey (1990) removed the upper part of the red-bed section along the rim from the Supai Formation/Group. Nevertheless, Schnebly Hill is a superfluous name that reduces stratigraphic resolution by applying one name to an interval of three already named units. So, Schnebly Hill Formation should be abandoned (cf. Peirce, 1989). Blakey (1990) also named three members of the Schnebbly Hill Formation, but the facies relationships of these strata (see especially Blakey, 1990, fig. 5) need to be re-evaluated.

Furthermore, use of the term Hermit Formation (Shale) on the Mogollon Rim has been inconsistent (e.g., Blakey 1979, 1990; Elston and DiPaolo, 1979) and needs to be reconsidered. For rocks near Sedona, Blakey (1990) proposed the Hermit was very low in the section, but Elston and DiPaolo (1979) considered it to be high in the section, just below the Fort Apache Limestone. Peirce (1989) concluded from several lines of evidence that the name Hermit should not be used in the Sedona area because the rocks were too old and subsurface data showed the Hermit to have pinched out well to the northwest of Sedona.

An important interval of the lower Supai is what Peirce referred to as the mineralized (primarily uranium) “zone of interest,” ~ 10 m of greenish siltstone, sandstone and conglomerate, and includes coaly beds that produced palynomorphs on Fossil Creek (Canwright, 1978) and a megaflora as well as a bivalve assemblage at Promontory Butte (Blazey, 1974; Eagar and Peirce, 1993). Initial work by us at Promontory Butte also indicates the presence there of invertebrate and tetrapod trace fossils, conchostracans, ostracodes, shark coprolites, bony fishes and eupelycosaur bones. This interval deserves a lithostratigraphic name and will prove critical to locating the Pennsylvanian-Permian boundary along the Mogollon Rim. At Tonto Creek, the lowermost part of the Supai section contains a Leonardian trace fossil assemblage (Lucas et al., 2019; Lucas and Henderson, 2021) that suggests that if Wolfcampian strata are present along the Mogollon Rim they are very thin and/or riddled with unconformities.

Fort Apache Limestone

The Fort Apache Limestone is a distinctive limestone-dominated unit along the Rim. Although relatively thin (up to ~ 30 m thick), it is a mappable key unit and should be regarded as a unit of formation rank. New conodont data reported by Lucas and Henderson (2021) assign a middle Leonardian (Kungurian) age to the Fort Apache Formation, so it is both an important lithostratigraphic and chronostratigrahic datum in the regional Permian section (also see Lucas et al., 2022a, b).

Conclusion

These preliminary observations on the Pennsylvanian-Permian lithostratigraphy along the Mogollon Rim are based on field research that began in 2018. Our conclusion is the same as that of Peirce (1989), that most or all of the Supai Group lithostratigraphic names needed along the Mogollon Rim are those of Winters (1951) and Jackson (1952) (Fig. 2). Charles Henderson is working with us to obtain conodont data from the Naco and Supai strata to make better age determinations, particularly to locate the base of the Permian and identify what part of the section may be of Wolfcampian age. Thus, ongoing and further work planned will produce a comprehensive lithostratigraphy and a much improved biostratigraphy of the upper Paleozoic section in this area.

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Short Note on the decision about the proposal for the Sakmarian-Artinskian Boundary GSSP by Chernykh et al., 2021

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The reply by Chernykh et al., 2022 (in the following named "reply") to my comment (Horacek, 2022) on the proposal for the Sakmarian-Artinskian Boundary (SAB) by Chernykh et al., 2021, has partially clarified the picture to me. However, only partially. Some few more (or persisting) concerns I want to quickly point out:

1) Correlation between Dal´ny Tulkas section and trench:

The answer in the reply concerning the bed-by-bed correlation is rather unsatisfying to me. If the mentioning of trench beds 3-4 together with section bed 2 (in section Interpreted Sequence Stratigraphy) is not intended as correlation by lithology, then what is meant by the listing of these beds and the indication of similar/identical fossil content? Has the correlation of the beds following upwards, between the two lowest correlation lines (below the SAB in Chernykh et al., 2021, fig. 7), also not been done by the following statement from the same paragraph (Interpreted Sequence Stratigraphy): "Units above these levels (above lowest dashed line in Fig. 7) include carbonate mudstone, with increasingly diverse and abundant marine fossils.", but on other evidence (hidden, as I cannot extract it from the data given in table 1 of Chernykh et al., 2021)?

Furthermore, I am uncertain, if the exact correlation of the SAB between trench (defined there by fusulines) and section (defined by conodonts) really is correct, as I don´t think there has been demonstrated the proof that the base-Artinskian fusulines (used to define the SAB in the trench, according to the reply) occur exactly at the same level as the FAD of *Sw. asymmetricus* (where do occur the Artinskian fusulines in the section? No fusulines have been reported from the conodont-containing layers in bed 4b). In the reply it is noted that "..trench and section are only about 30 metres apart.", thus I would expect a perfect, detailed and straightforward correlation, which I currently cannot find. As it is confirmed that the trench is intended to "..better display and conserve the GSSP.." this correlation between trench and section, in my opinion, is important, has to be excellent and unquestioned.

2) The conodont lineage:

Besides the existence of the described conodont lineage (*Sw. binodosus*-*Sw. anceps*-*Sw. asymmetricus*) in the Urals, South China and North America, has it been found elsewhere, demonstrating its global relevance? Is it certain that the new form *Sw. asymmetricus* (former *Sw.* aff. *whitei*) can and will be differentiated from (and not mixed up with) *Sw. whitei*, and shouldn´t another conodont species be selected as index fossil which might not be prone to potential confusion?

[Further details to correct: As in the reply is written with respect to fig. 7 of the original article: "The following three correlation lines [above the SAB] are based on ammonoids and fusulines contents.", the first correlation line above the SAB either needs to be moved up a bit on the section side to exactly correlate with the ammonoids-containing sample layer (or the fusulines symbol needs to be added on the trench side, if the correlation is based on that), and the third correlation line above the SAB needs to also be moved up a bit on the section side to correlate with the fossil layer (currently the correlation is below that bed), and on the trench side the type of fossil that is correlated needs to be indicated. The SAB in fig. 16 needs to be adjusted. (I know these are all just minor things and I will be scolded nitpicking, but, in my opinion, it´s all about exact (as can be) science.)]

I don´t want in any way to diminish the significant efforts undertaken by the numerous researchers who put together the data and the proposal. Currently however (unless the correlation uncertainties between section and trench can be removed on the spot), it seems to me that there still is some further work to be done, to produce a consistent and complete data set and exact correlation between section and trench. Also, I regard this correlation between section and trench as a test for the usability of the proposed boundary. It needs to be thought about: What happens, if the required excellent correlation between section and trench cannot be achieved?

Luckily, it is not on me to take the decision on the present proposal, but others have to fulfil this difficult task.

Addendum: The above statement has been sent to *Permophiles* well in advance before publication of the last volume (*Permophiles* 72), as obvious by its last sentence. Reading it now, I would like to slightly modify it, but refrain from that to leave it as it was submitted. While it has been forwarded to the voting members of the SAB committee, the editor decided not to include it in the last volume for the sake of a consistency in timeline (meaning that a contribution referring to a reply in Permophiles cannot be included in the same issue). While I understand this reasoning, I nevertheless think that it should have been included for the sake of transparency. In a case as the SAB-proposal, where the editor of *Permophiles* also is among the authors of the SAB-proposal, and the authors of the proposal make up for ca. 50% of the voting members (and rumours exist that indeed the exact and detailed correlation between section and trench is not clear), the impression of suppression of criticism on the proposal (irrespectively how irrelevant and unjustified it might be regarded) should be avoided at all costs. Unfortunately, this has not been done, giving space for such speculations.

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Editors Note to M. Horacek contribution

We make every effort to include all correspondence on Permian topics from members and, in fact, encourage the free exchange of ideas regarding the Permian. We did it in the past (see for instance the discussions in *Permophiles* 70 and 71) and we are doing this now.

It has previously been discussed that there is no issue regarding correlation of the section and trench. The section is the GSSP, where considerable research was accomplished and it was ratified by IUGS Feb 1, 2021. Additional samples were collected in a nearby trench, but the work was more limited in scope. There is no issue and no further discusson is needed. Charles Henderson (pers. comm.) reports that the identification of *Sweetognathus asymmetricus* is clear. For example, specimens of *Sw. whitei* from the Taiyuan Formation of north China were reported to be Artinskian. Charles tried to convince some colleagues in China that they were the real *Sw. whitei* and late Asselian age. His colleagues recently proved him right using geochronology of new ash bed levels. He promises to highlight this during the upcoming webinar on "the science of Permian conodonts".

A digital photograph collection of sedimentary structures from the Bromacker reveals a new interesting specimen

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Introduction

The launch of a collection of digital photographs of sedimentary structures from the Bromacker outcrop sections is reported herein. All photographed sedimentary specimens belong to the Tambach Formation (Rotliegend Group; Early Permian) in the Thuringian Forest Basin (Central Germany). The present study also describes one sandstone slab that shows sediment marks determined as a scratch circle. This report was submitted initially in July 2021 as a contribution to the Proceedings of the “Kazan Golovkinsky Stratigraphic Meeting 2021”; however, the production of the Proceedings volume became stopped recently. The original version of the article is slightly modified herein, in order to update some literature references.

The Bromacker

The Bromacker is an outcrop area located about 2 km north to the city centre of Tambach-Dietharz in the Thuringian Forest mountains (Free State of Thuringia, central Germany). The lithologic succession is composed exclusively of red beds, deposited in an Early Permian intramontaneous sedimentary basin under possibly semi-arid palaeoclimate conditions (e.g., Roscher and Schneider, 2006), and belongs lithostratigraphically to the Tambach Formation (Lützner et al., 2012). Pronounced continental palaeoenvironment conditions in the Tambach Formation are indicated by finds of reptile-like tetrapods (e.g., Martens et al., 2005), which are preserved either as isolated fragments (e.g., bones, teeth) or articulated skeletons (e.g., Martens et al., 2018). Trace fossils of tetrapods are preserved as well, allowing for track–trackmaker correlation (Voigt et al., 2007) and digital trackmaker modelling (e.g., Nyakatura, 2019).

The Bromacker section also yields various sedimentary structures (e.g., Lützner, 1981; Martens et al., 1981; Martens et al., 2009; Eberth et al., 2000; Martens, 2007), which can be observed frequently on loose (*ex situ*) sandstone blocks that are lying on the quarry ground. In the present study, hundreds of rock surfaces covered with well-preserved sedimentary structures were photographed in order to document their occurrences at the Bromacker. As a result, a digital photograph collection was newly established, including both the sedimentary structure photographs and a digital register (saved electronically as a *.xlsx*-

file) that involves the respective image numbers and keywords of the photographed specimens. This allows for both a verbal designation of the sedimentary structures and searching for specific photographs within the digital collection. Launching this new digital photograph collection contributes to a better understanding of various abiotic and biotic aspects of the sedimentology of the Tambach Formation, in order to reconstruct its depositional environment and habitat conditions through ongoing studies.

Lithology

Around the town Tambach-Dietharz, the Tambach Formation can be divided into three subunits in ascending stratigraphic order: the Bielstein Conglomerate Member ("Lower Conglomerate"), the Tambach Sandstone Member, and the Finsterbergen Conglomerate Member ("Upper Conglomerate"). The studied outcrop section at the Bromacker belongs lithostratigraphically to the Tambach Sandstone Member. It is well-exposed in both active and abandoned quarries, a scientific excavation site, and several shallow drill cores at the Bromacker (Fig. 1). The Tambach Sandstone Member is composed of various lithologies and lithofacies. In particular, channel-shaped, internally cross-bedded sandstones are interpreted as braided river deposits, whereas intercalations of internally horizontally stratified to massive sandstone banks are indicative of temporary flood deposits, possibly triggered by heavy rainfall (e.g., Schneider and Gebhardt, 1993; Schneider, 1996). Laminated clay-/siltstones in the Bromacker section are interpreted as the result of extensive draining mud flows, whereas the presence of brecciated layers of intraformational clay-/siltstones are characteristic of repeated reworking and redeposition processes (e.g., Martens et al., 1981). Temporarily pronounced terrestrial conditions (e.g., subaerial exposure, oxidation) are indicated by very frequent occurrence of desiccation cracks and, less intensive, palaeopedogenic overprinting. Immature palaeosoils and fossil plant remains occur in some places at the Bromacker and also in other nearby outcrops of the Tambach Sandstone Member.

Methods and Materials

The Bromacker is the centre of activities in a current geological–palaeontological research project (2020–2025), which also includes sedimentological fieldworks (e.g., local mapping, lithologic profile documentations, photographic documentations). Occurrences (*in situ* and *ex situ*) of both single sedimentary structures and assemblages of multiple structures had been photographed using digital cameras hand-held, under natural light, often perpendicular to the bedding plane. Size information are included in additional photographs showing scale bars (i.e., folding rulers) attached to the specimens. All photographs are saved as .jpg-files on a desktop computer in the Institute for Geoscience, Friedrich Schiller University Jena. In the present study, the software CorelDraw Graphics Suite 21 was used for making line drawings and mounting photographs to figures.

Results

Based on the new digital photograph collection, the most frequently observed sedimentary structures (Fig. 2) in the Bromacker section are desiccation cracks, raindrop imprints, load casts, scour marks, tool marks, water level marks, and ripples (e.g., Scholze, 2021; Scholze and Pint, 2021). Some other structures might also be present but require further investigation (i.e., questionable syneresis cracks, microbial mats; for potential finds of ice marks see recent discussions by Martens, 2022). Additionally, trace fossils (supposedly produced by invertebrates) determined as *Tambia spiralis*, *Striatichnium bromackerense*, and others (e.g., *Tambia*-sized circular sandy burrows) had been documented photographically, too. Scrape traces produced by tetrapods also occur frequently in the Bromacker section, and were described previously by Dr. Th. Martens and colleagues (e.g., Martens et al., 2009: see therein plate 2-fig. 5).

In the present study, an interesting sedimentary structure (Fig. 3) was newly discovered on the top side of a fine-grained to slightly medium-grained sandstone block, lying directly in front of the recent quarry wall (see position "e" in Fig. 1A). This sedimentary structure is determined herein as a scratch circle, consisting of a set of circularly curved scratches on a horizontal bedding plane (Fig. 3A). Although the rock slab with this scratch circle is fragmented, the curved arrangement of the scratches allows for a graphic full-circular reconstruction (Fig. 3B). The radius of this full circle measures 15.2 cm.

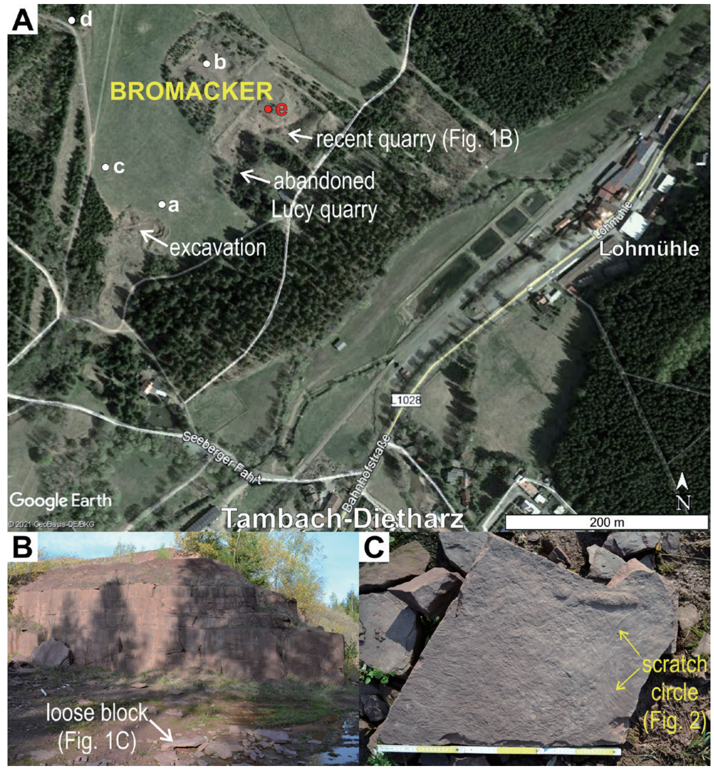

Fig. 1. Overview on the Bromacker locality (Early Permian; Thuringian Forest Basin). **A**: Aerial view showing the geographic position of the Bromacker, located north of the town Tambach-Dietharz (Thuringia, central Germany). The Bromacker outcrop section is composed of a recent quarry, an abandoned quarry ("Lucy quarry"), a palaeontological excavation site (e.g., Martens, 2018), and shallow core drillings from previous studies. Drill core sections (Krause et al., 2006; Martens et al., 2009): a=Bromacker 1/2004, b=Bromacker 2/2004, c=Bromacker BK1/2008, d=Bromacker BK2/2008). **B**: Loose block (=e in Fig. A; described in the present study) in front of the recent quarry wall. **C**: Bedding plane covered with sedimentary structures, including the scratch circle fragment; 62 cm long folding rule for scale.

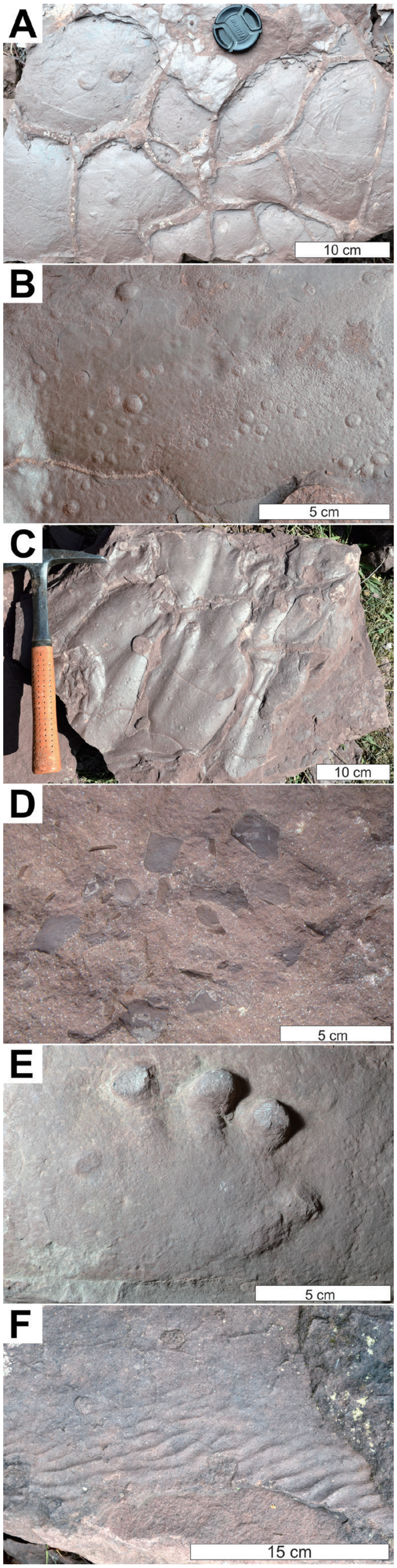

Fig. 2. Examples of observed sedimentary structures at the Bromacker (Thuringian Forest mountains, central Germany); all from the Tambach Sandstone Member (Tambach Formation, Rotliegend Group, Early Permian). **A**: Desiccation cracks. **B**: Raindrop marks. **C**: Scour marks. **D**: Intraformational rip-up clasts. **E**: tetrapod trace *Ichniotherium sphaerodactylum*. **F**: Ripples.

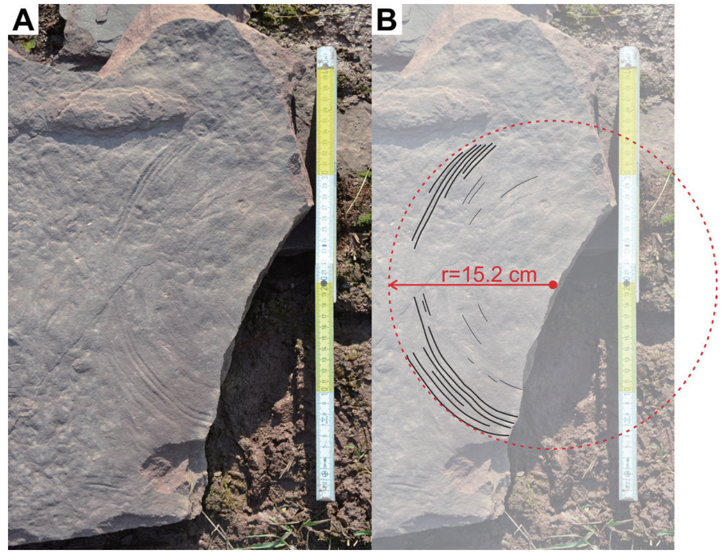

Fig. 3. Top side view on a red coloured, fine- to medium-grained sandstone slab from the Tambach Sandstone Member ("Bromacker Sandstone" horizon; Tambach Formation; Rotliegend Group); 42 cm folding rule as scale bar. **A**: Bedding plane showing the studied scratch circle fragment. **B**: Black line drawing highlighting the curved scratches; graphically reconstructed radius (r) of the full scratch circle.

Discussion

Although the scratch circle (Fig. 3A) was discovered *ex situ*, this slab can be assigned to the "Bromacker Sandstone" horizon (in the sense of Martens et al., 2009; a local informal stratigraphic unit), because this horizon is freshly exposed at the recent quarry base and it is typically composed of red coloured, predominantly fine- to medium-grained sandstones. According to literature, scratch circles are sediment marks, which are generated by the influences of both currents (i.e., water or wind) and gravity (e.g., Müller, 1983). In analogy to modern scratch circles, they are frequently generated by directed wind or water currents, when an axis of a plant is swivelling around is anchor point on a muddy or sandy surface; the swivel range of that plant can be preserved as scratches on the surrounding sediment (Müller, 1983). When the currents came from different directions, the generated scratch marks can be arranged elliptically to almost circularly.

The curved scratches described herein (Fig. 3) are interpreted as a scratch circle that was generated when a plant axis became moved by wind currents. The plant remained attached, most likely by its root, to the ground during the wind-driven movement of its axis. The graphically reconstructed full circle, fitting by its parallel alignment to these curved scratches (Fig. 3B), suggests that the formation of this scratch circle resulted from swivelling of a single plant. The measured radius of the reconstructed circle indicates a minimum plant size of 15.2 cm. Previously, plant remains (e.g., strobili of *Calamites gigas*, see Barthel and Rößler, 1994) had been found at the Bromacker; fossil plant roots were recorded in the Tambach Sandstone Member as well.

In comparison to other sedimentary structures known from Bromacker site-specific literature (e.g., Martens, 2007, 2022), this scratch circle (Fig. 3) appears to be unique. For example, it clearly differs from tetrapod scrape traces that are, in parts, helically arranged (Martens et al., 2009: therein plate 2-fig. 3) in the Tambach Sandstone Member. This tetrapod scrape trace corresponds to a certain type of ichnofossil, which had been previously designated as "*Megatambichnus*" (Martens, 2005). While both structures, the scratch circle (Fig. 3) and "*Megatambichnus*", occur at the Bromacker, the finds of "*Megatambichnus*" are much more frequent. In contrast, a rather straight sedimentary mark, showing an enigmatic kink, was reported recently by Scholze et al. (2022) from the Bromacker section. This mark was probably generated by an object that has been moved by water or wind currents.

Conclusion

By the author's present knowledge, the herein described specimen is the first find of a scratch circle from the Bromacker section (Tambach Formation, Early Permian). For a facies interpretation, a scenario is proposed as follows: (1) the observed circular scratches are result of a plant axis anchored at its base to a fixed position; (2) the top of the plant axis had been bent down, whereby wind currents let to a swivelling of the plant around its anchor point; (3) the movement of the plant axis on the sandy surface resulted in a formation of curved scratch marks. Changes of the palaeo-wind directions during the scratch circle formation might be inferred by its circular (non-linear) arrangement of the scratches. Plant axis or root remnants were not observed on the slab studied herein, indicating a low plant preservation potential. A more detailed publication of the sedimentary structure, determined herein as a scratch circle, is in progress (Scholze and Pint, accepted).

The photographic documentation of sedimentary structure occurrences at the Bromacker intends contributing to a digital storage of sedimentary fieldwork data, which had been obtained from an area that has repeatedly changed in its outcrop conditions during the past decades. In future studies, the new digital photograph collection of sedimentary structures could also become expanded to include field data from further surface outcrops of the Tambach Formation around Tambach-Dietharz (e.g., Scholze, 2022) in the Thuringian Forest Basin.

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The Pangaea Gap (Permian) in the Rotliegend of Central Europe

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The Rotliegend in Germany consists of continental sedimentary and volcanic rocks (German Stratigraphic Commission 1995, 2012). Reliable time indications are only found in its deepest and highest parts, the Early Rotliegend (≈ 300.5–295.5/294 Ma) and the Late Rotliegend (≈ 266–257.6 Ma), which are by far its thickest parts. The Middle Rotliegend is about twice as long as the Early and Late Rotliegend combined. It mainly consists of sedimentary "islands" ”within an enormous stratigraphic gap, or of a single very large stratigraphic gap lasting from ≈ 295.5/294 Ma to ≈ 266 Ma. This gap is called the Pangaea Gap (Menning et al. 2022, Fig. 1).

In the most important successions of the Rotliegend, the Saar-Nahe Basin (SW Germany) and the Thüringer Wald Basin (central Germany), time indications of the Early Rotliegend are concentrated in a time span of only 5–6.5 Ma (Glan, Gehren, Rennsteig subgroups). This revised numerical calibration is based on radio-isotopic U-Pb CA-ID-TIMS age determinations (Lützner et al. 2021, Voigt et al. 2022) and Rb-Sr age determinations of Lippolt and Hess (1989), the mean of which was recalculated by Menning et al. (2022) using the revised 87Rb decay constant of IUPAC-IUGS (Villa et al. 2016). The mean U-Pb SHRIMP age of volcanic rocks of the Rotliegend of the Central European Basin (Breitkreuz and Kennedy 1999; Altmark Subgroup), calculated for the first time, is 298.6 ± 1.9 Ma. On this basis, the Rotliegend there starts at ≈ 300.5 Ma. At the same time, the Rotliegend in the Thüringer Wald Basin also starts in the Pennsylvanian (Menning et al. 2022).

The upper part of the more than 1,700 m thick sedimentary Rotliegend of the Central European Basin (Southern Permian Basin) is numerically calibrated using the Illawarra Reversal of the Earth's magnetic field (Menning et al. 1988, Menning 1995: ≈ 265 Ma) and 14 long eccentricity cycles with a duration of ≈ 0.4 Ma each, resulting in a duration of ≈ 5.6 Ma for the Elbe Subgroup (latest Rotliegend) (Gast 2010). Only in the Central European Basin is the Late Rotliegend (Havel and Elbe subgroups) fully developed. In many other sections only the highest part of the Late Rotliegend is present, or it is completely absent there.

The Middle Rotliegend includes the Nahe Subgroup (Donnersberg, Standenbühl and Kreuznach formations) in the Saar-Nahe Basin, the Leina Subgroup (Tambach and Eisenach formations) in the Thüringer Wald Basin and most of the Müritz Subgroup in the Central European Basin (Menning et al. 2022: fig. 25). The successions are rich in stratigraphic gaps, especially in the time span ≈280–266 Ma, in which there is even a widespread gap in almost all Rotliegend successions. This is supported by conchostracans, the Illawarra Reversal and the significantly different palaeomagnetic properties of the sedimentary rocks below and above the gap (Menning et al. 1988, Langereis et al. 2010), which are discussed extensively for the first time in Menning et al. (2022).

The huge Pangaea Gap could be related to the progressive amalgamation of the supercontinent Pangaea. A first indication of this is the trend towards aridisation that started in the Pennsylvanian and accelerated in the Early Permian (Roscher and Schneider 2006, Schneider et al. 2006, Michel et al. 2015), which is probably related to the northward drift of Euramerica and a progressive uplift of central eastern Pangaea. This significant large-scale uplift is documented in the STG 2002 and the STG 2016 (Stratigraphic Table of Germany 2002, 2016). In this context, Menning and Steininger (2005) already noted that Central Europe has not seen any marine transgressions for more than 50 Ma - unique for this area during the Phanerozoic. This period extended from the last marine flooding of the Variscan foredeep, the Aegir Horizon in Westphalian C (Bolsovian), to the marine Zechstein ingression in the latest Rotliegend of the Central European Basin (≈ 311–258 Ma). This huge Pennsylvanian regression probably resulted from the heating and long-lasting uplift of the crust of Central Europe. It resulted in widespread denudation and a large stratigraphic gap or the formation of only single small sediment islands due to local

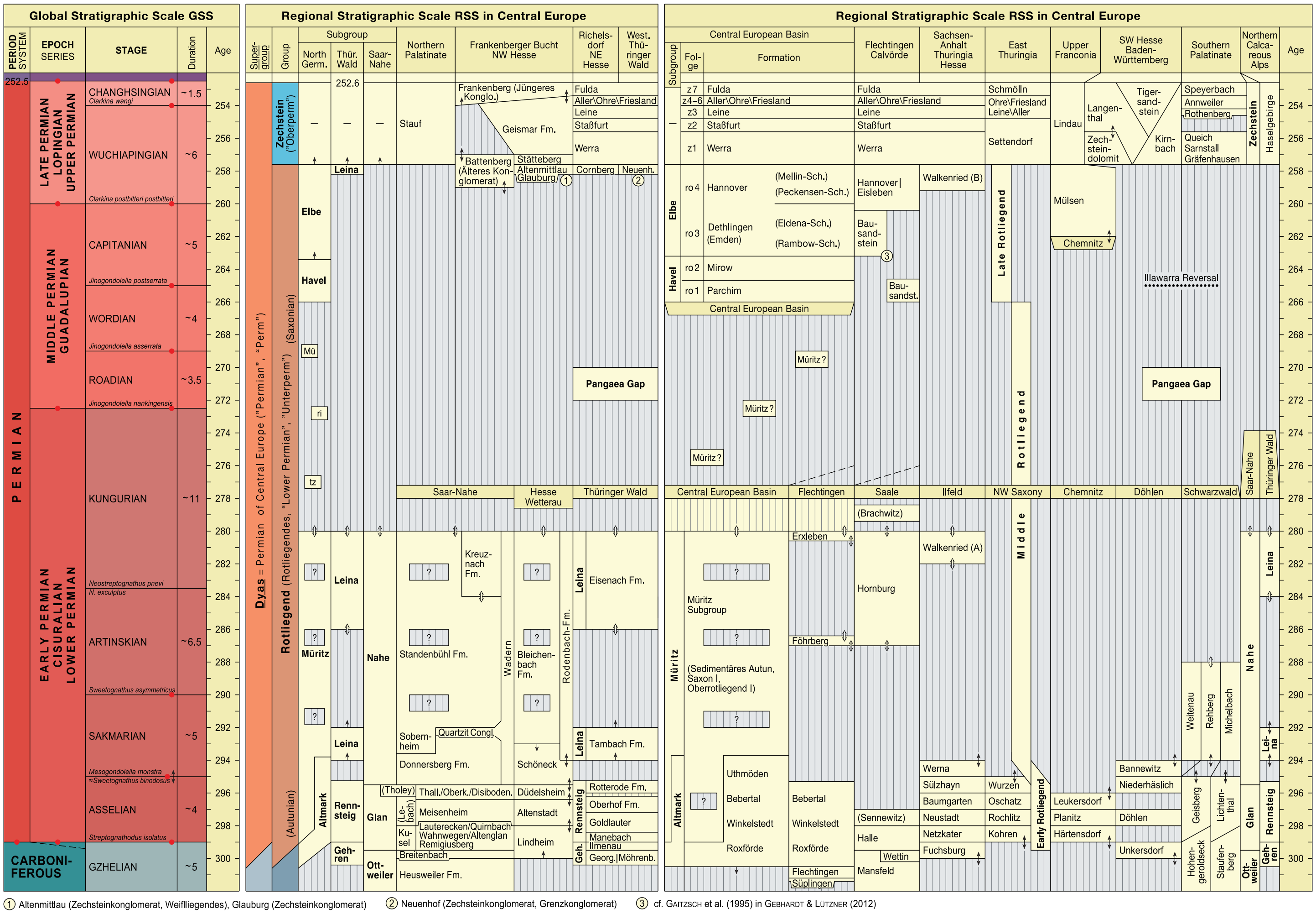

Fig. 1 Stratigraphic chart of the Dyas (Rotliegend and Zechstein, the "Permian of Germany") (from Menning et al. 2022, Fig. 25, left part).

redepositions. Protracted slow cooling led to thermal subsidence, and combined with intra-plate tectonics to the formation of the Central European Basin and smaller sedimentary areas.

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The Permian-Triassic boundary in Northern Patagonia (Argentina): eochronological and palaeontological issues of the Los Menucos Basin

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Introduction

In the last five years, a profound revision of the stratigraphy and geochronology of northern Patagonia has been carried out. The volcanic and sedimentary succession of the Los Menucos Basin has become the focus of paleontological and geochronological studies to determine and correlate the Permian-Triassic boundary in Argentina. Luppo et al. (2018) have initially proposed a correlative of the P-T boundary (Fig. 1) within a 6 km thick concordant volcanic and sedimentary succession, which was dated between 257 ± 2 and 248 ± 2 Ma (SHRIMP U-Pb in zircon). More recently, Falco et al. (2020, 2022a, 2022b) revised the volcanic and sedimentary stratigraphy of the same succession, proposing the existence of a low angle unconformity between the volcanic and sedimentary beds. With this unconformity in mind, a novel stratigraphic scheme for the Los Menucos Group was proposed, in which the P-T boundary is expected to be found within the succession because it was constrained between 253 ± 3 (LAICMPS U-Pb in zircon) and 250 ± 2 Ma (see further details in Falco et al., 2020, 2022b).

Sedimentology

The Los Menucos Group, *sensu* Falco et al. (2020), is divided into the Puesto Tscherig, Puesto Vera and Sierra Colorada formations. The Puesto Tscherig Formation (PTF) is up to 70 m thick at its type locality and two members are recognizable. The lower member, the Cerro La Laja Member, is dominated by sandstone, mudstone, conglomerate, and breccias resulting from

Figure 1. Barrancas Grandes Member of the Puesto Tscherig Formation, in which the Permian-Triassic boundary are located according to Bodnar et al. (2021).

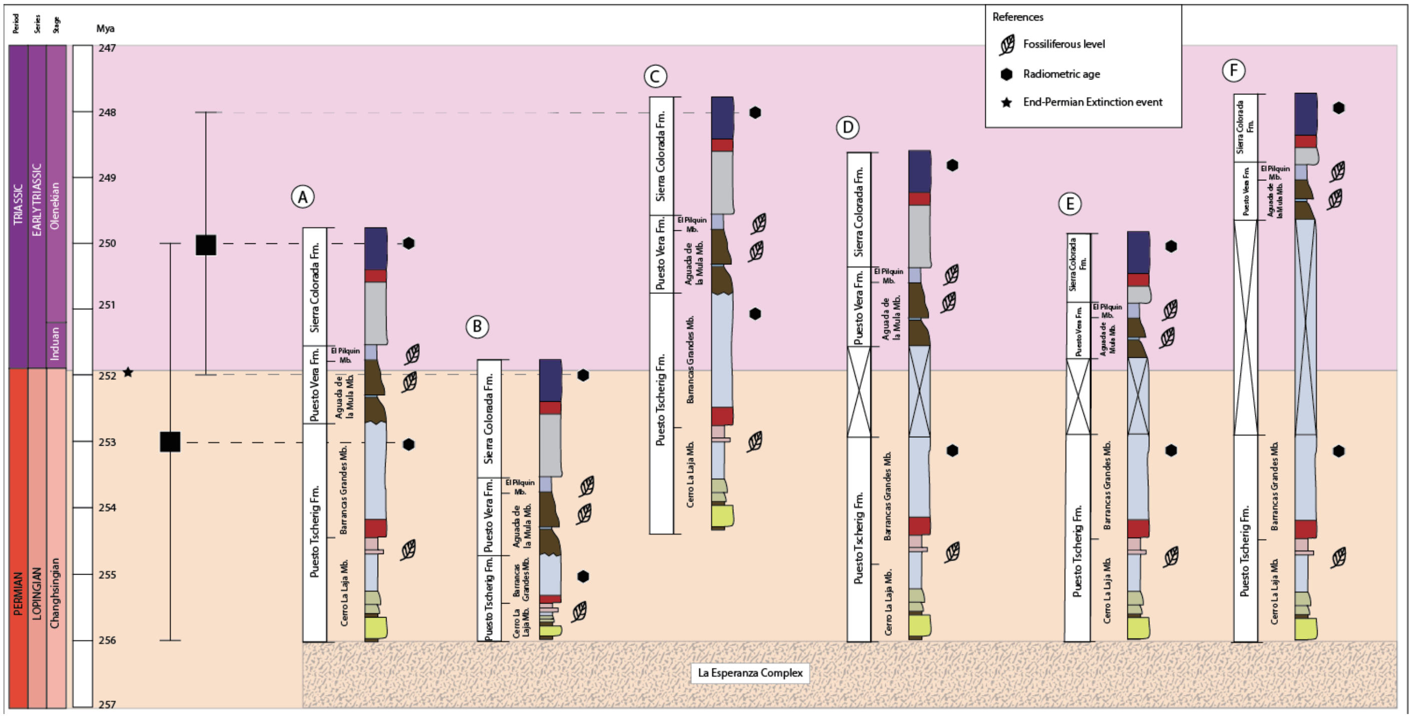

Fig. 2. Simplified figure of how the known geochronological dates of the sedimentary column and the error of the methods used can affect the comparisons and interpretation of the timing of the recovered flora. The older and youngest age hypothesis are related to the age obtained from the Sierra Colorada Fm. The basin overlies the La Esperanza Complex, an ignimbrite whose age is constrained between c. 257 Ma at the bottom (sample M265 in Luppo et al. 2018) and c. 256 Ma at the top (Falco et al., 2022b), so the Los Menucos Group deposition started as older as the top age.

the reworking of unconsolidated pyroclastic deposits. While debris flows dominate the proximal zones, distal sectors are characterized by deposition in ephemeral swamps. The upper part of the Puesto Tscherig Formation, named the Barrancas Grandes Member, is composed of a dacitic ignimbrite deposit (with an age of 253 ± 3 Ma at its type locality).

The overlying Puesto Vera Formation (PVF) is up to 20 m thick and has been divided into the Aguada de la Mula and El Pilquin members. The lower Aguada de la Mula Member is dominated by gravelly sandstone, medium to fine sandstone, and mudstone, deposited in fluvial channels and on floodplains affected by volcanism. The upper El Pilquin Member is exclusively composed of ash fall deposits.

The Sierra Colorada Formation is composed of three ignimbrite pulses that reach up to 80 m thick, of which the upper two pulses are well developed throughout the basin (with an age of 250 ± 2 Ma at the Puesto Tscherig locality).

Regarding the Puesto Tscherig type locality, in which the three formations of the Los Menucos Group were recognized (Fig. 2), latest geochronological and palaeontological latest results suggest that it could represent the P-T transition (Fig. 2A, as in Bodnar et al., 2021). The 253 ± 3 Ma age obtained for the ignimbrite of the Barrancas Grandes Member (Fig. 1) and the 250 ± 2 Ma age for the ignimbrite of the Sierra Colorada Formation in the Puesto Tscherig locality, together with the palaeontological record, suggest that the P-T boundary (placed at 251.902 ± 0.024 Ma) should be in this succession. The Cerro La Laja Member (PTF) is Chansinghian in age, and the Barrancas Grandes Member could include the P-T Boundary. Given the known ages and errors from the locality and the basin, El Pilquín Member of the Puesto Vera Formation could encompass the P-T boundary or the Early Triassic.

Palaeontology

Abundant fossil flora, and fauna have been recovered from both the Cerro la Laja Member of the Puesto Tscherig Formation, and the Puesto Vera Formation (Fig. 3).

The Cerro La Laja Member of the Puesto Tscherig Formation bears a diverse fossil plant assemblage that was described by Artabe (1985a, b) and revised by Bodnar et al. (2021). It is composed of *Ctenis japonica* (Cycadales), *Ginkgoites* (=*Ginkgo*) *digitata*, *Gontriglossa moribunda* (Gnetales), *Heidiphyllum elongatum* (Voltziales), *Lepidopteris madagascariensis*, *Moltenia wardii*, *Pachydermophyllum praecordillerae* (Peltaspermales), *Pseudoctenis grandifolia*, *P. spectabilis*, *P. capensis*, *Pterophyllum inconstans* (Bennettitales), *Rhipidopsis densinervis* (Ginkgoales), *Sphenobaiera stormbergensis*, *S. argentinae*, *Taeniopteris lata*, *T. magnifolia*, *T. crassinervis*, *T. wianamattae*, *T. lentriculiformis*, *T. vittata* (Cycadales or Bennettitales), and *Zuberia sahnii* (Umkomasiales=Corystospermales). According to the radiometric dating, this would be restricted to the latest Permian. Although this assemblage is different from other Lopingian taphofloras of Argentina, it has various taxa in common with the Lopingian palaeoflora from the Umm Irna Formation (Dead Sea, Jordan; Blomenkemper et al. 2018). The Puesto Tscherig Formation vegetation was exclusively composed of seed plants, most of which are considered as xeromorphic (Bodnar et al., 2021, and references therein), that would have allowed them to live in

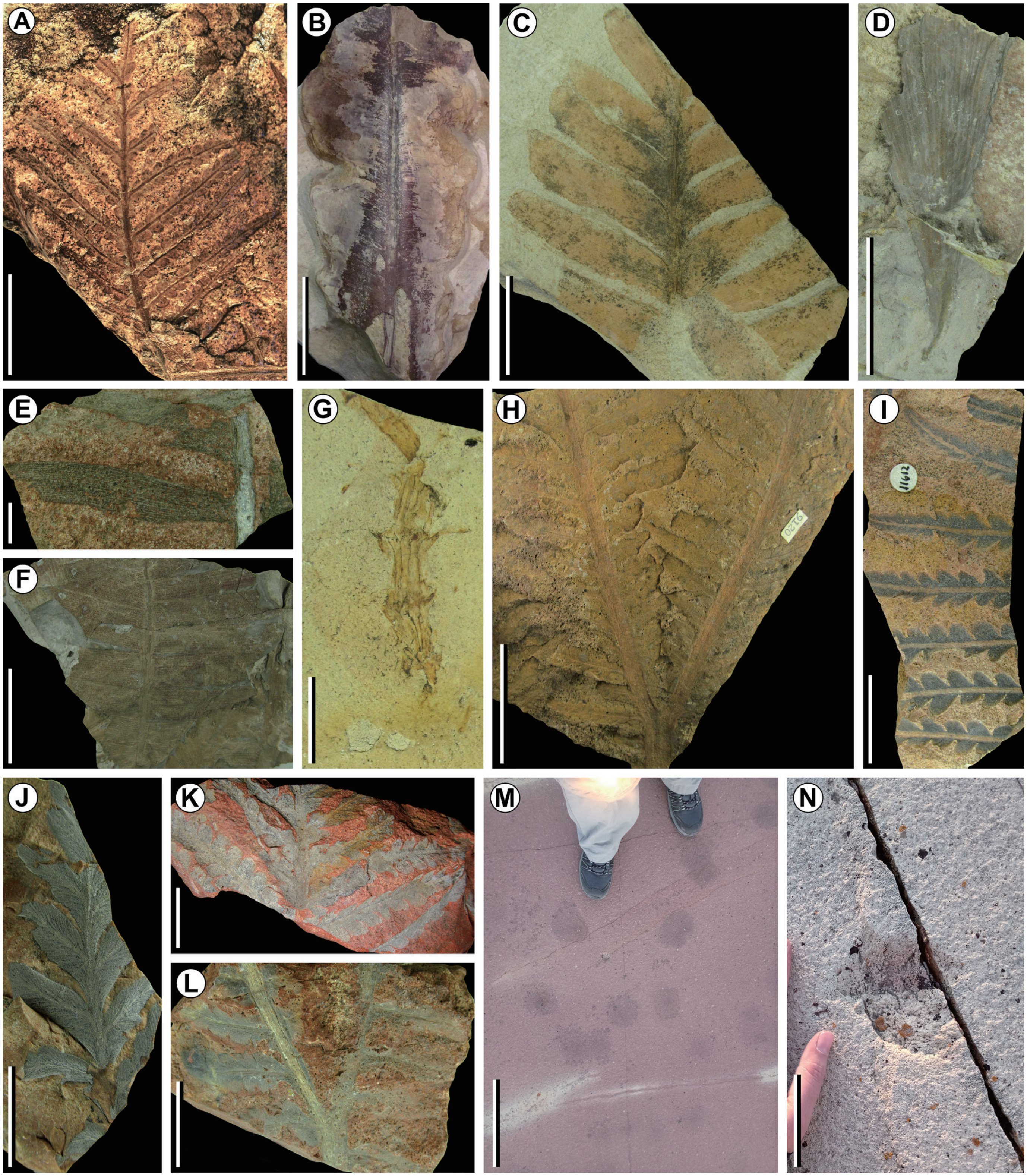

Fig. 3. Fossiliferous content of the Los Menucos Group. **A-F**. Fossil flora of the Cerro La Laja Member of the Puesto Tscherig Formation. **A**. *Zuberia sahnii* (leaf of Umkomasiales). Scale bar= 5 cm. **B**. *Taeniopteris lata* (leaf of Cycadales or Bennettitales). Scale bar= 6 cm. **C**. *Moltenia wardii* (leaf of Cycadales). Scale bar= 4cm. **D**. *Rhipidopsis densinervis* (leaf of Ginkgoales). Scale bar= 3 cm. **E**. *Pseudoctenis capensis* (leaf of Cycadales). Scale bar= 1 cm. **F**. *Pterophyllum inconstans* (Bennettitales). Scale bar= 2 cm. **G-L**. Fossil flora of the El Pilquín Member of the Puesto Vera Formation. **G**. *Phyllotheca australis* (stem of Equisetales). Scale bar = 1 cm; **H**. *Zuberia sahnii* (leaf of Umkomasiales). Scale bar= 4 cm. **I**. Z. *feistmantelii* (leaf of Umkomasiales). Scale bar= 4 cm. **J**. *Dicroidium incisum* (leaf of Umkomasiales). Scale bar= 4 cm. **K**. *Z. papillata* (leaf of Umkomasiales). Scale bar= 3 cm. **L**. *D. dubium* (leaf of Umkomasiales). Scale bar= 3 cm. **M-N**. Tetrapod tracks of the Cerro La Laja Member of the Puesto Tscherig. **M**. *Dicynodontipus*-like track. Scale bars= 30. **N**. detail of a *Dicynodontipus*-like footprint. Scale bar= 3 cm.

stress-related environments and arid circumstances caused by the active volcanism of that time in the area.

The Puesto Vera Formation paleoflora is constituted by *Dicroidium dubium*, *D. incisum*, *Equisetites fertilis*, *Phyllotheca australis*, *Pseudoctenis spathulata*, *Pteruchus barrealensis*, *Zuberia feistmantelii*, *Z. brownii*, *Z. zuberi*, *Z. sahnii*, *Z. papillata*, and undetermined gymnosperm woods (Artabe, 1985a,b; Bodnar et al., 2021; Falco et al., 2020). A diversification of corystosperms occurs in the Puesto Vera Formation. Unlike the Puesto Tsherig Formation paleocommunity, the arboreal and shrubby corystosperms are here dominant, while cycads are subordinate. The Puesto Vera Formation exhibits species considered as indicative of the Early Triassic-Anisian interval (Retallack, 1977; Bodnar et al., 2021).

The fossil faunas are not as diverse as the fossil floras. In the Cerro La Laja Member of the Puesto Tscherig Formation and in the Puesto Vera Formation, one species of fossil spinicaudata (Gallego 2010), abundant tetrapod tracks (Diaz-Martinez & De Valais 2014), and remains of an amiiform fish (Bogan et al. 2013) were found. Casamiquela (1964) indicated that the tetrapod fauna from Los Menucos is younger than the Late Triassic and older than the Late Jurassic. Gallego (2010) proposed an early Late Triassic age based on the clam shrimp *Menucoestheria wichmanni*. More recently, Citton et al. (2021) suggested a Lopingian-Early Triassic age for the *Dicynodontipus*-dominated record of the Puesto Tscherig and Puesto Vera Formations based on the global record of that genus. This is broadly consistent with the age obtained by radiometric methods.

In summary, the Los Menucos Group includes a Changhsinghian paleoflora without *Glossopteris*, the Permian-Triassic boundary, and a biota that developed probably during or after the end-Permian crisis, but for the moment appears to be without the record of a *Pleuromeia* flora, which was very conspicuous in the Early Triassic world. A palynoflora with elements of the *Pleuromeia* flora was recently recorded in La Veteada Formation (Gutiérrez et al., 2018) but the age is disputed between the Late Permian and the Olenekian (Césari et al., 2022). Therefore, the data gaps still need to be filled, by finding more fossiliferous levels, calculating deposition rates of sedimentary sequences, and especially by dating with lower error methods. The ultimate objective is to know exactly where we are in the events related to the end Permian extinction and to propose high-resolution evolution models for Southwestern Gondwana.

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Late Early Permian timescale correlations between International scale and Tethyan scale: new evidence from the Lugu Formation in the South Qiangtang Block, Tibet

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Introduction

During the Permian time, conodonts, fusulines, ammonites, brachiopods, radiolarians, and corals all have more or less biostratigraphic significance (e.g., Henderson, 2018; Zhang and Wang, 2018; Shen et al., 2019). Of these marine groups, conodonts and fusulines are two major taxa in Permian biostratigraphy and chronostratigraphy. The conodont biostratigraphy has been widely acknowledged by ICS to represent the International Permian Timescale, in which the Permian timescale has been divided into Asselian, Sakmarian, Artinskian, Kungurian, Roadian, Wordian, Capitanian, Wuchiapingian and Changhsingian (Jin et al., 1997). By contrast, Tethyan Permian timescale was established based on the evolution of fusulines (Leven, 2003). In this scale, the Permian was gradually divided into Asselian, Sakmarian, Yakhtashian, Bolorian, Kubergandian, Murgabian, Midian, Dzhulfian and Dorashamian in past decades. Both scales were all widely applied and cited in the Permian community.

The correlations between the conodont-based chronostratigraphy and fusuline-based chronostratigraphy were a contentious issue because conodonts did not always coexist with fusulines that makes a direct correlation difficult. For example, late Cisuralian and early Guadalupian chronostratigraphic correlations between the International and Tethyan scales have been differently interpreted (Table 1). Jin et al. (1997) proposed that Kungurian stage is correlative with the Bolorian stage. However, the discovery of fusulines *Neoschwagerina simplex* and *Praesumatrina neoschwagerinoides* within the conodonts *Mesogondolella siciliensis-Sweetognathus subsymmetricus* zone in the Luodian Section in South China suggests that the base of the Murgabian stage was in the Kungurian stage (Henderson and Mei, 2003). This correlation was not widely accepted in the later correlations (e.g., Gaillot and Vachard, 2007; Leven and Gorgij, 2011). Another study from the Hatahoko, Japan confirmed again the coexistence of Kungurian conodonts and Murgabian *Neoschwagerina simplex* fusuline fauna (Shen et al., 2012; Ueno et al., 2006). However, it was not fully accepted by Permian experts (e.g., Gaetani and Leven, 2014; Nejad et al., 2015; Angiolini et al., 2015, 2016). In this contribution, we will report a fauna consisting of both conodonts and fusulines from the South Qiangtang Block (SQB), Tibet. The description of this fauna has been published in the journal *Palaeogeography, Palaeoclimatology, Palaeoecology* but focused on the paleobiogeographic significance of the fauna in that paper (Yuan et al., 2022). Here, we will highlight the correlations between the International and Tethyan scales.

Geological background

The South Qiangtang Block lies between the Bangong-Nujiang suture zones in the south and the Longmu Co-Shuanghu suture zone in the north (Fig. 1). The Permian in the South Qiangtang Block is very complex and composed of two different sequences

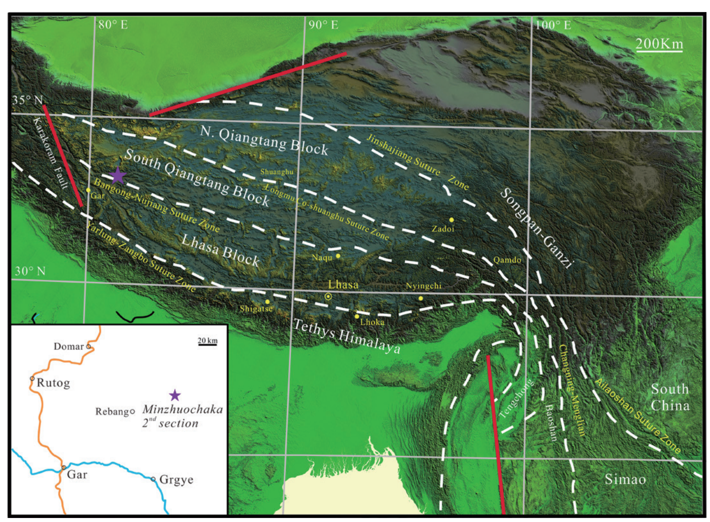

Fig. 1. The tectonic subdivisions of the Qinghai-Tibetan Plateau with the locality of the studied section.

Table 1. Correlations between the international and Tethyan Permian timescales around the studied interval

<table>
<tr><th rowspan="2">International scale</th><th colspan="9">Tethyan scale</th></tr>
<tr><th>Jin et al., 1997</th><th>Henderson and Mei, 2003</th><th>Gaillot and Vachard, 2007</th><th>Leven and Gorgij, 2011</th><th>Nejad et al., 2015</th><th>Angiolini et al., 2015</th><th>Angiolini et al., 2016</th><th>Zhang and Wang, 2018</th><th>This study</th></tr>
<tr><td rowspan="1">Capitanian</td><td rowspan="1">Midian</td><td rowspan="4">Midian</td><td rowspan="2">Midian</td><td rowspan="2">Midian
?</td><td rowspan="1">Midian</td><td rowspan="1">Midian</td><td rowspan="1">Not avilable</td><td rowspan="2">Midian</td><td rowspan="2">Not avilable</td></tr>
<tr><td rowspan="2">Wordian</td><td rowspan="2">Murgabian</td><td rowspan="3">Murgabian</td><td rowspan="3">Murgabian</td><td rowspan="3">Murgabian</td></tr>
<tr><td rowspan="1">Murgabian</td><td rowspan="2">Murgabian
?</td><td rowspan="4">Murgabian</td><td rowspan="4">Murgabian</td></tr>
<tr><td rowspan="2">Roadian</td><td rowspan="2">Kubergandian</td><td rowspan="2">Kubergandian</td></tr>
<tr><td rowspan="2">Murgabian</td><td rowspan="3">Kubergandian
?</td><td rowspan="1">Kubergandian</td><td rowspan="2">Kubergandian</td><td rowspan="2">Kubergandian</td></tr>
<tr><td rowspan="4">Kungurian</td><td rowspan="4">Bolorian</td><td rowspan="4">Bolorian</td><td rowspan="4">Bolorian</td></tr>
<tr><td rowspan="2">Kubergandian</td><td rowspan="3">Bolorian</td><td rowspan="3">Bolorian</td><td rowspan="2">Kubergandian</td><td rowspan="2">Kubergandian</td></tr>
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</table>

(Zhang et al., 2019). In the western part of the SQB, the Upper Permian Jipuria Group overlies unconformably on the Lower Permian Tunlonggongba Formation. By contrast, in the eastern part of the block, the Permian sequence is mostly composed of layers of basalts and limestones, which were named the Lugu Formation. Previously, diverse Kungurian and Roadian fusulines and brachiopods have been documented from the Shuanghu area in the central part of the SQB (Zhang et al., 2012, 2014; Shen et al., 2016). The conodonts and fusulines reported in this paper were collected from the Minzhuochaka area, which is located about 130 km east of the Bangong Lake. The Permian sequence from this area is also dominated by the basalt layers in the lower part and limestone layers in the upper part. The conodonts and fusulines were collected from the lower part of the limestones.

Conodont and fusuline compositions and correlations between International and Tethyan Permian scales

The conodonts from the limestones yield *Sweetognathus guizhouensis*, *S. qiangtangensis*, *Sweetognathus* sp., *Mesogondolella qiangtangensis* and *M. siciliensis* (Fig. 2). These conodonts together suggest a late Kungurian age (Yuan et al., 2022). The coexisting fusulines include *Armenina asiatica*, *Cancellina* sp., *Neoschwagerina simplex* and *Pseudodoliolina ozawa minima* (Fig. 3). *Neoschwagerina simplex* belongs to the primitive species of *Neoschwagerina* (Zhang and Wang, 2018). The advent of this species was considered as an index species to mark the base of the Murgabian stage (Leven, 2004). It should be noteworthy that this species can also range up to the late Middle Permian (e.g., Zhang et al., 2009). But current fauna is not possible late Guadalupian because of the presence of *Cancellina* species. The fauna overall indicates a Murgabian age.

The coexistence of both conodonts and fusulines in the Minzhuochaka area in the SQB demonstrates again that the Murgabian fusulines occur together with upper Kungurian conodonts. This correlation is similar to the faunas in the Luodian in South China and in Hatahoko, Japan. The coexistence of fusulines and conodonts in different areas in the Tethyan region confirm that the base of the Murgabian stage correlate with the upper part of the Kungurian stage.

Fig. 2. Conodonts from the Lugu Formation in the Minzhuochaka 2nd section. **1.** *Sweetognathus* sp., from Sample MZCK2-17; **2.** *Sweetognathus guizhouensis,* from Sample MZCK2-11; **3.** *Sweetognathus subsymmericus,* from Sample MZCK2-8; **4, 5.** *Mesogondolella qiangtangensis*, from Sample MZCK2-15; **6, 7.** *Mesogondolella siciliensis*, **6** from Sample MZCK2-15, **7** from Sample MZCK2-17.

Perspective of the Kungurian stage

The Kungurian stage is the longest stage in Permian chronostratigraphy, which has a duration over than 10 Ma (Shen et al., 2019, 2020). Also, this stage is a significant interval as

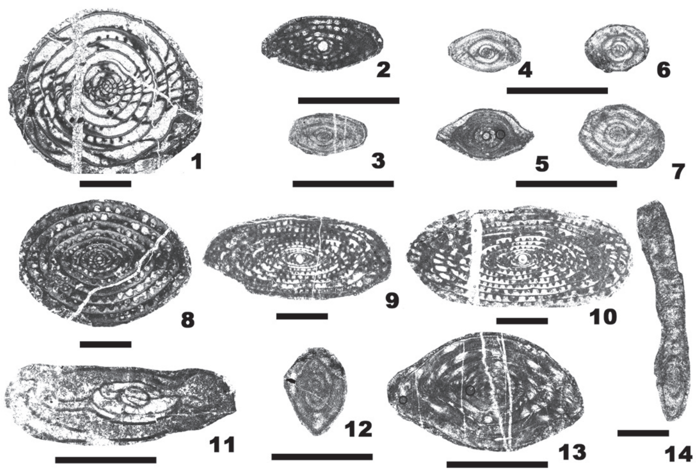

Fig. 3. Fusulines from the Lugu Formation in the Minzhuochaka 2nd section. **1.** *Armenina asiatica* Leven, from Sample MZCK2-F7-C(4), subaxial section; **2.** *Cancellina* sp., from Sample MZCK2-F7-C(2), axial section; **3, 4.** *Mesoschubertella* sp. 3 from Sample MZCK2-F6-C(1), subaxial section; 4 from Sample MZCK2-F6-I(4), axial section; **5-7.** *Mesoschubertella thompsoni* Kanuma and Sakagami, 5 from Sample MZCK2-F2-B(4), axial section; 6 from Sample MZCK2-F6-E(1), subaxial section; 7 from Sample MZCK2-F7-N(2), subaxial section; **8.** *Neoschwagerina simplex* Ozawa, from Sample MZCK2-F7-A(3), axial section.; **9,10.** *Pseudodoliolina ozawai minima* Miklukho-Maklay, 9 from Sample MZCK2-F7-N(1), axial section; 10 from Sample MZCK2-F1-K(4), axial section; **11.** *Toriyamaia* cf. *laxiseptata* Kanmera, from Sample MZCK2-F12-K(4), oblique section. 12, *Nankinella* sp., from Sample MZCK2-F1-L(1), axial section. 13, *Yangchienia tobleri* Thompson, from Sample MZCK2-F4-P(1), axial section. 14. *Pseudoreichelina* cf. *discoidea* Ueno, from Sample MZCK2-F12-C(5), subaxial section. The scale bar is 1mm.

characterized by the pronounced climatic change from icehouse condition to greenhouse condition accompanied by widespread sea-level rise (e.g., Chen et al., 2013; Liu et al., 2017). After the ratification of all GSSPs of Permian by SPS and ICS, more attention should be paid on the internal classification of the Kungurian stage. Considering that the fusulines *Neoschwagerina simplex* zone can be found in the upper part of the Kungurian stage, the Kungurian stage may contain many fusuline zones such as *Misellina* (*Bravaxina*) *dyhrenfurthi*, *Misellina termieri*, *M.claudiae*, *Shengella simplex*, *Maklaya elliptica*, *Cancellina liuzhiensis* and *Neoschwagerina simplex* (Zhang and Wang, 2018). The rapid evolution of fusulines may assist in the subdivision of the Kungurian stage. Considering the coexistence of conodonts and fusulines in the SQB, South China and Japan during the Late Kungurian time, a more precise correlation is anticipated with respect to the correlations between base-Kubergandian, base-Bolorian and Kugurian or possible Artinskian stages.

Acknowledgements

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Report on the activities of the Carboniferous – Permian –Triassic Nonmarine-Marine Correlation Working Group for 2021 to 2022

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The two years before 2022 were marked worldwide by the corona pandemic with restrictions on fieldwork at home and abroad, and with limited personal communication and restricted access to fossil and rock collections. Nevertheless, fieldwork in our respective home countries was possible, and we had time to work up and publish the results and findings from fieldwork often done long ago. Moving up through the geological timescale, some of these publications and results of field work of the last year will be reported in the following to demonstrate and publicize progress of our working group.

Carboniferous

As already announced in the last report of Schneider et al. (2021a), the Geological Society, London, has published in 2022 two volumes (altogether 1016 pages) titled "The Carboniferous Timescale", Special Publication 512, co-edited by Spencer G. Lucas, Joerg W. Schneider, Xiangdong Wang and Svetlana Nikolaeva. In 20, partly multi-authored articles the latest state of the art in all fields of Carboniferous stratigraphy is reported starting with a chapter on Carboniferous Chronostratigraphy (Fig. 1), followed by chapters on Magnetostratigraphy, Isotope Stratigraphy, Cyclostratigraphy, Marine biostratigraphy, and Non-marine biostratigraphy as shown below:

Lucas, S. G., Schneider, J. W., Nikolaeva, S. & Wang, X.: The Carboniferous timescale: an introduction

Lucas, S. G., Schneider, J. W., Nikolaeva, S. & Wang, X.: The Carboniferous chronostratigraphic scale: history, status and prospectus

Alekseev, A. S., Nikolaeva, S. V., Goreva, N. V., Donova, N. B., Kossovaya, O. L., Kulagina, E. I., Kurilenko, A. V., Kutygin, R. V., Popeko, L. I. & Stepanova, T.: Russian regional Carboniferous stratigraphy.

González, C. R. & Díaz Saravia, P.: Proposed chronostratigraphic units for the Carboniferous and early Permian of the southwestern Gondwana margin.

Chen, J., Chen, B. & Isabel P. Montañez, I. P.: Carboniferous isotope stratigraphy.

Hounslow, M. W.: A geomagnetic polarity timescale for the Carboniferous.

Montañez, I. P.: Current synthesis of the penultimate icehouse and its imprint on the Upper Devonian through Permian stratigraphic record.

Vachard, D. & Le Coze, F.: Carboniferous smaller Foraminifera: convergences and divergences.

Ueno, K.: Carboniferous fusulines: taxonomy, regional biostratigraphy, and paleobiogeographic faunal development.

Angiolini, L., Cisterna, G. A., Mottequin, B., Shen, S. Z. & Muttoni, G.: Global Carboniferous brachiopod biostratigraphy.

Ausich, W. I., Kammer, T. W. & Mirantsev, G. V.: Carboniferous crinoids.

Wang, X., Yang, S., Yao, L., Sugiyama, T. & Hu, K.: Carboniferous biostratigraphy of rugose corals.

Amler, M. R. W. & Silantiev, V. V.: A global review of Carboniferous marine and non-marine bivalve biostratigraphy.

Nikolaeva, S. V.: Carboniferous ammonoid genozones.

Barrick, J. E., Alekseev, A. S., Blanco-Ferrera, S., Goreva, N. V., Hu, K., Lambert, L. L., Nemyrovska, T. I., Qi, Y., Ritter, S. M. & Sanz-López, J.: Carboniferous conodont biostratigraphy.

Ginter, M.: The biostratigraphy of Carboniferous chondrichthyans.

Eble, C. F.: Appalachian coal bed palynofloras: changes in composition through time and comparison with other areas.

Opluštil, S., Cleal, C. J., Wang, J. & Wan, M.: Carboniferous macrofloral biostratigraphy: an overview.

Schneider, J. W., Scholze, F., Ross, A. J., Blake, B. M. Jr. & Lucas, S. G.: Improved blattoid insect and conchostracan zonation for the late Carboniferous, Pennsylvanian, of Euramerica.

Lucas, S. G., Stimson, M. R., King, O. A., Calder, J. H., Mansky, C. F., Hebert, B. L. & Hunt, A. P.: Carboniferous tetrapod footprint biostratigraphy, biochronology and evolutionary events.

Lucas, S. G.: Carboniferous tetrapod biostratigraphy, biochronology and evolutionary events.

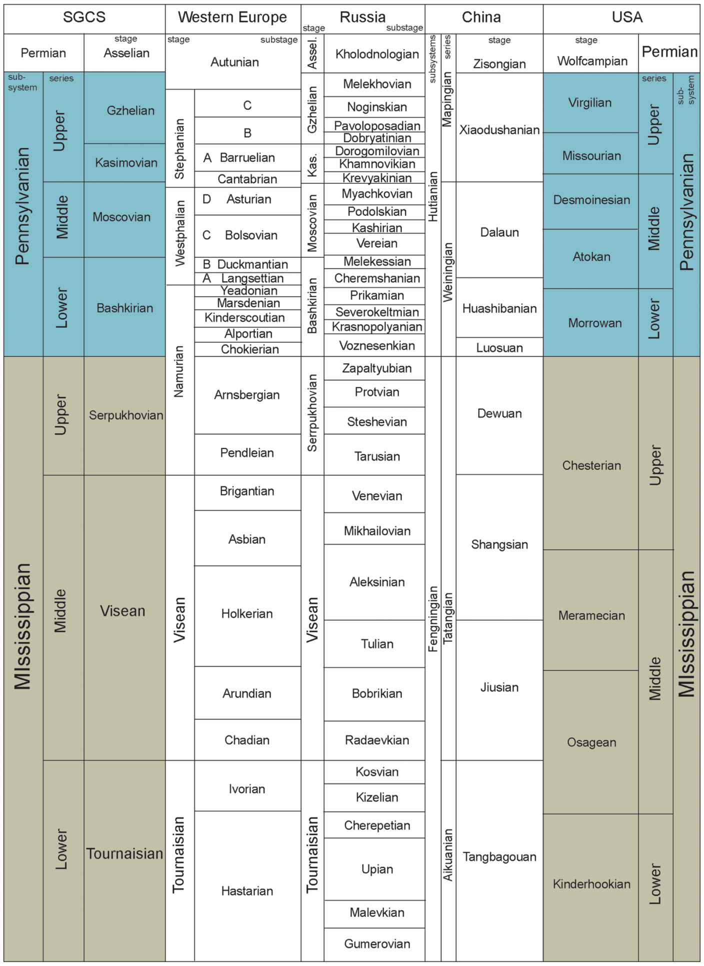

Fig. 1. Regional Carboniferous chronostratigraphic scales (modified from Davydov et al. 2012 and Wang et al. 2019). From Lucas et al. (2022a); for the references see there.

Further information are available under the link https://www.lyellcollection.org/toc/sp/512/1

Not of biostratigraphic interest but of importance for understanding Pennsylvanian terrestrial ecosystems is the discovery of a giant *Arthropleura* of reconstructed 2.6 m length in life, reported by Davies et al. (2021) from the UK (Fig. 2). Viewed in the context of all the other global reports for this largest terrestrial arthropod in Earth history, the dataset shows a palaeogeographical range restricted to the equatorial region of Euramerica, and that the animal achieved gigantism prior to late Palaeozoic peaks in atmospheric oxygen, and that it was relatively unaffected by climatic events in the Pennsylvanian, but went extinct most possibly because of the disappearance of its preferred habitat, the riparian forests along perennial rivers, during increasing aridisation in the Early Permian.

Permian

The team of Shuzhong Shen from China (Shen et al. 2022) delivered a very detailed Carboniferous and Permian integrative stratigraphy and timescale of the North China Block (Fig. 3). The North China Block experienced a long erosional history after the Middle Ordovician uplift, then accepted deposits again in the Middle Pennsylvanian. The Carboniferous and Permian systems in the North China Block (NCB) consist of the Penchi, Taiyuan, Shansi, Lower Shihhotse, Upper Shihhotse and Sunjiagou formations, in ascending order, of which the Upper Carboniferous and lower Cisuralian contain the most important coal- and gas-bearing strata. This is generally comparable with the widespread coal-bearing strata in Europe from the Upper Pennsylvanian to the lower Cisuralian. The Upper Carboniferous and lowest Cisuralian strata are mainly marine and marine/non-marine alternating deposits and contain abundant conodont and fusuline fossils, so they are relatively well correlated with the equivalents

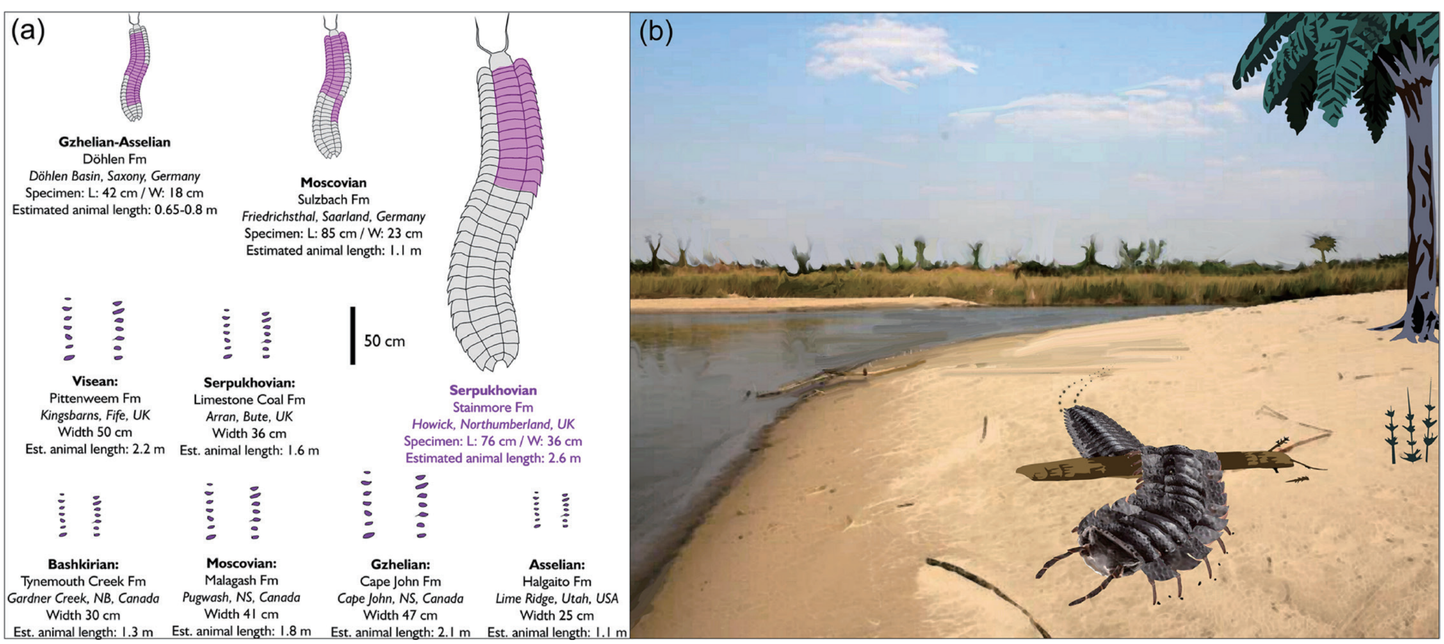

Fig. 2. Body remains and tracks of the largest terrestrial arthropod in the history of the earth – *Arthropleura*. **(a)** Best preserved body remains and calculations of the natural size of the animal as well as calculations of the length of the animal based on tracks. **(b)** Live reconstruction of *Arthropleura* in the preferred habitat, the riparian forests along river courses. Compiled from Davis et al. (2021).

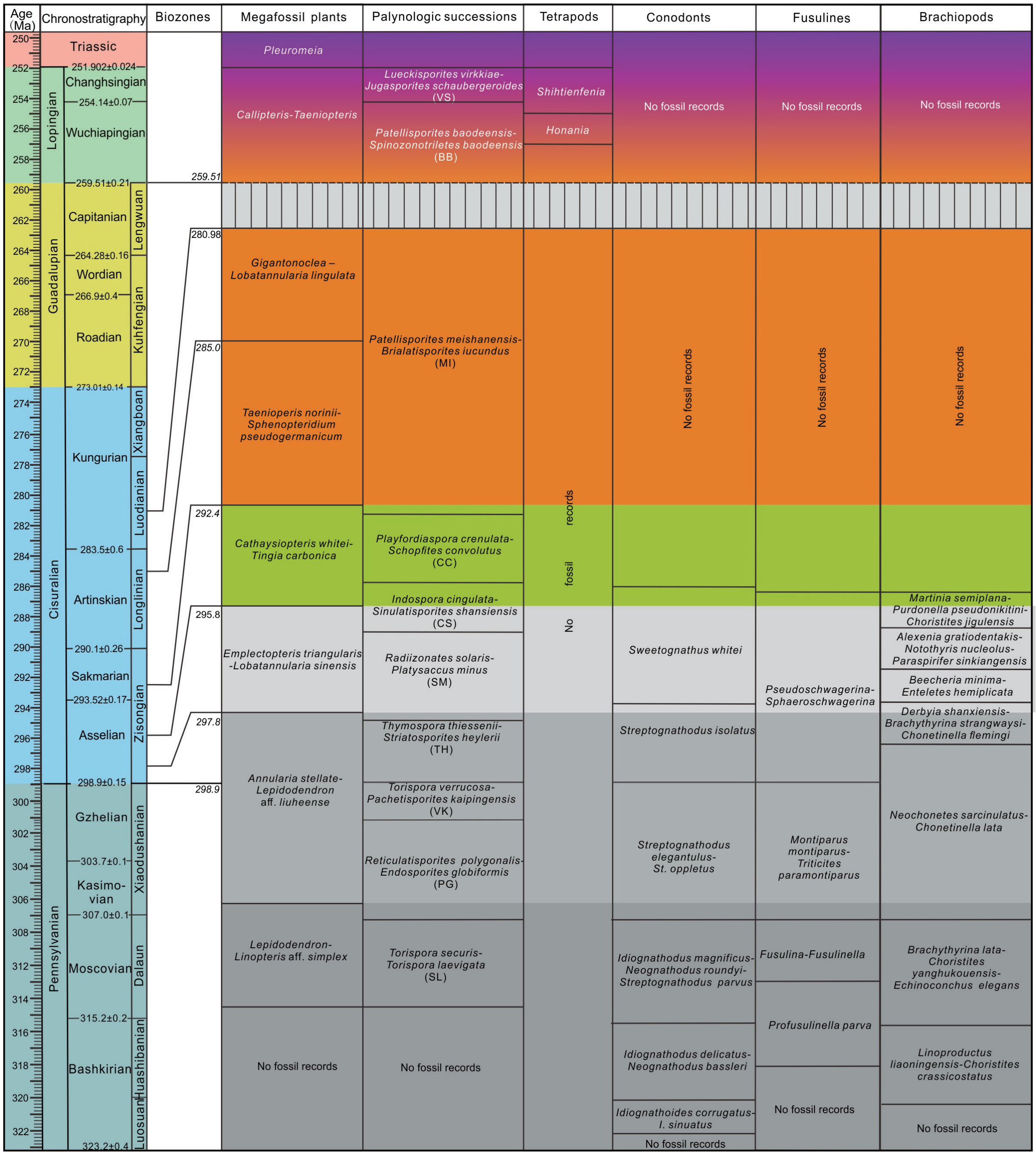

Fig. 3. Carboniferous and Permian biostratigraphic framework in the North China Block. From Shen et al. (2022).

in other regions. The Carboniferous-Permian boundary was traditionally placed in the middle part of the Taiyuan Formation (Shen et al., 2019). In contrast, the Permian strata above the Taiyuan Formation are mainly composed of terrestrial deposits without marine index fossils, although some *Lingula* were reported occasionally in the North China Block. The Permian terrestrial strata were thought to be largely continuous, and their correlation with those in the other regions mainly relied on plant fossils and palynological zones. Based on megaplant fossils, the Shansi Formation was traditionally assigned to Longlinian (=Artinskian), the Lower Shihhotse Formation was assigned to late Cisuralian and early Guadalupian, and the Upper Shihhotse Formation was considered to be late Guadalupian and Wuchiapingian. This correlation has been used for more than a century in China (Shen et al., 2022). However, a set of new weighted mean 206Pb/238U dates by the CA-ID-TIMS method from bentonites in the Permian at the Palougou section in Shanxi Province in the NCB for the first time provide a near-complete temporal calibration for the terrestrial Permian system of North China, and these high-precision dates changed the ages of the terrestrial Permian lithostratigraphic units of the NCB greatly (Wu et al., 2021). Based on the summary of the latest geochronological and biostratigraphic researches of the Carboniferous-Permian systems of the NCB (Shen et al., 2022), the Penchi Formation ranges from early Bashkirian to early Gzhelian; the Taiyuan Formation is assigned to the late Gzhelian to early Asselian; the

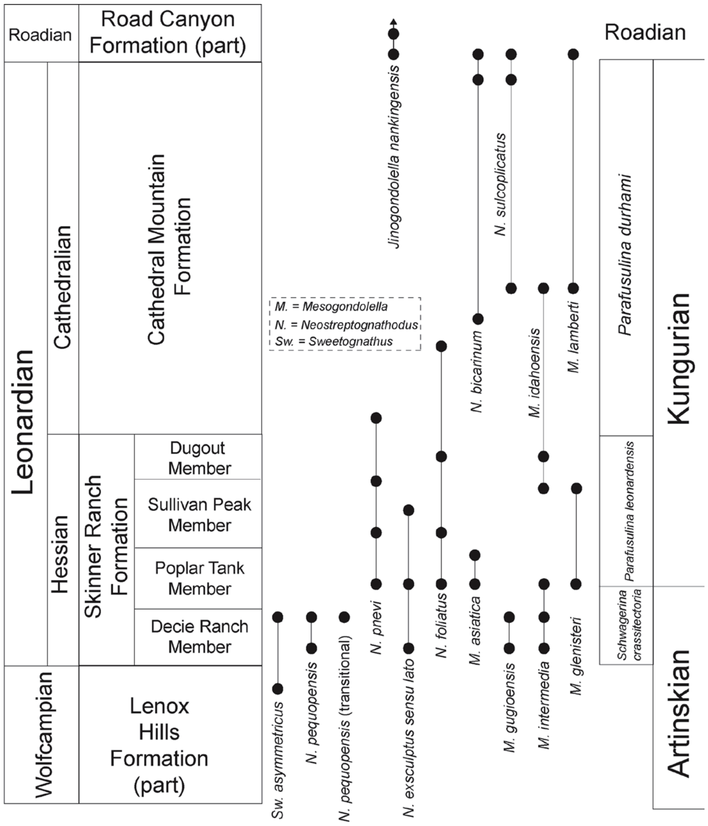

Fig. 4. Conodont biozonation of the Leonardian stratotype in the Glass Mountains of west Texas. From Lucas et al., 2022b.

Shansi and Lower Shihhotse formations are from middle Asselian to early Sakmarian; the Upper Shihhotse Formation is assigned to late Artinskian to early Kungurian, and the Sunjiagou Formation was assigned to the Lopingian, respectively. A ~20 Myr long gap or multiple gaps are probably present between the Upper Shihhotse Formation and the overlying Sunjiagou Formation, which is marked by multiple widespread conglomerate units and paleosol units in the upper part of the Upper Shihhotse Formation in the NCB. The gaps were probably derived from the uplift of the NCB during the closure of the Paleo Asian Ocean (PAO) and collision between the NCB and the Siberian Plate.

Recent work by Spencer G. Lucas and collaborators has uncovered new Permian fossils of palecological and biostratigraphic significance. In the palecological arena, Voigt et al. (2021, 2022aa) have recently reported the unusual trace fossil *Augerinoichnus* (a helical-shaped, open burrow likely made by a worm) in Early Permian strata of the Saar-Nahe basin in Germany. This is the first record of *Augerinoichnus* outside of the American Southwest and, significantly, document the trace fossil in an inland fluvial floodplain setting (previous records were in coastal plain deposits). *Augerinoichnus* thus can be added to the ever growing number of facies-crossing ichnofossils.

In the biostratigraphic arena, Lucas has been working with Charles Henderson, Karl Krainer, Jim Barrick and others to establish better age constraints for Lower Permian marine strata in the American Southwest (Fig. 4). This has determined conodont-based ages for units in Arizona, New Mexico and Texas that represent Kungurian transgressions/seaways that previously had relatively imprecise age constraints. The older transgression is the Cathedral Mountain transgression seen in the middle of the Yeso Group in New Mexico and the Fort Apache Limestone in Arizona (also Lucas and Henderson, 2021; Lucas et al., 2019, 2022a, b). The younger event is the San Andres transgression in New Mexico, which correlates to the Blaine transgression in Texas-Oklahoma and the Kaibab transgression in northern Arizona. A manuscript on the Blaine conodont assemblages, which confirm the late Kungurian-earliest Roadian age of Olson's gap, is in progress.

Recent studies on the important Permian French tracksite of Gonfaron (Pelitic Formation, Le Luc Basin, Var, France),

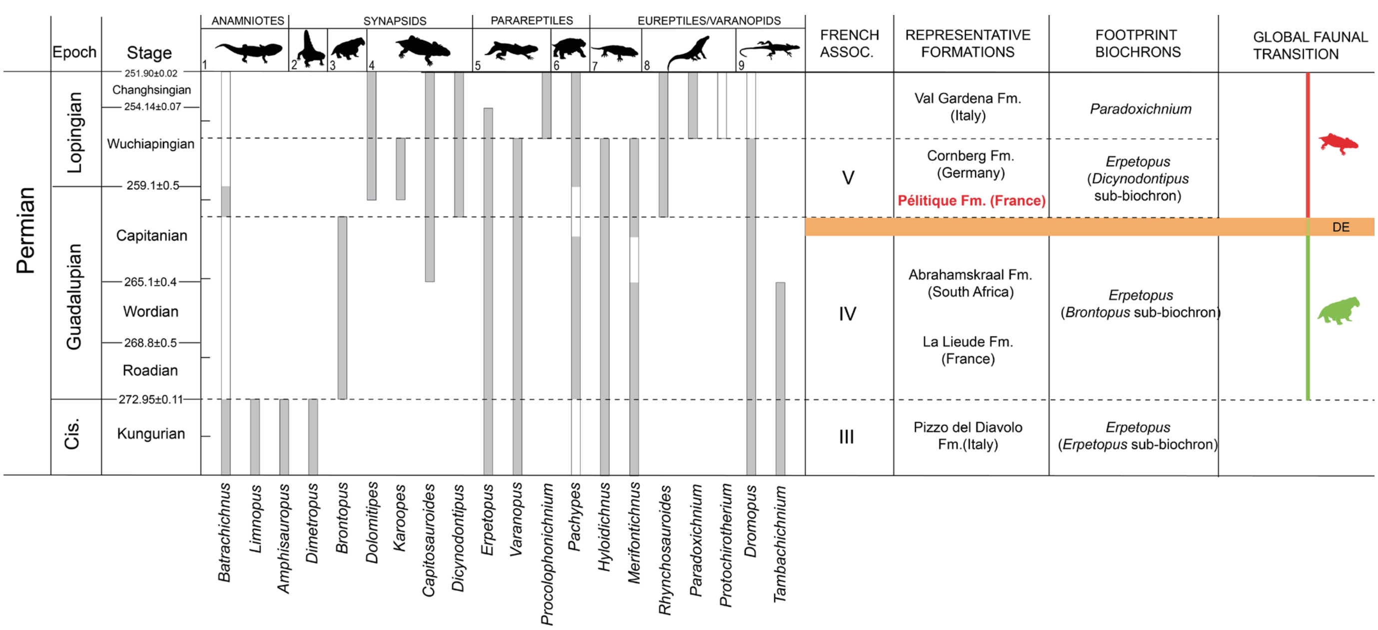

Fig. 5. Late Cisuralian–Lopingian tetrapod footprint chronostratigraphy. Empty bars are uncertain occurrences. 1 = temnospondyl and reptiliomorph anamniotes, 2 = non-therapsid synapsids, 3 = dinocephalian therapsid synapsids, 4 = anomodont and eutheriodont therapsid synapsids, 5 = non-pareiasauromorph parareptiles, 6 = pareiasauromorph parareptiles, 7 = captorhinid eureptiles, 8 = neodiapsid eureptiles, 9 = diapsid eureptiles/varanopids. DE - Dinocephalian Extinction event. Modified after Marchetti et al. (2022).

including both new field work and a revision of the collections, were carried out. The first results were published in Logghe et al. (2021), in which the locomotion of captorhinomorphs is analysed based on trackways. Marchetti et al. (2022a) revised the tetrapod ichnoassociation from Gonfaron and introduced two new tetrapod footprint biozones: the Association V of France and the *Dicynodontipus* sub-biochron of the *Erpetopus* biochron, spanning from the late Capitanian to the early Wuchiapingian (Fig. 5).

Marchetti et al. (2022b) published a comprehensive review of the well-constrained tetrapod ichnofauna, macroflora, and microflora from the late Cisuralian of the Southern Alps and compared it to other Cisuralian assemblages from Europe, North Africa and North America in an up-to-date stratigraphy. The results show a dramatic and sudden increase in both diversity and relative abundance of drought-tolerant forms during the Artinskian. This biotic replacement in Europe is sudden, conspicuous, widespread and time-equivalent to the biotic replacement observed in the low palaeolatitudes of western Pangea (present-day western USA) and to a major increase of pCO_2 and Na_2O values in Euramerican successions (Fig. 6). It is possibly related to volcanic eruptions that may have caused the final melting of the Gondwanan ice sheets. This global climatic event (Artinskian Warming Event, AWE) increased temperature and aridity at the low palaeolatitudes of Pangaea, enhancing the apparent abundance and diversity of drought-tolerant taxa.

New studies on the freshwater bivalve collections from the Cisuralian Southern Alps continental basins are published in Silantiev et al. (2022). Non-marine bivalves are key fossils in

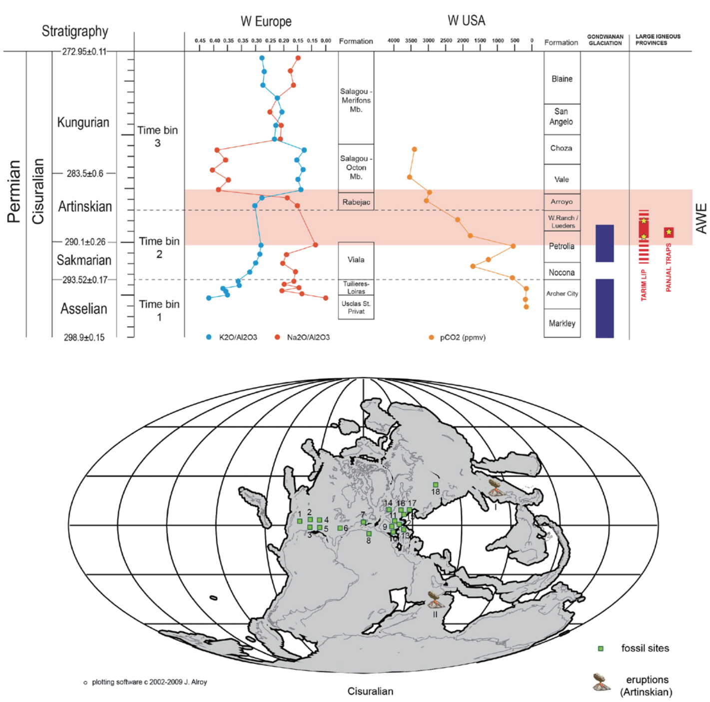

Fig. 6. Data for the Artinskian Warming Event (AWE) as discussed in Marchetti et al. (2022b). Above: Cisuralian climate indicative geochemical data of Euramerica and North America. Curves extrapolated from Körner et al. (2003) for Western Europe and Montañez et al. (2007) for western USA. Below: Palaeogeographical scheme showing the approximate position of the Cisuralian fossil localities (1–18) and the Artinskian volcanic provinces (I-II). For details see Marchetti et al. (2022b).

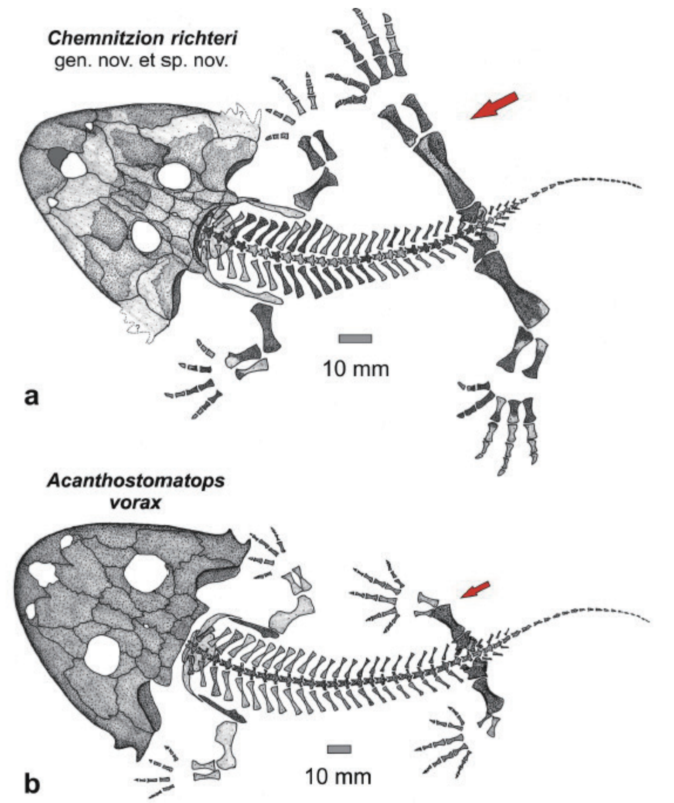

Fig. 7. A new temnospondyl from the fossil-rich T0 assemblage of the Chemnitz Fossil Lagerstätte (Chemnitz Basin, Sakmarian–Artinskian transition): *Chemnitzion richteri* Werneburg et al. 2022a; (a) skeletal reconstruction in comparison with (b) *Acanthostomatops vorax*. Note the much larger hind limbs of the smaller skeleton of *C. richteri* in comparison to *A. vorax* (red arrows). *Chemnitzion* was an ambush predator in the Chemnitz Petrified Forest, the early Permian Pompeii (Rößler, 2021). Modified from Werneburg et al. (2022a).

Permian continental stratigraphy and palaeogeography on the East European Platform, the Cis-Ural Foredeep and of Angara (Silantiev, 2018). The discovery of the genera *Palaeomutela* and *Redikorella* in the early-middle Kungurian of southwestern Europe, well constrained by radioisotopic dating, suggest new First Appearance Data (FAD) and possible new centres of origin potentially situated in SW Europe of these genera.

Werneburg et al. (2022a) described a new zatracheid temnospondyl form the Chemnitz Petrified Forest Fossillagerstätte in Germany (Fig. 7). This so called Pompeii of the Permian forms a fossil-rich T0 assemblage buried by volcanic ash falls in the Chemnitz Basin at the Sakmarian–Artinskian transition (Rößler, 2021). The skeleton of the new taxon, *Chemnitzion richteri*, was found together with other vertebrates (Spindler et al., 2018) in basal air-fall tuffs of the Zeisigwald Tuff in the Leukersdorf Formation, which is dominated by wet red-bed facies. The Chemnitz Petrified Forest forms a local wet-spot habitat in this formation with various vertebrates, arthropods and gastropods, etc. constituting a vital community that lived in a dense, seasonally influenced forest habitat dominated by tree-sized ferns, calamitaleans, medullosans and cordaitaleans.

Werneburg et al. (2022b) reported the new taxon *Lalieudorhynchus gandi*, a caseid synapsid from the middle Permian, Guadalupian, La Lieude Formation of the Lodève Basin in Southern France. The first skeleton remains were already

Fig. 8. Life restoration of *Lalieudorhynchus gandi* Werneburg et al. 2022b in its possible environment based on sedimentological and taphonomical analyses of the type locality in the La Lieude Formation (Roadian-Capitanian) of the Lodève basin, Southern France, and preliminary osteohistological observations. Associated aquatic tupilakosaurid temnospondyl (bottom left) described by Werneburg et al. (2007). Artwork by Frederik Spindler.

discovered by field work of J.W. Schneider and F. Körner in 2001. Common German and French excavations, realised by student's field courses in 2002, 2006, and 2008, unearthed a partial but well-preserved postcranial skeleton of this estimated 3.6 m long, huge animal. Long lasting preparation of the bones and extensive comparisons with so far known caseid remains in collections of the US, Europe, and Russia as well as a phylogenetic analysis of caseids show that *Lalieudorhynchus gandi* is closer to the North American "*Cotylorhynchus*" *hancocki* than to the other French caseids *Ruthenosaurus* and *Euromycter* from the Artinskian of the geographically closer Rodez Basin. These two last caseids document the Artinskian radiation of the clade, which remained diverse until Olson's gap (Reisz et al., 2011). *Lalieudorhynchus* is one of the youngest representatives of the clade, and may have used novel ecological strategies to access their vegetarian food sources. A very detailed sedimentological analysis of the La Lieude Formation and a taphonomical analysis of the type locality, together with preliminary osteohistological observations, support the previous hypothesis of a semi-aquatic, hippopotamid-like lifestyle in at least a variety of large caseids (Fig. 8).

For the Saar–Nahe Basin, which is one of the largest intra-continental perimontaneous basins of the European Variscides, Voigt et al. (2022b) presented the first high-precision U–Pb CA-ID-TIMS age. An ash tuff layer of the Altenglan Formation near the middle part of the 6500 m thick volcano-sedimentary deposits of Early Pennsylvanian to the late Early Permian/? early Middle Permian age were dated as 298.7 +/- 0.4 Ma. Based on the new data, which is in good accordance with nonmarine-marine biostratigraphic correlations based on insects and conchostracans from the Saar-Nahe Basin (Schneider et al., 2021b), the Pennsylvanian-Permian boundary in the study area is close to or even within the Altenglan Formation, and overlying Rotliegend formations have to be considered of clearly Permian age. A recently discovered and globally important fossil tetrapod Lagerstätte of the Remigiusberg Formation (Voigt et al., 2019) lying immediately below the Altenglan Formation at the base of the Saar–Nahe Rotliegend is suggested to be of latest Gzhelian to earliest Asselian age.

Between July and August 2021, an excavation at the important Early Permian fossil Lagerstätte of Bromacker in the Tambach Formation of the Thuringian Forest basin (Lützner et al., 2012), Germany, has been carried out in the framework of the five year long project "Opening science: new ways of knowledge transfer using the example of the research project Bromacker", funded by the Federal Ministry of Research and Education. Participating institutions are the Museum für Naturkunde Berlin (MfN) – Leibniz-Institute for Evolution and Biodiversity Research, the Stiftung Schloss Friedenstein Gotha (SSFG), the Friedrich-Schiller-Universität Jena and the UNESCO Global GeoPark Thüringen Inselsberg-Drei Gleichen, as well as other national and international partners (Fig. 9). The excavation lasted 4 weeks, involved 54 participants and yielded more than 300 fossil finds including tetrapod bones, footprints, burrows and coprolites, invertebrate trace fossils, invertebrates and plant remains. The preparation of the finds is carried out at the SSFG and the MfN, Berlin. The documentation system included measuring of fossil findspots and key horizons by a tachymeter and drone photos of the site for photogrammetry. The 2022 excavation season began on 25th July with an event for the media (press, TV) and lasted until 19th August. Numerous finds and detailed lithofacies documentation will deliver new insights on this singular fossillagerstätte. In this way, there will be documentation of a time slice in which the transition from wet to dry reds beds took place in the Euramerican continental basins, which is otherwise very rarely represented by fossiliferous deposits in Europe.

Gondwana Permian

The continuous and fossiliferous deposits of the transitional Permian-Triassic Beaufort Group of the main Karoo Basin in

Fig. 9. Scene from 2022 excavation at the important Lower Permian fossil Lagerstätte of Bromacker in the Tambach Formation of the Thuringian Forest basin, Germany, in the framework of a five year long project funded by the Federal Ministry of Research and Education. Photo by courtesy of the Bromacker team.

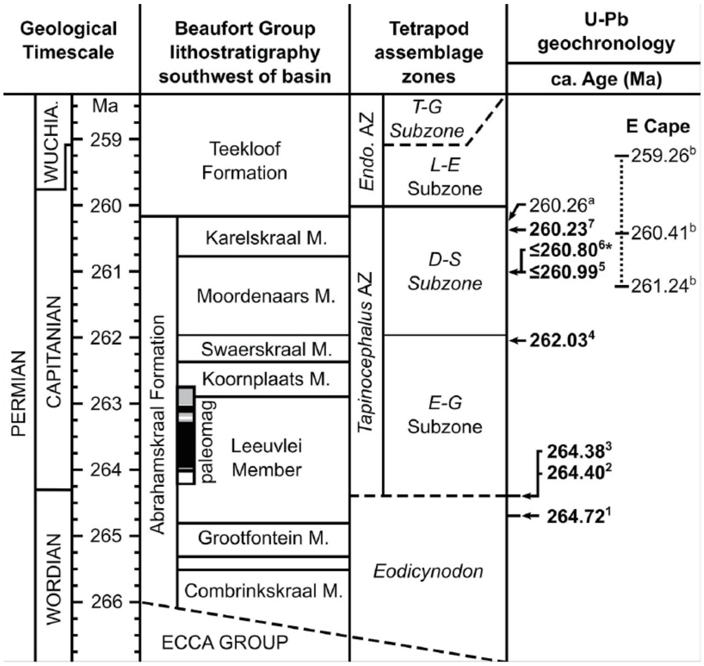

Fig. 10. Compilation of CA-ID-TIMS geochronology from the Beaufort Group, with age results of Day et al. (2022) shown in bold. Lithostratigraphy based on that for the SW Karoo from Day and Rubidge (2014). Permian stage boundary calibrations from Zhong et al. (2020) and Wu et al. (2020). D-S, *Diictodon-Styracocephalus*; E-G, *Eosimops-Glanosuchus*; Endo., *Endothiodon*; L-E, *Lycosuchus-Eunotosaurus*; T-G, *Tropidostoma-Gorgonops*; WUCHIA., Wuchiapingian. From Day et al. (2022), modified; for references see there.

South Africa serves as a reference sequence for Gondwanan tetrapod biochronology and provides a singular window into the evolution of terrestrial ecosystems between the Middle Permian and Middle Triassic. Day et al. (2022) presented new CA-ID-TIMS U-Pb age data from tuff beds that provide the first high-resolution chronostratigraphy for the upper two thirds of the Abrahamskraal Formation in the lower Beaufort Group. These ages constrain the base of the *Tapinocephalus* Assemblage Zone to be older than 264.4 Ma, and closely constrain the boundary between its two subzones to ca. 262 Ma (Fig. 10). Combined with ages from literature data for the overlying Teekloof Formation, the new data show the *Tapinocephalus* Assemblage Zone is latest Wordian to late Capitanian in age. Additionally, it is shown that a magnetostratigraphic normal polarity interval observed in the middle Abrahamskraal Formation may represent a normal (probably third) chron within the mixed-polarity Illawarra Superchron.

The exact timing of the Permian-Triassic boundary in the Karoo basin continues to be disputed but the evidence is increasingly suggestive of a crisis amongst vertebrates occurred before that of the main extinctions in the marine realm (see Dal Corso et al. 2022). In an analysis of extinction and turnover using a large vertebrate dataset, Viglietti et al. (2021) found that extinctions occurred over a long period of up to 1 million years, with a peak in extinctions and ecosystem collapse occurring in the upper Palingkloof Member. Gastaldo et al. (2022) provided further high-precision U-Pb dates from the extinction interval that supports the model that this extinction interval was within the latest Permian and thus preceded the marine extinctions. These authors also claim that taxa diagnostic of the *Daptocephalus* AZ and *L. declivis* AZ in the Lootsberg Pass area were contemporaries sometime in the early Changhsingian and that, consequently, the *L. declivis* AZ did not replace the *Daptocephalus* AZ stratigraphically. This would cast doubt on existing models of the mass extinction but suspicions are aroused by their correlation across a dolerite dyke. The field remains open for further work.

In South America, new high-resolution TIMS ages of 277.26 ± 0.62 Ma and 275.75 ± 0.29 Ma from the upper Irati Formation were reported by Bastos et al. (2022) and Cagliari et al. (2022), respectively. This adds to existing evidence suggesting a mid–late Kungurian age for the Irati Formation and thus the *Mesosaurus* fauna of the Irati-Whitehill sea that covered a large part of southwestern Gondwana at that time.

Triassic

After years of intensive work by 73 authors from all over Europe, Hauschke, Fanz and Bachmann (editors) 2021 have published the two-volume book "Trias - Aufbruch in das Erdmittelalter" (Departure into the middle age of Earth), albeit written entirely in German. The richly illustrated work offers in 668 pages a uniquely complete overview of the Triassic in the Central European Basin, namely the Germanic Basin (Fig. 11). Volume 1 contains the foreword and the introduction with a historical outline of the term Triassic, followed by contributions on the main topics: A) palaeogeography, stratigraphy and facies as well as B) fossil content; volume 2 contains the articles on the main topics, C) fossil sites and fossil lagerstätten (Fig. 12) and D) economic use as well as the complete bibliography and the index.

Scholze & Matamales-Andreu (2021) described four upper Lower Triassic to lower Middle Triassic conchostracan-bearing intervals from Mallorca, which include the conchostracan (clam shrimp) species *Hornestheria* sp. aff. *Hornestheria sollingensis* and other undetermined carapace valve morphologies (Fig. 13). All of this material was obtained from red-bed units

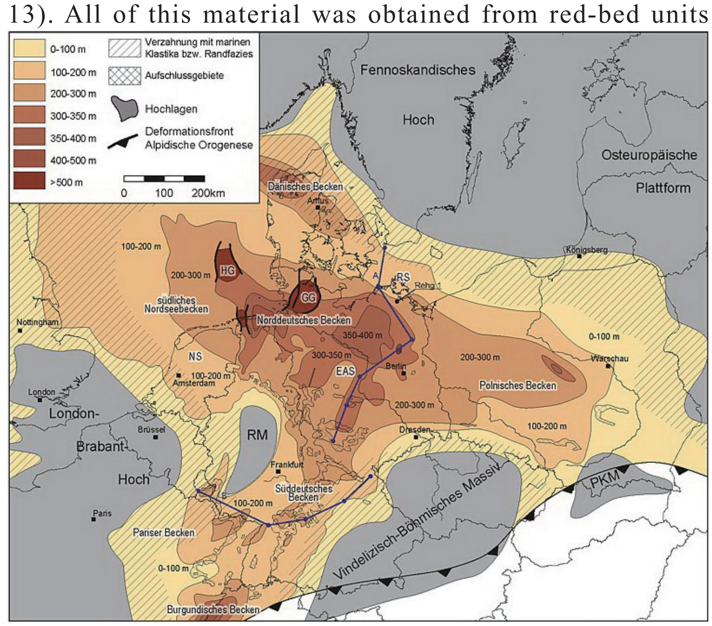

Fig. 11. Palaeogeographic map of the epicontinental Central European Basin (in the Triassic also called the Germanic Basin) extending during the Late Triassic Norian from UK via Scandinavia to Poland in the Southeast and France in the Southwest. From Bachmann in Hauschke et al. (2021), chapter A1, fig. 1.

Fig. 12. Typical outcrop of fluvial-lacustrine deposits of the Triassic middle Keuper, Carnian, Hassberge Formation in Franconia (Northern Bavaria), Germany. The active and abandoned quarries in the Hassberge region are important Triassic fossillagerstätten mainly for invertebrates, fishes, and plants. Photo: J.W. Schneider.

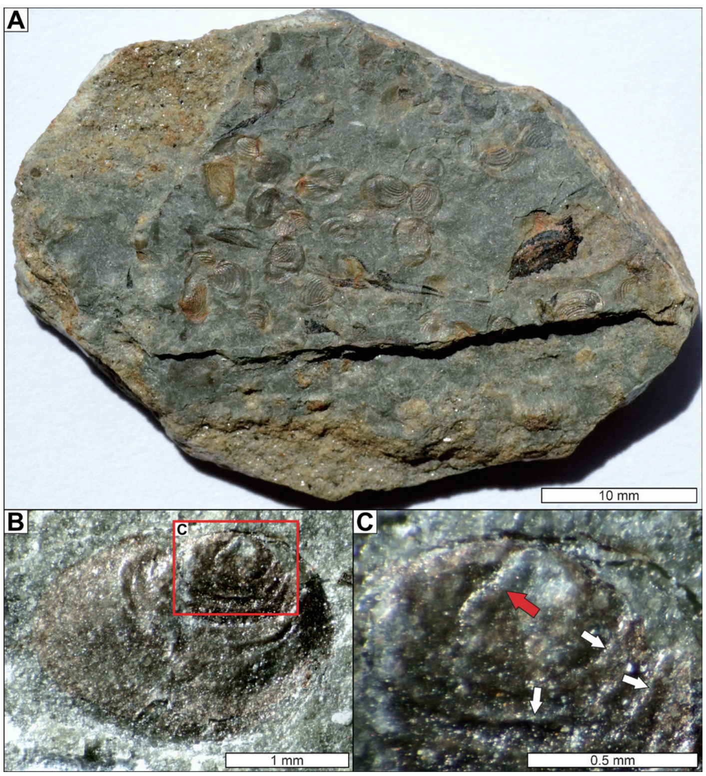

Fig. 13. Conchostracans (clam shrimps; Branchiopoda: Diplostraca) and plants from Pedra Alta section (lower Anisian?), Serra de Tramuntana mountains of Mallorca (western Mediterranean, Spain). A: mass-occurrence of *Hornestheria* sp. aff. *Hornestheria sollingensis* and coalified plant remains. B: external view on a right carapace valve of *Hornestheria* sp. aff. *Hornestheria sollingensis.* C: radial sculpture on the larval carapace valve (marked by red arrow), which is a diagnostic character for the genus *Hornestheria*; white arrows mark concentric growth lines in the umbonal area of the carapace valve. From Scholze & Matamales-Andreu (2021) by courtesy of F. Scholze.

cropping out in the Serra de Tramuntana Mountains of Mallorca (western Mediterranean). Except for a few morphologically similar carapace valves of Middle Triassic age from China, *Hornestheria* is known only from the type locality of its type species, *Hornestheria sollingensis* Kozur et Lepper, in the Solling Formation (Middle Buntsandstein Subgroup) in the German part of the Central European Basin. According to its original definition, the larval carapace valve of *Hornestheria* Kozur et Lepper is characterized by a radial sculpture, but this characteristic apparently is only variably developed. Due to both a limited number of previously known occurrences of *Hornestheria* and its poorly known carapace valve morphology, open taxonomic nomenclature was applied. The conchostracan specimens were freshly collected from outcrop sections composed of greyish-green to greyish-red laminated claystones and siltstones that accumulated in a fluvial facies. The conchostracans are accompanied by remains of insects and fishes, invertebrate and tetrapod ichnofossils, and micro-/macroplant remains, all of which either have been described by previous workers or were part of a separate study by Matamales-Andreu et al. (2021).

Zouheir et al. (2022) report on ichnodiversity and facies from Middle-Upper Triassic continental deposits of the Timezgadiouine Formation in the Argana Basin, Western High Atlas of Morocco. Based on detailed measured sections, 17 lithofacies are distinguished, with alluvial fan, fluvial, floodplain and lacustrine associations. The rich invertebrate trace fauna includes *Archaeonassa fossulata*, *Arenicolites* isp., cf. *Arenituba*, *Beaconites* isp., cf. *Camborygma*, *Cruziana problematica*, *Diplocraterion* isp., *Fuersichnus* isp., *Helminthoidichnites tenuis*, *Lockeia* isp., *Palaeophycus striatus*, *Palaeophycus tubularis*, *Planolites* isp., *Rusophycus carbonarius*, *Scoyenia gracilis*, *Skolithos* isp., *Spongeliomorpha carlsbergi*, *Taenidium* isp. and *Taenidium barretti*. Based on facies pattern and fossil content, six ichnoassemblages were distinguished: overbank facies with (1) Rhizolith ichnoassemblage in a low-energy floodplain environment and (2) *Scoyenia-Palaeophycus* ichnoassemblage in crevasse splay deposits. The fluvial ichnoassociation is of moderate ichnodiversity consisting of the following assemblages: (3) *Arenicolites*, developed under higher flow velocities of active channels, (4) *Taenidium-Scoyenia*, formed by the colonization of inactive channels, (5) *Arenicolites*-horizontal meniscate burrows, reflecting a rapid transition between active and abandoned channels and (6) *Lockeia*-vertebrate footprint, formed in littoral

Fig. 14. Middle-Upper Triassic continental deposits of the Timezgadiouine Formation in the Argana Basin, Western High Atlas of Morocco, at Irohalene village. The greyish beds are some of 13 lake horizons in a roughly 70 m thick section of the lower part of the formation which point to a rapid climate change from dry to intermittent wet and dry (Zouheir et al., 2022). It is hypothesized that this change mirrored the Peri-Tethyan and/or global Carnian Pluvial Event. Photo by courtesy of T. Zouheir.

lakes. Interestingly, the Aglegal and Irohalene members of the Timezgadiouine Formation indicate climatic shifts between arid dry, semiarid and subhumid in a dryland river environment. The observed sudden onset and the high frequency of lacustrine deposits in the lower Irohalene Member (13 lake horizons in a roughly 70 m thick section; see Figure 14) point to a rapid climate change from dry to intermittent wet and dry. It is hypothesized that this change mirrored the Peri-Tethyan and/or global Carnian Pluvial Event. The well exposed and fossil-rich Carnian deposits of the Argana Basin represent a remarkable opportunity to test ideas about the fine-scale climatic structure of this event.

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17th international Permian-Triassic field workshop in the Cantabrian Mountains, N. Spain

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Due to the COVID pandemic situation, the AGPT (Association des Géologues du Permien et du Trias, https://agpt.wordpress.com/) decided that the organization of its 2021 field trip would be held together with the 16th International Permian-Triassic Field Workshop, and this was held in Ardèche, France. The 17th International Permian-Triassic Workshop (from July 4 to 6, 2022) (coordinated by S. Bourquin, Géosciences Rennes, Univ. Rennes France), associated with the AGPT, was held in Oviedo (Asturias, N Spain) and focused on the Permian and Triassic sedimentary record of the Cantabrian Mountains (N Spain) and its tectonic control. The field guide and the explanation of the excursion stops were coordinated by 16 co-authors, whose names appear at the end of this text. The aim of the excursion was to show recent research of this sedimentary record in the area (e.g., Juncal et al., 2016; López-Gómez et al., 2019, 2021; Lloret et al., 2021; Heredia et al., 2022).

There were 25 participants from 8 different countries. A minibus for the participants allowed easy access to 10 stops over three days. Both the overnight stays and the breakfasts were held at the University Residence of the University of Oviedo. These excursion took place between the Cantabrian coast and the Cantabrian Mountains.

The first day started with the welcome to the Faculty of Geology of the University of Oviedo by its Dean, Dr. Juan Belmonte. In the field trip, the first stop showed the sedimentary transition between the Carboniferous and the Permian (upper Gzhelian-lowest Asselian) represented by the San Tirso Formation, and the control on these sediments of strike-slip tectonics related to the; Late Variscan, the last episode of the Variscan orogeny. At the second stop, located in the southern end of the Permian Villaviciosa basin, the calc-alkaline volcano-sedimentary complex represented by the Acebal Formation (Upper Asselian - Sakmarian) was shown (Fig. 1A). The last stop of this first day was at Xivares beach, where the different tectonic directions of Variscan structures conditioned the sedimentary basins of the Lower Permian and Upper Triassic (Fig. 1B). This day ended with a lecture given by Dr. Pedro Farias at the Faculty of Geology of Oviedo University.

The second day concerned in the Picos de Europa Unit of the Cantabrian Zone (Variscan Orogen), showing the tectonics of the post-orogenic basins related to the first extensive phase of the Alpine cycle (Fig. 1C), related to the final orogenic collapse of the Variscan Belt in Early Permian times. In this area, the filling of these basins is represented by the Sotres Formation (Artinskian - Kungurian). This shows important sedimentary changes, from fluvial environments (proximal - distal) at the base, evolving upwards to carbonated lacustrine and palustrine environments with important evaporation processes which indicate a rapid climatic change in the early Kungurian. The day ended with a typical Asturian celebration (Espicha) in the center of Oviedo.

The third and last day focused on: the Lower Permian – Middle Triassic unconformity. The first stop was located in the southern limb of the Tudanca syncline of the Vasco-Cantabrian Region of the Pyrenean-Cantabrian belt, where almost 1 km

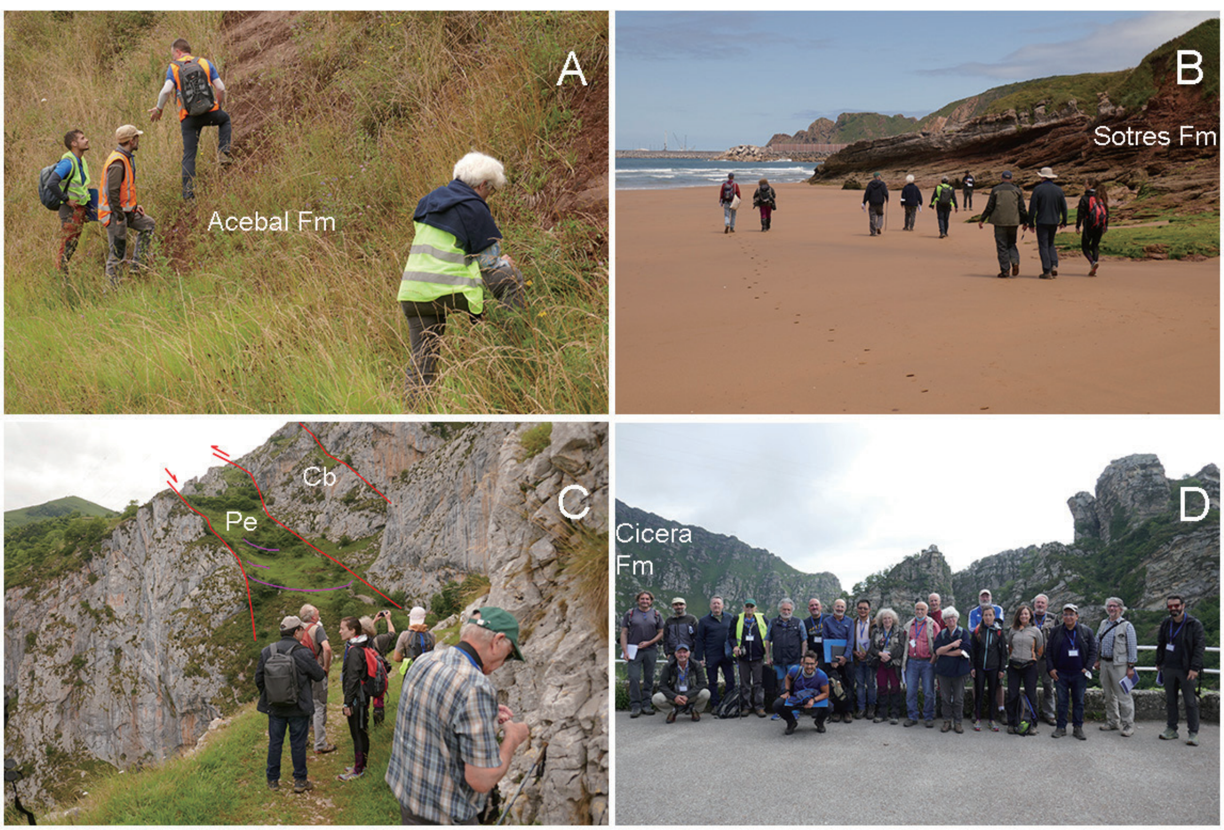

Fig. 1. **A.** Calc-alkaline and felsic magmatism (Acebal Formation, Asselian-Sakmarian); **B.** Lower Sotres Formation (Artinskian – Kungurian) in Xivares beach; **C.** Fragment of the Tresviso-La Hermida-Carmona Permian basin close to the Tresviso village, Cantabria. Cb: Carboniferous limestones, Pe: Permian Sotres Formation; **D.** The Cicera Formation (Ladinian – early Carnian) in La Cohilla section.

Fig. 2. Visit to the MUJA (Jurassic of Asturias Museum).

thick of fluvial deposits of the Cicera Formation (Ladinian – early Carnian) were deposited (Fig. 1C). The extensional Alpine tectonic regime that conditioned the deposition of these Triassic sediments is related to the reactivation of the late Variscan San Carlos fault. At the Stop 2 an important karstic paleorelief, developed on the marine Carboniferous limestones deformed by the Variscan orogeny, was observed. This paleorelief was developed over 30 My and before the deposition of the Triassic Cicera Formation. The last stop of the field trip was at the Arenal de Moris beach, where the transition between the terminal Triassic, in sabkha facies, and the marine Jurassic, represented all of this by the Transición Formation, was shown. The field trip ended at the Jurassic Museum of Asturias (MUJA) (Fig. 2), where some magnificent specimens from the paleontological record of the Asturian region were shown. The excursion was closed at the MUJA where the president of the AGPT, Sylvie Bourquin, announced that the 18th International Permian - Triassic Field Workshop will be held in the South of France, about which information will arrive in the coming months.

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ANNOUNCEMENTS

1. XVIII Argentinian Paleobotany and palynology Symposium, Jujuy, Argentina, 28th-30th September 2022. http://www.sapp2022.com.ar/

2. The 6th International Palaeontological Congress (IPC6), Khon Kaen, Thailand, 7th-11th November 2022. https://ipc6.msu.ac.th/

3. The 4th International Congress on Stratigraphy Strati 2023, Lille, France, 11th-13th July 2023. https://stratigraphy.org/news/141

SUBMISSION GUIDELINES FOR ISSUE 74

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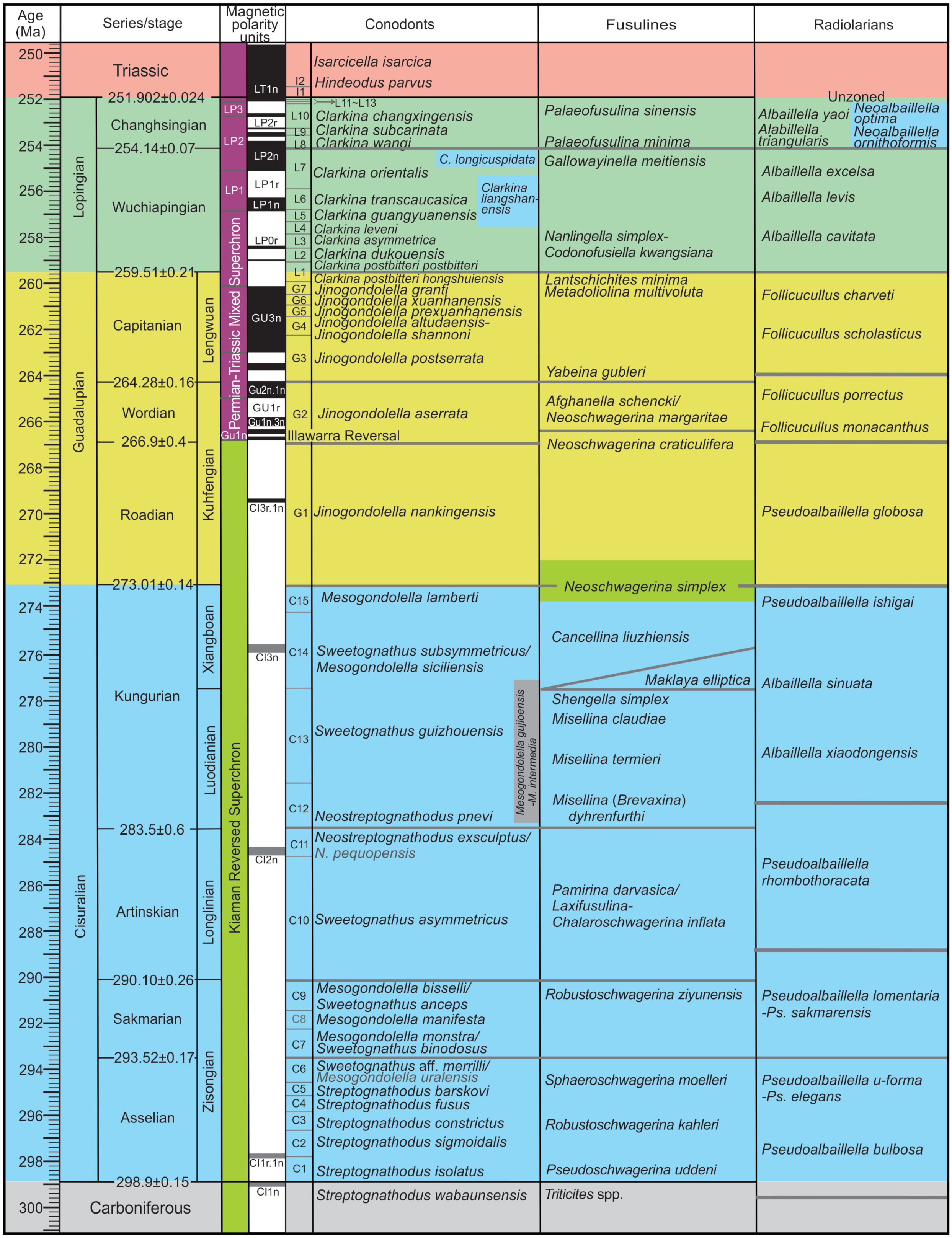

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