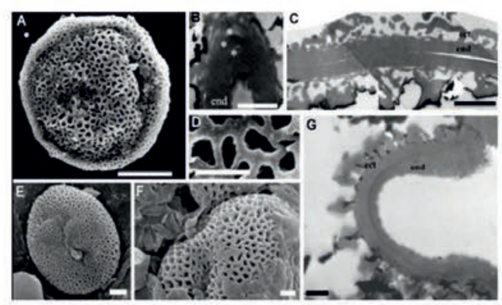
Permophiles

International Commission on Stratigraphy



Newsletter of the Subcommission on Permian Stratigraphy

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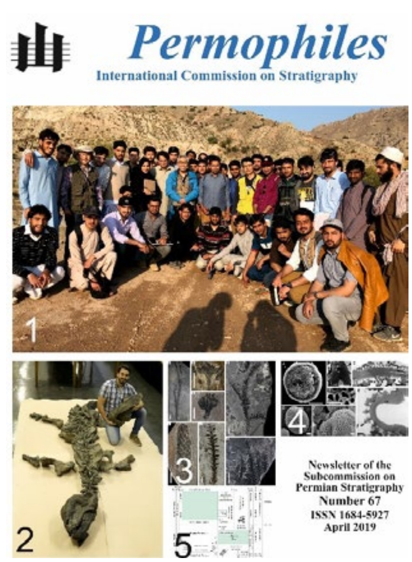

EXECUTIVE NOTES

Notes from the SPS Secretary

Lucia Angiolini

Introduction and thanks

The present issue was scheduled for end-December 2018, but we delayed its publication in order to receive more contributions. The richness, detail and variety of the contributions we got in March and April, made this issue really interesting and valuable for the Permian community, and meant that it was the right decision.

To promote Permian research, in March 2019, SPS has decided to cover the registration fees to Strati 2019, 3th International Congress on Stratigraphy in Milano, and to the 19th International Congress on the Carboniferous and Permian (XIX ICCP 2019) in Cologne for a few participants, either voting members or young students recommended by voting members. The Permian researchers who will benefit from this support are Valeriy Golubev for ICCP 2019 and Alexander Biakov, Massimo Bernardi and Marco Romano for Strati 2019. Besides presenting very interesting results at these congresses, Veleriy, Alexander, Massimo, and Marco have also submitted an extended summary of their presentations for this issue of *Permophiles*.

My warm thanks go to the contributors of this issue: Charles Henderson, Natalia Zaviolova and co-authors, Giuseppa Forte and co-authors, Spencer Lucas and Valeriy Golubev, Marco Romano and Bruce Rubidge, Massimo Bernardi and co-authors, Alexander Biakov, Valeriy Golubev, the Chinese-Pakistan working group, and to those who have written obituaries to celebrate and remember eminent stratigraphers recently passed away.

I would like to thank Claudio Garbelli for his assistance in also editing this issue of *Permophiles*.

Finally, I would like to keep drawing your attention to the new SPS webpage that Shuzhong Shen has provided at http://permian.stratigraphy.org/, where you can find information about *Permophiles*, what's going on in the Permian Subcommission, an updated version of the list with addresses of the SPS corresponding members, and the updated Permian timescale.

Forthcoming SPS Meetings

A forthcoming SPS business meeting is scheduled at Strati 2019, 3th International Congress on Stratigraphy, Milano, 2-5 July 2019. The session ST3.5 "Carboniferous-Permian GSSPs and correlations: state of the art" is scheduled for Tuesday 2 July and will be followed by the SPS business meeting. http://www.strati2019.it/

A second important meeting will be organized at the 19th International Congress on the Carboniferous and Permian (XIX ICCP 2019), in Cologne, July 29th -August 2nd, 2019.

http://iccp2019-cologne.uni-koeln.de/

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This issue starts with the fifth harangue of Charles Henderson who deals with several important topics concerning the "theory and practice" of the Permian. His first paragraph made me really happy as I always spend a lot of time in capitalizing the lower/early, middle, upper/late Permian in my editing. His call "Let's Capitalize" is a cry for justice and I hope all Permian workers will follow it. Then, Charles opens a discussion on the criticisms of the GSSP process, which is a very good starting point to stimulate contributions and replies for the next issue of *Permophiles*. Charles' view is that the GSSP process has the merit to produce a well-defined Geologic Time Scale and to move stratigraphic studies forward.

Natalia Zaviolova and co-authors discuss the importance of dispersed pollen grains and spores as stratigraphic tools, particularly in the Permian, characterized by abundant terrestrial deposits. They underline that the Permian record is unique because of the first appearance of Mesozoic-morphological types, even though their relationships with younger pollen taxa are still poorly known. One way to solve this conundrum and to enhance their importance as stratigraphic tools is to get more information about the plant-producers by more widely using electron microscopy (SEM, TEM).

Giuseppa Forte and co-authors present a comprehensive study of the Tregiovo Formation which bears important palaeoenvironmental and palaeoclimate implications. In particular, the plant assemblages of the Tregiovo Formation - one of the largest and best documented Kungurian floras of the eastern Pangea palaeotropics - record the Cisuralian aridification event, with Walchian and Voltzian conifers occurring together. The authors report a negative trend $\delta^{13}C$ at Tregiovo, which may record the global decrease of $\delta^{13}C$ during the Kungurian.

Spencer Lucas and Valeriy Golubev discuss the estimation of the age and duration of Olson's gap. If, based on marine biostratigraphic data, Olson's gap corresponds to a substantial interval of Kungurian time, it will be more difficult to evaluate its duration in millions of years. The authors suggest it may be at least 4 million years long, but more precise numerical age constraints are needed to obtain a more reliable estimate.

Marco Romano and Bruce Rubidge report about body mass and posture of dinocephalians, the first large tetrapods to live on land in Gondwana. They have studied in details very well preserved specimens of *Tapinocaninus* and they have reconstructed an *in-vivo* 3D model of the taxon, to show the life appearance of the animal in a Guadalupian environment. The authors have calculated a body mass close to a tonne for *Tapinocaninus*, and, as a structural response, its posture.

Massimo Bernardi and co-authors discuss the use of relaxed clocks to identify the time of divergence for lepidosaurs, archosaurs, protorosaurs, and many lineages of marine reptiles, including sauropterygians, ichthyosaurs and thalattosaurs, a time of divergence that was deep into the Permian. They prove that their origin is least a few million years older than the oldest fossils, as, at the point of divergence of most lineages, clades are not abundant enough to generate fossils. Thus, it is fundamental that precise models of fossilization and fossil sampling are incorporated into relaxed clock approaches and into palaeontological models in general, as also discussed by other authors in previous issues of *Permophiles*.

Alexander Biakov shows that the bivalve biostratigraphic scale is very important for intra- and interbasin correlations in the Boreal Realm. In addition, he reports that new U-Pb TIMS and SHRIMP dating of zircons allows the calibration of this scale and correlates it with the ISS. Important for this correlation are also δ^{13}Corg chemostratigraphy and ^{87}Sr / ^{86}Sr ratio data. Many of these new data allow the recording of the occurrence of the Changhsingian Stage – previously unknown - in Northeast Asia.

Valeriy Golubev presents the state of the art of the Permian-Triassic boundary successions of the East European platform, referring to many new data and recently published literature and showing that, based on biostratigraphic, magnetostratigraphic and chemostratigraphic data, there is no gap at the Permian-Triassic in the East European successions.

The Chinese-Pakistan working group describes a field trip organized in the Salt Range. During the field trip, the party sampled for conodonts, foraminifers, brachiopods, palynology, ichnofossils and corals as well as sedimentology, and geochemistry with the aim to revise the biostratigraphy, chemostratigraphy and stratigraphic evolution of these very important sections. Among the new discoveries, are important palaeontological findings and new data on the Guadalupian-Lopingian boundary and on the Permian-Triassic boundary.

Lucia Angiolini, Fabrizio Berra and Cristina Lombardo present Rivista Italiana di Paleontologia e Stratigrafia volume 125, 1 (2019) dedicated to the memory of Maurizio Gaetani (1940-2017), an open access issue which contains several contributions on Permian stratigraphy.

Finally, three obituaries commemorate eminent experts on Carboniferous, Permian and Triassic stratigraphy: Michaela Bernecker, Vladlen Lozovsky and Tuncer Güvenç, who very sadly passed away in 2017 and 2018.

Future issues of Permophiles

The next issue of *Permophiles* will be the 68th issue.

Contributions from Permian workers are very important to move Permian studies forward and to improve correlation and the resolution of the Permian Timescale, so I kindly invite our colleagues in the Permian community to contribute papers, reports, comments and communications.

I take the opportunity to underline Charles Henderson's harangues and invite colleagues to reply to his discussion points.

The deadline for submission to Issue 68 is 31th December, 2019. Manuscripts and figures can be submitted via email address (lucia.angiolini@unimi.it) as attachments.

To format the manuscripts, please follow the TEMPLATE

Notes from the SPS Chair

Shuzhong Shen

This year has been and will be a busy year again. We will have the Strati 2019 between 2-5 July in Milano, Italy and the 19th International Congress on Carboniferous and Permian between July 29th-August 2nd, 2019 in Köln, Germany. These are two important events for our Permian colleagues. I hope all the SPS voting and corresponding members could attend these two meetings. SPS will spend a part of the SPS budget to support a few members to participate these two meetings. We will have two SPS business meetings during these two congresses.

The most important recent event for paleontologists and stratigraphers is the initiative of the Deep-time Digital Earth (DDE) Big Science Program which has been approved by the IUGS Executive Committee during the EC meeting in late February, 2019 in Beijing. Both the International Commission on Stratigraphy and the International Palaeontological Association are the two out of 13 international organizations and national geological surveys to sign the accord to initiate this program. The DDE program will be formally launched during the 36th International Geological Congress in March, 2020, India. According to the DDE program proposal, DDE aims to establish linked earth big-data hubs that are interoperable with other databases including published data in the public domain and unpublished data in institutions and centres of expertise. It is an international consortium aiming to develop a platform of connected geoscience informatics efforts with FAIR data (Findable, Accessible, Interoperable, and Re-usable) with adequate quality control linking various Earth's spheres (hydrosphere, geosphere, atmosphere, biosphere) in geological history. It also aims at providing interoperability of existing databases. DDE will provide a digital earth in 3D (deep space, deep ocean, deep earth) plus an additional D; deep-time, which will be established based on palaeontological and stratigraphical data). These parameters represent the complete evolution of Earth from the past, the current to the future. This "4D" framework will support, guide and change geoscientific research including: 1) Reconstruction of the evolution of the Earth and life, such as the reconstruction of geobiodiversity, paleogeography, palaeoclimate and plate tectonic evolution in high spatial and temporal resolutions; 2) Recognition of formation and distribution of resources, energy and geohazards; 3) Predictions about future Earth in the context of global change. Ultimately DDE will help at better identification and solutions to major global pure and applied research questions such as, the origin and evolution of life on earth, the future population capacity of Earth, identifying and distinguishing between natural and anthropogenic hazards, interaction and self-organization of complex earth systems, and prediction of global change.

The joint working group between China and Pakistan visited some Permian-Triassic boundary sections in the Salt Range, Pakistan again (see a report in this issue). I would thank our Pakistani colleagues for their kind assistance to complete this field work.

Our Russian colleagues have excavated the Kungurian-base GSSP candidate section, the Mechetlino Quarry section, and the Artinskian-base GSSP candidate section, Dalny Tulkas section. I would call your visit and field work on these two sections again. We hope we can move the remaining GSSP works forward as soon as possible.

A Special Issue on Integrative Stratigraphy and timescale of China (Shen and Rong, editors, 2019) has been published online on Science China Earth Sciences (Springer) now (http://engine.scichina.com/publisher/scp/journal/SCES/62/1?slug=browse). This issue includes 13 periods and summarized the advances in stratigraphy and timescale from Ediacaran to Quaternary in China during the last two decades.

SUBCOMMISSION ON PERMIAN STRATIGRAPHY

ANNUAL REPORT 2018

1. TITLE OF CONSTITUENT BODY and NAME OF REPORTER

International Subcommission on Permian Stratigraphy (SPS)
Submitted by:
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2. OVERALL OBJECTIVES, AND FIT WITHIN IUGS SCIENCE POLICY

Subcommission Objectives: The Subcommission's primary objective is to define the series and stages of the Permian by means of internationally agreed GSSPs and establish a high-resolution temporal framework based on multidisciplinary (biostratigraphical, geochronologic, chemostratigraphical, megnatostratigraphical etc.) approaches, and to provide the international forum for scientific discussion and interchange on all aspects of the Permian, but specifically on refined intercontinental and regional correlations.

Fit within IUGS Science Policy: The objectives of the Subcommission involve two main aspects of IUGS policy: 1) The development of an internationally agreed chronostratigraphic scale with units defined by GSSPs where appropriate and related to a hierarchy of units to maximize relative time resolution within the Permian System; and 2, establishment of framework and systems to encourage international collaboration in understanding the evolution of the Earth and life during the Permian Period.

3. ORGANISATION-Interfaces with other international project/groups

SPS interacts with many international projects on formal and informal levels. Shuzhong Shen, as one of the principal proposer, we are applying for funding from various resources in China to support the Deep Time Digital Earth (DDE) program. The current sponsors of the DDE proposal include the following IUGS constituent groups (affiliated international organizations and national members). These members will serve as founding members to support this proposal. This type of initiative could also provide an opportunity for partnership with regional and international associations of universities, publishers and datacenters.

List of members supporting the initiative:

International Commission on Stratigraphy (ICS)
International Association of Paleontology (IAP)
International Association of Sedimentologists (IAS)
International Association for Mathematical Geosciences (IAMG)
China Geological Survey (CGS)
British Geological Survey (BGS)
Russian Geological Research Institute
Commission on the Management & Application of Geoscience Information
American Association of Petroleum Geologists
International Association on the Genesis of Ore Deposits
Commission for Geological Map of the World
International Association of Geomorphologists

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4. EXTENT OF NATIONAL/REGIONAL/GLOBAL SUPPORT FROM SOURCES OTHER THAN IUGS

SPS chair Shuzhong Shen organized an international cooperative project on the correlation of the Guadalupian Series between South China and Mt. Guadalupe in Texas, USA, which is supported by NSFC.

A Strategic Priority Research Program "Processes and Mechanisms of Organismal and Environmental Evolution during the Critical Intervals in Earth History" led by Shuzhong Shen has been approved by Chinese Academy of Science (2018-2023). With the national team of more than 200 expert scientists in collaboration with numerous oversea scientists in synthetic stratigraphy, paleontology, sedimentology, geochemistry, geochronology and big data analysis and modeling, this program adopts interdisciplinary approaches to addressing major issues about evolution of life on earth from both temporal and spatial perspectives.

5. CHIEF ACCOMPLISHMENTS AND PRODUCTS IN 2018

A formal proposal of the Sakmarian-base GSSP was submitted to International Commission on Stratigraphy, which was approved by 100% in ICS. This proposal then was submitted to IUGS on June 30, 2018 and formally ratified by IUGS EC on July 21, 2018.

A volume of Special Publication (*The Permian Timescales*. Geological Society, London, Special Publication **450**) has been published by Lucas, S.G. and Shen, S.Z. (2018). This volume reviews the state of the art of the Permian timescales of the SPS including geochronology, high-resolution biostratigraphy based on various fossil groups (conodonts, fusulinids, brachiopods, plant fossils, radiolarians etc.), magnetostratigraphy etc. and a latest Permian timescale is also presented.

A Special Issue on Integrative Stratigraphy and timescale of China has been published on Science China Earth Sciences (Shen and Rong, edited, 2019) now. This issue includes 13 periods and summarized the advances in stratigraphy and timescale from Ediacaran to Quaternary in China during the last two decades.

One regular issue of *Permophiles* (Issues 66) and a supplementary issue of *Permophiles* for the 8th Brachiopod Congress (66-Suppl. Issue) have been published in 2018. They are all available on the SPS website (http://permian.stratigraphy.org/pub/pub.asp).

6. SUMMARY OF EXPENDITURES IN 2018

We received a budget $3000 from ICS a few days ago. As planned in the 2017 annual report, this money was mainly pre-used for supporting the publication of *Permophiles*, and SPS Chair to meet SPS secretary Lucia Angiolini Milano in September, 2018 to edit *Permophiles*.

7. SUMMARY OF INCOME 2018

An amount 2195 Euro was allocated from ICS.

8. BUDGET REQUESTS FROM ICS IN 2019

We apply for 5000US$ from ICS for SPS activities in 2019. SPS Chair Shuzhong Shen will attend the 3rd International Congress on Stratigraphy (STRATI 2019, 2-5 July, Milano, Italy) and the International Congress on Carboniferous and Permian (ICCP, July 29-August 2, 2019, Cologne, Germany). Two SPS business meetings have been planned respectively during these two meetings. We will use a part of the money to support SPS voting members and young scholars recommended by SPS voting members to attend these two meeting.

We will also start to prepare the Artinskian and Kungurian GSSPs.

9. WORK PLAN, CRITICAL MILESTONES, ANTICIPATED RESULTS AND COMMUNICATIONS TO BE ACHIEVED NEXT YEAR

The primary objectives are to complete the remaining two GSSPs (Artinskian and Kungurian stages) and re-define/study the three GSSPs of the Guadalupian Series (Roadian, Wordian and Capitanian). The Russian Stratigraphic Committee has excavated the Dalny Tukas (Artinskian-base) and Mechetlino Quarry (Kungurian-base) sections as well. The next target of SPS is to publish the Sakmarian GSSP paper and complete the proposal for these remaining two Cisuralian GSSPs.

The priority of 2019 for GSSP is to:

1) Completing the Artinskian-base GSSP proposal for discussion and voting in SPS;

2) intensively study and clarify the problems in the three defined Guadalupian GSSPs;

3) Working on the replacement candidate section for the Lopingian-base GSSP at Penglaitan, South China.

10. OBJECTIVES AND WORK PLAN FOR NEXT 4 YEARS (2019-2022)

1) SPS Chair Shuzhong Shen together with Junxuan Fan of the GBDB group is actively involved in organizing the IUGS Recognized Big Science Program "Reconstruction of Paleogeography and Deep Time Big Data (DDE Program)". The main purpose and mission of DDE Program are to provide a dynamically linked, paleogeologically- and paleogeographically-referenced (spatially and temporally) digital earth database so a researcher, teacher or student can not only access the comprehensive datasets, but also analyze the data spatially, temporally and genetically. A formal proposal has been submitted to IUGS EC. This plan will be finally decided in the IUGS EC meeting held in February, 2019 in Beijing

2) Publishing the revised version of the proposals, organizing the field excursions and establishing the remaining two GSSPs for the Cisuralian.

3) Continue to work on the Guadalupian GSSPs and global correlation for chemostratigraphy and geochronologic calibration. Publish the official papers for the three Guadalupian GSSPs.

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List of Working (Task) Groups and their officers

1) Artinskian-base and Kungurian-base GSSP Working Groups; Chair-Valery Chernykh.
2) Guadalupian Series and global correlation; Chair-Charles Henderson.
3) Correlation between marine and continental Carboniferous-Permian Transition; Chair-Joerg Schneider.
4) Neotethys, Paleotethys, and South China correlations; Chairs Lucia Angiolini and Yue Wang.

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Henderson's Harangue #5

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Introduction

As an attempt to stimulate debate, or perhaps simply because something smells fishy, I deliver my fifth harangue. In Italian, it would be "*L' arringa di Henderson*" (the double "r" is important). Why is the double "r" important? Because *aringa* means herring, and one of my favourite lunch foods in the field is *aringa affumicata* (smoked herring). This is especially true as I type this on April 1st, which is often called April Fool's Day, but my colleagues in Quebec call it '*poisson d'avril'* (April Fish Day).

To capitalize or not to capitalize? That is the question.

I have seen variations in use and have been questioned by editors as to whether it should be Lower Permian or lower Permian; the latter being informal because, supposedly, there is a formal Cisuralian. Does it matter? Yes, according to the International Stratigraphic Guide (ISG 2nd Edition, Salvador (editor) p. 14), "the informal use of formal stratigraphic terms (formation, series…) in publications is *strongly discouraged*". There are also suggestions in the ISG that the intent of the originator(s) is important. The intention of the originators (Jin et al., 1997) seems very clear to me. Referring to the series of the Permian, they said "these are the Cisuralian, Guadalupian, and Lopingian Series and their constituent stages standardized respectively in the Urals, Southwest USA, and South China for the Lower, Middle, and Upper Permian". They capitalized!

When we formalize the Lopingian Series, are we not also formalizing the Upper Permian? If we do not, then we would have one definition for Lopingian and many for upper Permian. Lopingian is understood to the Permian specialist, but to most other workers it would be a strange word, poorly understood, until they were told it equals the Upper Permian. What is better for communication? I say "Let's Capitalize". The Global Stratotype Section and Point (GSSP) for the base-Lopingian, or base Upper Permian (also base-Wuchiapingian Stage), is located at the Penglaitan section of Guangxi Province (Jin et al., 2006).

Is the Global Stratotype Section and Point (GSSP) process useful?

I am feeling a little grumpy. Why? It is early spring so I shouldn't be, but in Calgary the transition from spring to summer is so slow. Spring arrived with the vernal equinox on March 20 at 14:58 MDT, but is it spring? The snow is all gone from the city, but it is only April 1, which means it could snow again at any time for two more months. The two metres of frost in the ground is just starting to thaw – soon it will be mud season. I am also feeling a bit grumpy because of criticisms of the GSSP process, which has been a focus of my career - we have not yet transitioned to full acceptance of this process.

Spencer Lucas (2018) wrote a critical review of the GSSP method of Chronostratigraphy. It is a well written article, and it is useful to debate the merits of having a well-defined Geologic Time Scale. However, I disagree with several points and will begin my critique in this harangue, hopefully to be continued in a more formal publication.

Spencer's argument primarily focuses on four issues including 1) the fact that GSSPs are arbitrary decisions and not natural, 2) the fact that decisions are made by too few stratigraphic researchers, but by too many conodontologists, 3) the reductionism of chronostratigraphic hierarchy and 4) precision. He concludes by arguing "that the way forward is a return to the concepts of natural chronostratigraphy with improvements from techniques like quantitative biostratigraphy (p. 2)". I will briefly address these points and will conclude "that the GSSP process has and is continuing to produce a well-defined Geologic Time Scale and has been the impetus to significantly advance stratigraphic knowledge".

Arbitrary and Natural Decisions

I have heard the criticism many times: the philosophy of arbitrary decisions result in a random time scale reflecting the scientific and political bias of a few workers on a working group. Part of this stems from the fact that "arbitrary" is an interesting word, which can be used in both a negative and positive tone. In one case it can mean "based on random choice or personal whim without concern for reason or system or the wishes of others". In another case, it can mean "to judge based on only the facts" since the root of the word is 'arbiter' (to judge). Of course, not everyone wishes to believe that the judge is always fair, especially in today's political climate.

What did Ager intend (1993, p. 110) when he said "*let us make an arbitrary decision* (by a show of hands if necessary) *to define the base of every stratigraphical unit in a selected section*"? His next sentence makes it clear that a decision is needed before we can move on "with the real work of stratigraphy, which is correlation and interpretation." He is arguing that we must be the judge – we must decide. Imagine if there were different definitions for the Carboniferous-Permian boundary, as was the case less than 50 years ago. How could we correlate an event like the end of the Late Palaeozoic Ice Age (LPIA)? The Chinese originally defined the C-P boundary at the Maping/Chihsia contact, as I learned on my first trip to China during 1987. This arguably coincides with the end of the LPIA. This level was younger than the boundary in North America and Europe (more on that later). The final solution, at the FAD (first appearance datum) of *Streptognathodus isolatus* in a cyclic succession at Aidaralash, Kazakhstan may have been an arbitrary point in a lineage of accessory-noded conodonts, but it was a point that was chosen by many palaeontologists from around the world, respecting proximity to the traditional boundary in Russia (Davydov et al., 1998). This was not a random personal whim, but rather a choice that reflected an evolutionary event near a traditional boundary, long correlated by Russian workers.

At this level, as in many Ordovician to Triassic levels, a conodont evolutionary event was chosen because conodonts can be recovered from most closely spaced samples in great abundance. As a result, evolutionary patterns can be readily interpreted. Even though I have used the term "chronomorphocline", I have never been a big fan, because conodont species exhibit many patterns of evolution, including punctuated equilibria by heterochrony (changes in developmental timing) as well as gradual anagenetic patterns. Lucas (2018, p. 10) incorrectly assumes all conodonts exhibit anagenesis, suggesting the impossibility of selecting a point exactly within something continuous. I am willing to agree that the base-Permian was a random choice, but it was a level voted on by a majority of workers on the C-P Working Group, in the Permian Subcommission, and in the International Commission on Stratigraphy. It was voted on (paper ballots, not a show of hands) and passed after considerable scrutiny. I think this was a wise choice. This is true of most, if not all GSSPs. The GSSP at the base-Wuchiapingian is not so random – in fact, it might be described as a natural choice.

Natural Choices

Many systems in the days of Smith, Sedgwick and Murchison were defined at unconformities, because time gaps would accentuate biotic assemblage differences on either side of the unconformity. The GSSP process has forced the community to look for events/surfaces that can be correlated within continuous successions. I argue that a natural GSSP boundary can be chosen at the correlative conformity or maximum regressive surface (MRS) associated with a sequence boundary unconformity (Henderson's Harangue #1, 2016). The greatest sea-level lowstand of the Phanerozoic is at or near the end of the Middle Permian or Guadalupian. The chosen GSSP is at an arbitrary evolutionary event of *Clarkina postbitteri* (*postbitteri*). Henderson et al. (2002) argued that isolation during this lowstand may have led to the evolution of a new conodont genus, and chose the second species (or subspecies) of that new lineage to mark the boundary. This was because it was not clear whether the sudden appearance of *Clarkina postbitteri hongshuiensis* was the result of migration or of an evolutionary event at Penglaitan. By choosing this event in proximity to the MRS, strata above the unconformity will always be Lopingian.

What exactly are natural events? Lucas (2018) lists events like the Cambrian explosion, the great Ordovician biodiversification event, and the Devonian extinctions, as natural events. The Cambrian explosion and Ordovician biodiversification occurred over an interval of time that is still under debate. The definition of stages within these event intervals would allow their correlation and improve interpretation. I suggest that sea-level fluctuations are as natural as any event in stratigraphy. The coupling of these abiotic events with evolutionary biotic events makes them among the best choices for GSSP levels.

Another natural event might be the LPIA with major continental glaciation ending sometime during the Early Permian. An issue of homeomorphy of the conodont genus *Sweetognathus* has hampered correlation of the LPIA termination (see Henderson, 2018 and my Strati2019 paper at Milano). Lucas (2018) indicated that NA stages like Wolfcampian cannot be correlated with the international scale and suggested that "the idea of standard stages that can be applied globally is thus little more than an abstraction that should be abandoned (p. 13)". Lucas (2018) said that "the Wolfcampian and Leonardian of West Texas are two very distinct lithosomes and readily distinguished and correlated by fusulinid and ammonoid biotic events and physical events, namely regional depositional cycles (p. 13)". Earlier correlations suggested that the W-L boundary occurred within the Artinskian or Kungurian stages (Henderson et al., 2012). However, the newly minted base-Sakmarian boundary (293.5 Ma; Chernykh et al., 2016) correlates with the W-L boundary, as shown by a new interpretation of the *Sweetognathus* lineage. It seems that international stages and regional stages like the Wolfcampian can be correlated. It could be argued that this points to the so-called "infancy" of conodont study, but this is not true. It points to the value of integrating multidisciplinary studies and especially biostratigraphy and geochronology that can identify problems like homeomorphy. This correction has transpired because of the GSSP process.

Chronostratigraphic Hierarchy

The hierarchy of chronostratigraphy is generally accepted, and includes stage, series, system, erathem, and eonothem. Lucas (2018) referred to chronostratigraphic hierarchical reductionism, meaning that the GSSP process uses the lowest unit to define higher units, and that this trivializes those higher-level units. It is said that the term *reductionism* is one of the most used and abused terms. In a negative sense, reductionism might mean that a system is nothing but the sum of its stages. In a more positive sense, it could be said that a system is composed entirely of its parts and that the system will have features lacking in the stages. As it stands, the Permian System begins with a great ice age and ends with Earth's greatest extinction, with many additional climatic and base-level changes in between. I will need to read more on the philosophy of reductionism to comment further, but in summary, I see no alternative to the current system.

It is not possible to have a different definition for the base of the Asselian and base of the Permian. The ends of the Changhsingian Stage, Lopingian Series, Permian System and Palaeozoic Erathem are focused on a level close to Earth's greatest extinction, as seems appropriate. The Mesozoic Erathem, Triassic System, Lower Triassic Series and Induan Stage are defined by the evolution of a conodont species *Hindeodus parvus*, but are in fact heralded by many other perturbations including proximity to carbon isotopic shifts, temperature spikes and the survival and slow recovery of life as a whole. It seems the boundary was well chosen. We must not forget that the Triassic base is defined only at Meishan section D; everywhere else it is correlated using many stratigraphic tools and proxies.

Instability and Imprecision

I agree with Spencer that chronostratigraphy is a science, and that the science of chronostratigraphy will never end. I remember being chastised once at a meeting by Professor Vai (see Vai, 2001) for suggesting that a boundary should not be immutable. At the time I took it that my inexperience did not allow me to see why a boundary should not be revised in light of new data. However, the ISG (p. 24) does indicate that "revision or redefinition of an adequately established unit without changing its name requires as much justification and the same kind of information as proposing a new unit and generally requires the same procedures". This means that a working group should be formed by a subcommission of ICS and, if justified, a vote on the change should be conducted requiring 60% approval (see Lucas, 2018 figure 5). This allows many workers to be involved, if not directly then by commenting on a proposal in newsletters like *Permophiles*. In my opinion, we should consider only refinement and minor revision. In other words, we should embrace the Geologic Time Scale as constructed and not look for wholesale changes that would bring instability to the science of chronostratigraphy.

How precise is precise enough? Most phenomena that might be used to define boundaries, such as the migration of taxa once they have evolved, magnetic reversals, shifts in isotopic signatures, or the settling of iridium from a bolide impact, occur over an interval of time. In most cases, these would be viewed as geologically instantaneous and perhaps beyond the resolution of our various techniques. I suppose it could be argued that you cannot then establish a single point in the rock record as the definition of a stage boundary. The key to this dilemma is the recognition that the definition holds only at the stratotype section. For a section to be considered a stratotype, other chronostratigraphic tools for correlation must be established at the section with the knowledge that they will be correlated at other locations. The PTB is defined at Meishan by the FO of *Hindeodus parvus* (considered to be the FAD; see below), but a normal magnetochron, negative carbon isotopic shift, and a temperature spike (from conodont oxygen isotopes) also provide means to correlate. The shifts don't all coincide within a brief interval, meaning that a defining point is necessary. But the FO of *Hindeodus parvus* at Otto Fiord (Henderson and Baud, 1997) or Opal Creek (Schoepfer et al., 2013) do not define the PTB, but rather indicate proximity to the boundary and within an interval that can be narrowed using other stratigraphic tools. This can be tested using various quantitative methods like Unitary Associations (see, Brosse et al., 2016), but the UA method does not "produce a much more robust biozonation of higher lateral reproducibility than traditional biostratigraphic interval zones", as claimed by Lucas (2018 p. 13; a paper edited by Hugo Bucher and reviewed by Jean Guex who remain the primary users of UA). I teach the UA method to my students now (I admit that I have much yet to learn) and we use the Brosse et al. (2016) dataset, which includes data from some of my own papers, among others, as examples. The UA method is a deterministic program indicating that a single answer is produced, which is certainly appealing. However, data used for the method are the very same FOs of taxa used to define interval zones. Initial unitary association runs normally produce cycles that are resolved by deleting the weakest links and contradictions that are decided by majority rule. This indicates that those "arcs" must be replaced with virtual co-occurrences that may not have been observed, but in which there is some statistical probability that they could be observed. In other words, data are manipulated, presumably using expertise and experience, to come to a result with zero contradictions (run 2 in Brosse et al., 2016). The end result is essentially a program-generated series of assemblage zones separated by an interval in which the unitary association zone is not resolvable. As such, Unitary Association Zones can never be used in a GSSP process since they don't define a point. I am not downplaying the UA method, because I think it is an excellent independent procedure to test zonations and to point to correlation problems – this is why I ask my students to use it alongside traditional biostratigraphy (see Yuan et al., 2019). If the use of FOs is fallible or imprecise using one method, then their use is imprecise using any method. This is simply the nature of the "imperfections" of the rock record.

FOs and FADs

I wrote a short paper several years ago that still gets cited from time to time, called "Beware of your FO and be aware of the FAD" (Henderson, 2006). In this paper, I talked about local First Occurrence and First Appearance Datum as well as local Last Occurrence and Last Appearance Datum. The use of FO, FAD, LO and LAD seem well established, so I recommend we refrain from the use of LO and HO (as used in Lucas, 2018) to mean Lowest Occurrence and Highest Occurrence. Please don't ask me to elaborate on the importance of being aware of and beware of the HO.

Conclusion

The GSSP process has produced, and is continuing to produce, a well-defined Geologic Time Scale, and has been the impetus to significantly advance stratigraphic knowledge. To see how advanced we are in our knowledge of the sedimentary rock record, you need only glance at the 1000-plus pages in the Geologic Time Scale 2012 by Gradstein and others – and the updated 2020 version will appear soon. GSSPs are carefully selected arbitrary or natural points decided by a wide group of geoscientists, and are sufficiently both stable and precise enough to allow students of the Earth to begin to understand Earth's history. All we need are a few more decisions to complete the initial process – then we can continue to refine the GTS and interpret and correlate Earth's history in increasing levels of detail as we gather new data.

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The Permian through the eyes of pollen morphologists

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Dispersed pollen grains and spores are a useful stratigraphic tool, and that is particularly true for the Permian, with its abundant terrestrial deposits. For pollen morphologists, the Permian is unique because of the first appearance of several morphological types which became prominent later, during the Mesozoic. What might be the relation between such pollen taxa from the Permian and those found in the Mesozoic? Were the former produced by early members of plant groups whose heyday happened in the Mesozoic or by some their precursors? Alternatively, do we deal with cases of convergence or repeated independent appearance of the same characters in unrelated plant groups? One more aspect should not be forgotten: early members of a particular plant group did not necessarily have the same pollen as later members. Data on in situ pollen grains from Permian male fructifications can shed light on the problem. However, the amount of dispersed pollen types of unknown botanical affinities exceeds many times the amount of pollen types whose affinities are defined with certainty by in situ finds. This is true both for the Mesozoic and Permian, but for the latter even more so. The situation will become better with time, but we fear that many pollen variants will probably never be discovered in situ because of the incompleteness of the palaeontological record. A good remedy is to collect all possible information about such dispersed pollen grains not only by means of conventional light

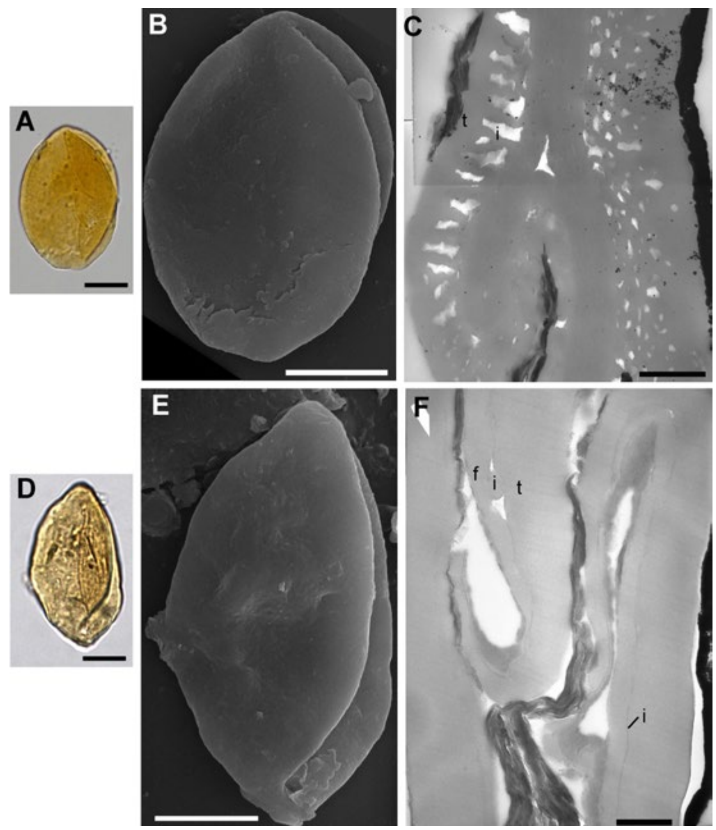

Fig. 1. A-C. Cycad in situ pollen grains from cones of *Androstrobus manis*, Jurassic of Yorkshire (reproduced from Zavialova, van Konijnenburg-van Cittert, 2016 and raw materials to this paper). D-F. Dispersed pollen grains of the hypothesized ginkgoalean affinity from the Cretaceous of the Russian Far East (reproduced from Zavialova et al., 2011). A, D. Light microscopical images. B, E. SEM images. C, F. TEM images. C. Note a thin tectum (t) and a typically cycadalean infratectum (i) with regular perpendicular alveolae, visible to the left of the image. **F.** A co-occurrence of a thick solid tectum, a thin infratectum, and a thin foot layer is typical of a ginkgoalean exine ultrastructure. Compare with Osborn and Taylor (1995, fig. 1, 9 for the morphology and ultrastructure of bennettite pollen). Scale bar (A, B, D, E) 10 µm, (C, F) 0.5 µm.

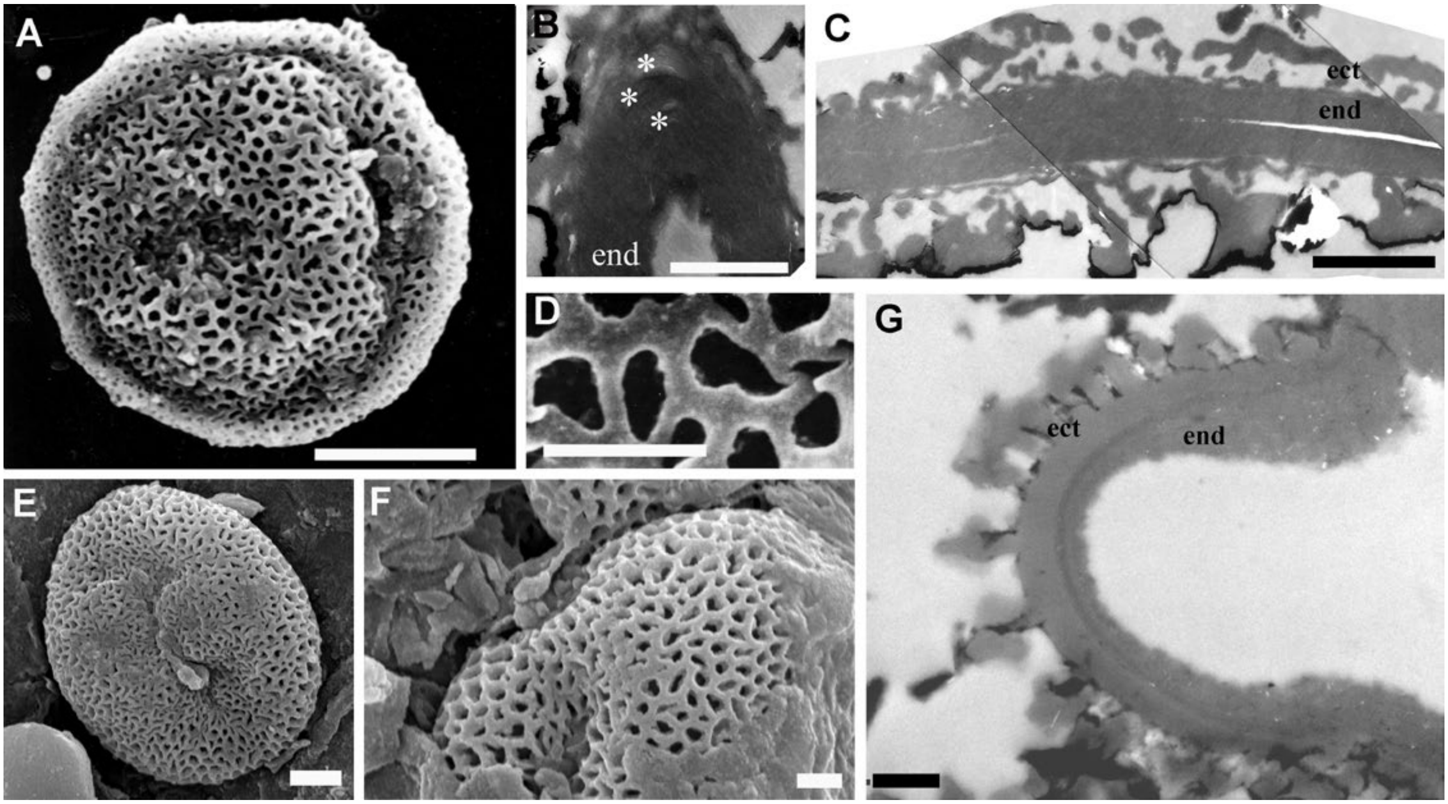

Fig. 2. A-D. Dispersed pollen grains of *Reticulatina microreticulata* from the Permian of the Russian Platform (reproduced from Zavialova and Gomankov, 2009). A. Reticulate surface is evident. B. Enlargement of a section showing lamellae (asterisks) in the endexine (end), typical of a gymnospermous exine. C. Flattened exine of the pollen grain, note the endexine of a constant thickness. D. Enlargement of A. E-G. Pollen grains adhered to infructescences of *Frisiicarpus kubaensis* from the Cretaceous of the Kemerovo region, Russia. E. Pollen grain with a reticulate surface. F. Enlargement of pollen surface. G. Area of the exine, note columellate ectexine (ect) and non-lamellate endexine (end), which becomes thicker towards the aperture; both features are typical of an angiospermous exine. A, D, E, F. SEM images. B, C, G. TEM images. Scale bar (A) 20 µm, (B, F) 1 µm, (C, E) 2 µm, (D) 4 µm, (G) 0.5 µm.

microscope, but also by electron microscopes (scanning electron microscopy, SEM, and especially transmission electron microscopy, TEM), to hypothesize about their affinity.

For example, boat-shaped monosulcate pollen ascribed to the genus *Cycadopites* are common in Mesozoic deposits, where they are known to have been produced by bennettites, cycads, ginkgoaleans, as well as several other gymnosperm groups (Balme, 1995). This Mesozoic trio of gymnosperm groups is known from the Palaeozoic as well, but the majority of records are represented by fossil leaves, and the information about in situ pollen has been so far lacking (Taylor et al., 2009). On the other hand, *Cycadopites* sporadically occurs also in the Permian (e.g., Zavialova et al., 2001), but unlike in the Mesozoic it has never been found in plant macrofossils. Available data on in situ *Cycadopites* from pollen organs of different Mesozoic gymnosperms show that such pollen grains though being very uniform in general morphology discernible in transmitted light, are different in the ultrastructure of their exines, and TEM data allows us to differentiate between *Cycadopites* pollen grains of different botanical affinities (Fig. 1; Zavialova and Nosova, submitted). While waiting for in situ Permian *Cycadopites* to be found, a TEM study of dispersed *Cycadopites* from the Permian seems desirable.

Reticulate pollen grains are a reliable marker of the advent of flowering (angiosperm) plants, if one finds such pollen in Cretaceous palynological assemblages. However, reticulate pollen grains are known from much older deposits, including the Permian, where they are a challenge for interpretation rather than a proof of the presence of this plant group a hundred million years earlier than all other indices suggest. A dispersed reticulate pollen *Reticulatina* was studied from the Permian of the Russian Platform with TEM and a typically gymnospermous lamellate endexine was found in its exine (Zavialova and Gomankov, 2009). Earlier, pollen grains of this type were discovered in male cones of a Permian primitive conifer *Kungurodendron* (Meyer-Melikian et al., 1998). Both studies proved the gymnospermous affinity of this angiosperm-like pollen, whatever was the reason for the appearance of an angiosperm-like character much earlier than angiosperms appeared (Fig. 2).

Recently, we have studied the morphology and ultrastructure of another peculiar pollen, *Pretricolpipollenites bharadwaji*, from the Permian of Jordan (Tekleva et al., submitted). This is thought to be the earliest pollen grain with three sulci. Later, in the Mesozoic, similar pollen grains are incorporated in *Eucommiidites* (Tekleva et al., 2006). Much is still to be understood about this Mesozoic genus as well, which is

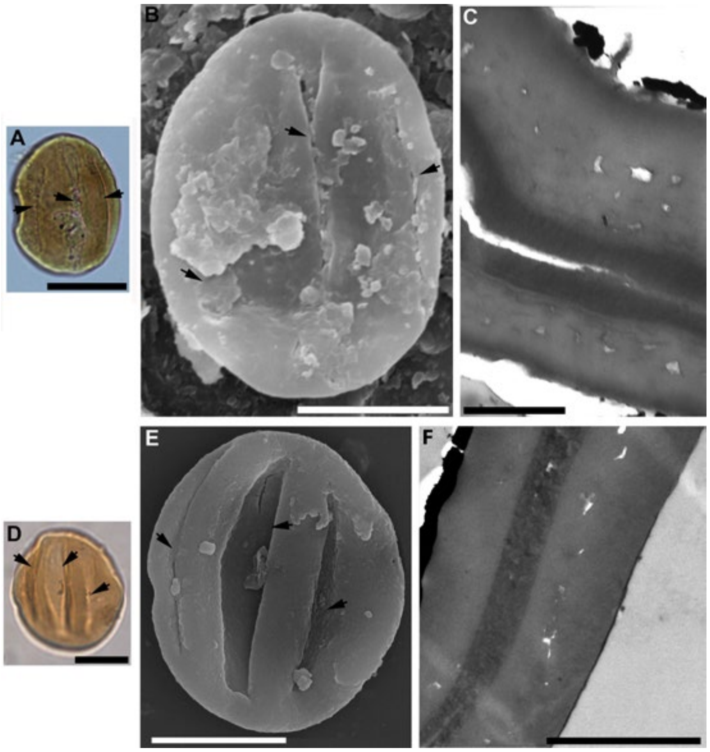

Fig. 3. A-C. *Eucommiidites* type pollen grains from pollen organs of *Hastystrobus muirii*, Jurassic of Yorkshire (B, C reproduced from Tekleva, 2012). D-F. Dispersed pollen grains of *Pretricolpipollenites bharadwaji*, Permian of Jordan. A, D. Light microscopical images. B, E. SEM images. C, F. TEM images. C. Note a difference in the ectexine thickness of proximal and distal pollen sides, with infratectal granules in several rows. **F.** The infratectal structure is not always discernable on proximal pollen side, the infratectal granules are disposed in one row. Arrowheads indicate the apertures. Scale bar (A) 20 µm, (B, D, E) 10 µm, (C) 0.5 µm, (F) 1 µm.

supposedly related to several groups within gnetophytes. As to *Pretricolpipollenites*, our study provides the first data on the exine ultrastructure of a member of this genus. The present state of knowledge of *Pretricolpipollenites* pollen does not allow any definite conclusion on its relationship with other similar taxa. Most probably, *Pretricolpipollenites* species are related to some *Eucommiidites* species, so these two genera might require taxonomic reconsideration (Fig. 3).

This note is to stress the importance of deeper knowledge of members of palynological assemblages. Their potential for stratigraphy is a consequence of the evolutionary fate of the parent plants. The more information about the plant-producers we are able to draw from pollen grains, the more substantiated their usage in stratigraphic and other reconstructions will be. A prospective method for this is an electron-microscopical study, particularly with help of TEM. Unfortunately, the number of studies on fossil pollen made with application of TEM constantly decreases. About twenty years ago, Hesse et al. (2003) wrote that “pollen morphologists are an endangered species and their field of work should be put on a Red data list”. The situation has not been much improved since their appeal.

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The Kungurian (Cisuralian) palaeoenvironment and palaeoclimate of the Tregiovo Basin (NE Italy)

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Introduction

The Permian was a time of profound climate and palaeogeographic changes. The end of consolidation of Pangea and the Late Palaeozoic Ice Age transformed terrestrial environments. The formation of the widespread continental ice sheets in the southern hemisphere and their waxing and waning gave origin to sea level changes (e.g., Ziegler et al., 1997; Montañez et al 2007; Montañez and Poulsen 2013) and caused palaeogeographic and palaeoenvironmental changes. The transition from humid and sub-humid climates (Pennsylvanian) to semi-arid and arid climates (late Cisuralian) was a stepwise change at low latitudes of Pangea (e.g., Montañez et al 2007; Montañez and Poulsen 2013; Falcon-Lang et al., 2014). The tropical terrestrial ecosystems were characterized by a transition from widespread humid to more drought tolerant floras. Conifers and other gymnosperms, better adapted to drier conditions, moved progressively from extrabasinal areas to the lowlands, increasing their preservational potential (e.g., DiMichele et al., 2011; Looy et al., 2014). Climate change and the turnover of the terrestrial biota left a strong imprint on the stable carbon isotope composition of atmospheric CO_2 and on its concentration (e.g., Arens et al., 2000; Montañez et al., 2007, 2016) as recorded by marine carbonates and terrestrial organic matter (e.g., Liu et a., 2016; Peters-Kottig et al., 2006). The carbon stable isotopic composition of Permian terrestrial organic matter ($\delta^{13}C_{org}$) ranges between −25.5‰ and −22.9‰, which is comparable to modern C3 plants (from −34‰ to −20‰; O'Leary, 1988). During the Cisuralian, the $\delta^{13}C_{org}$ values increased for several reasons, such as the sequestration of organic matter that started during the Carboniferous, tectonic and climatic processes linked to the consolidation of Pangea, the increase of weathering and the release of CH_4 from clathrate deposits (e.g., de Wit et al., 2002; Berner 2003; Peters-Kottig et al., 2006). The study of the plant remains from the small Tregiovo Basin (NE Italy), one of the few well-dated (Kungurian, late Cisuralian) and diverse fossil plant assemblages in western palaeoequatorial Pangea, provides new insights on the Kungurian floras and on the timing and dynamics of the hygrophytic–xerophytic transition. Moreover, a continental $\delta^{13}C_{org}$ record of a well dated portion of the Kungurian was obtained and possible relationships between the flora composition and potential local environmental factors versus global climatic forcing are suggested.

Geological setting

The Tregiovo Basin is a small, fault-bounded sedimentary basin in the upper Val di Non (Trento Province, NE-Italy) within volcanic deposits of the Athesian Volcanic Group (Marocchi et al., 2008). The Tregiovo Formation is overlain by the Auer/Ora Formation (274.1 ± 1.6 Ma) and sits on the Gargazzon/Gargazzone and Gries formations (276.5 ± 1.1 Ma); thus, it is mid Kungurian in age (Avanzini et al., 2007; Marocchi et al., 2008). The Tregiovo Formation has been subdivided into five lithozones: i) basal conglomerates, ii) laminated pelites, iii) carbonate-cemented and laminated pelites and iv) sandstones and conglomerates. The type section is no longer accessible (Remy and Remy 1978). The fossil locality of "Le Fraine" (Tregiovo Formation) near Tregiovo yielded one of the best-documented Kungurian (Cisuralian) floras of eastern palaeoequatorial Pangea, although it is also well-known for vertebrate footprints and invertebrate traces and palynomorphs. The Le Fraine section is about 135 mm thick and crops out near the small village of Tregiovo (Fig. 1A). The lower part mainly consists of very thin laminated, dark, siliceous argillites and shales, deposited in a playa-lake to lacustrine environment (Marchetti et al., 2015). The plant fossils and footprints mainly occur from this part of the section. The upper part of the section consists of massive pelites, conglomerates and sandstones. The second Tregiovo outcrop, named Tregiovo village section (Fig. 1B), corresponds to the uppermost part of the Le Fraine section. The best preserved part of the Tregiovo village section (27 m) was studied from the palynological and geochemical points of view.

Material

Plant fossils come from the type section and from the Le Fraine section. The material from the type section consists of 12 specimens, stored at the Museo Civico di Storia Naturale of Brescia (Brescia Province, Lombardy Region, N-Italy) is labelled with the prefix "PA" followed by progressive but not consecutive numbers (00058–91). The material from the Le Fraine section consists of about one thousand slabs with plant remains that are partly stored at the MUSE Museo delle Scienze of Trento, labelled with the prefix "MUSE PAG" followed by progressive numbers (7089–7427) and part temporarily stored in the private collection of Mr. Ferruccio Valentini (Tuenno, Trento Province). The stratigraphic position of the plant remains from the type section is unknown. The plant fossils from Le Fraine were collected from two horizons, called "Flora A" and "Flora B", which respectively are at 45 m and 105 m from the base of the section (Fig. 1B). Flora A consists of about 400 slabs with plant remains and Flora B consists of about 700 slabs. Eight palynological samples have been collected from the two horizons of the Le Fraine section yielding plants (Fig. 1B), and six along the Tregiovo village section (Fig. 2). The palynological samples have been prepared at the laboratory

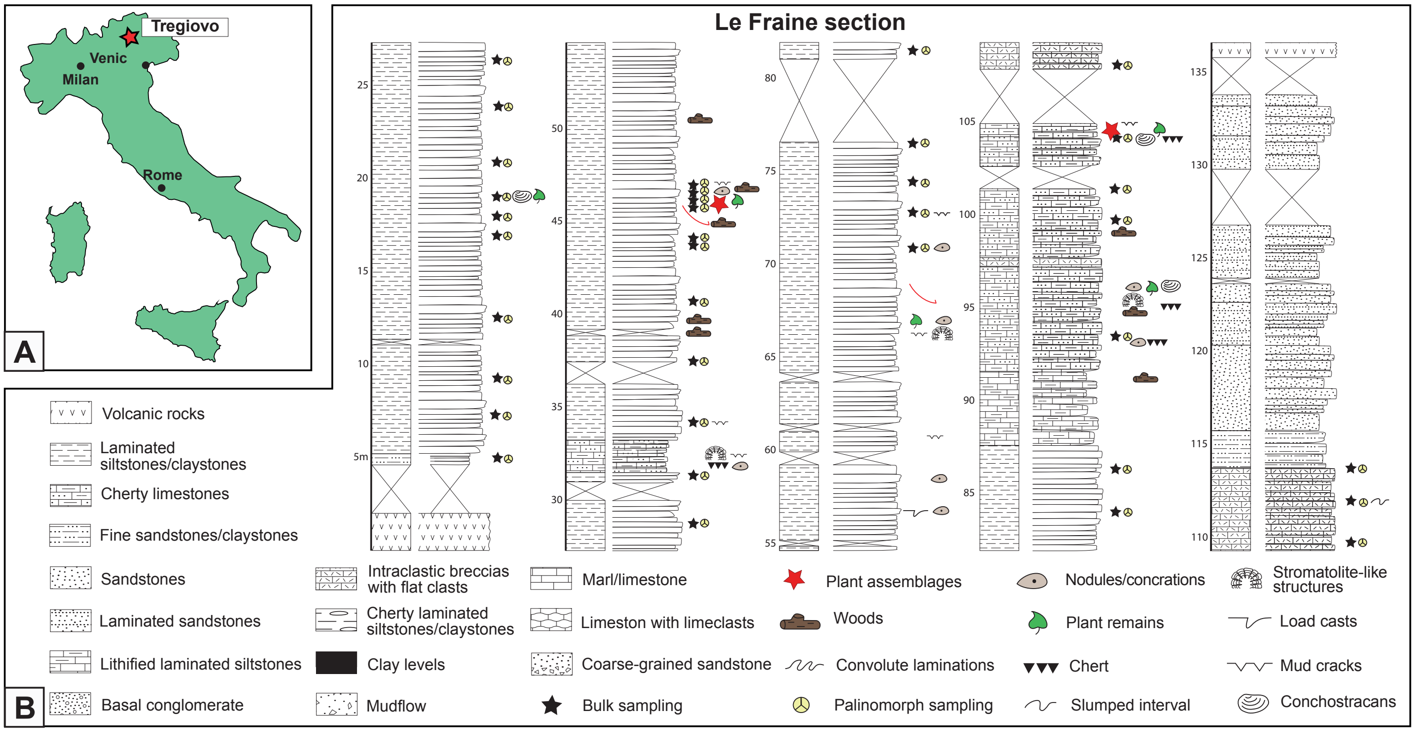

Fig. 1. A) Location of Tregiovo Basin; B) Detailed log of Le Fraine section.

of palynology of the Geosciences Department of Padova. Stable carbon isotope and TOC (Total Organic Carbon) analyses were carried out on 70 bulk rock samples collected along the Le Fraine and the Tregiovo village sections (Figs. 1B and 2). The samples were collected approximately every five meters, with a denser sampling interval (every 0.5–1 m) in the Le Fraine section near to the two horizons yielding plant remains.

Results

The sedimentological study of the Le Fraine and Tregiovo village sections allowed us to improve and reinterpret the former work of Marchetti et al. (2015), which was only focused on the Le Fraine section. In particular, the 27 m long portion of the Tregiovo village section, undisturbed and better exposed, allowed us to give a better description of the laminated pelites and microbial carbonate lithozones. In the laminated pelites, the most common facies is grey thin laminated pelites, which are from <1 mm to few mm thick, sometimes exhibiting normal grading. These pelites are more or less erodible, depending on their degree of cementation. X-ray powder diffraction analyses revealed the presence of quartz, feldspars and white mica of detrital origin. Fe-bearing minerals are also common, originating probably from the alteration of mafic minerals of volcanic rocks. Calcite is present throughout the Le Fraine section. The upper part of the laminated pelites lithozone is more cemented and nodules and layers of secondary calcite and chert are common. The contact between the laminated pelites and the overlying microbial carbonate lithozone is sharp in the Tregiovo village section, whereas it is poorly exposed at the Le Fraine. The microbial carbonates lithozone is made of an alternation of poorly sorted breccia beds intercalated with intervals of laminated pelites and thin poorly cemented beds of laminated fine sandstone. Laminated pelites, similar to those of the underlying lithozone, are affected by soft-sediment deformation indicated by the presence of convoluted lamination. Breccias occur in m-scale intervals of amalgamated beds, each 10–30 cm thick, made of carbonate intraclasts (from 1 mm to few cm in diameter) with a clotted peloidal fabric. Flat pebbles of laminated clotted peloidal micrite and sporadic calcitic spheroids, which are typical fabrics of microbial carbonates, occur as well. Carbonate clasts are embedded in a fine sandstone matrix with mainly quartz, lithics of possible volcanic origin, biotite, white mica and feldspar.

The palaeobotanical study revealed two very rich and diversified plant assemblages (A and B, Fig. 1B). Both assemblages are dominated by conifers. Other accessory groups are sphenophytes, ginkgophytes, ferns and/or seed ferns and at least three *incertae sedis* taxa. Sphenophytes are poorly represented, only two axis fragments (one specimen from each assemblage) with whorls of lanceolate leaves are attributable to the genus *Annularia* Sternberg, ubiquitous during the Carboniferous-Cisuralian. This represents the only occurrence of *Annularia* sp. from the Cisuralian of Southern Alps known so far. Several other remains, such as external impressions of stems with longitudinal vascular bundles and diaphragm of sphenophytes, have been found but not attributed to any genus.

The heterogeneous group named “ferns and/or seed ferns” includes several fronds, frond fragments, pinnae fragments and pinnules which belong to ferns and or seed ferns and ovuliferous organs of seed ferns. The latter are umbrella-shaped, lobed ovuliferous discs assigned to the genus *Peltaspermum* Harris, a peltaspermalean female reproductive organ, which are more abundant in the assemblage B (10%; Fig. 3) than in the assemblage A (2%; Fig. 3). Pinnules of the seed fern *Lodevia* (Zeiller) Haubold et Kerp occur in the assemblage A and in the collection of the Museo Civico di Storia Naturale of Brescia as well. Several

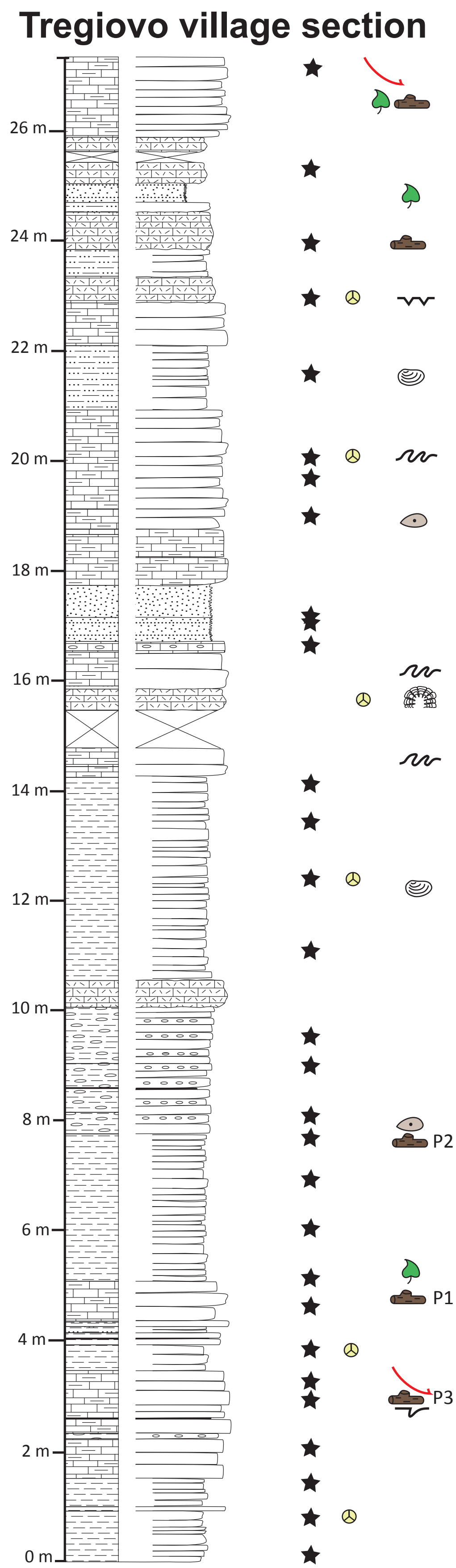

Fig. 2. Detailed log of Tregiovo village section. Symbols legend as in Fig. 1B

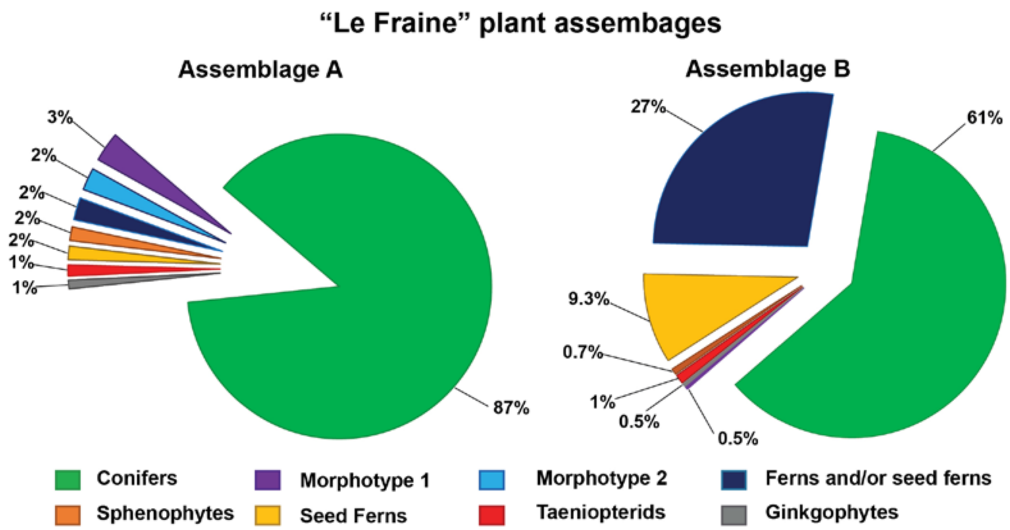

Fig. 3. Abundance of plant groups for the two different Le Fraine assemblages (A and B).

frond fragments are attributed to the genus *Sphenopteris*. The diversity of this genus is remarkable in the Tregiovo assemblage, where at least five different species have been found, respectively *S. kukukiana* Gothan et Nagalhard, *S. patens* (Althaus) Geinitz, *S. suessii* Geinitz, *Sphenopteris* sp. cf. *S. geinitzii* (Geinitz) Göppert and *Sphenopteris* sp. (Forte et al., 2018). The reproductive organs associated to *Sphenopteris* fronds are so far unknown and this prevents their attribution to the group of ferns or seed ferns. Ginkgophytes are poorly represented in the Le Fraine assemblages (2%; Fig. 3). Wedge-shaped leaves, deeply incised and forming two narrow lobes with rounded apex, are putatively attributed to the genus *Sphenobaiera* Florin (Fig. 4A) and were found only in assemblage A. Conifers are the dominant group in both assemblages (85% in assemblage A and 60% in assemblage B; Fig. 3). Foliate shoot fragments, leave and cones are very abundant and dwarf-shoots were also found. Among these, *Dolomitia* (Fig. 4B) and *Pseudovoltzia*-like dwarf-shoots were identified in addition to three dwarf-shoots morphotypes (i.e., Types A, B, C; Fig. 4C) with uncertain affinity (Forte et al., 2017). Foliate shoot fragments with helically arranged falcate needle-like leaves have been attributed to the genus *Hermitia* Kerp et Clement-Westerhof (Fig. 4G), whereas several foliate shoots, with rounded and short squamous leaves, have been attributed to the species *Hermitia geinitzii* Kerp et Clement-Westerhof, which was known previously only from the Cisuralian Collio Basin (north-western Italy, Lombardy region). *Feysia* Broutin et Kerp (Fig. 4F) is the most abundant taxon of the two assemblages (A and B). It is a broad-leaved conifer, with non- or hardly decurrent leaves, triangular to obovate and spirally arranged on the axis. Other foliate shoot fragments with spirally arranged spatulate leaves belong to the genus *Quadrocladus* Mädler (Fig. 4D), which is here reported for the first time in the Southern Alps. Further leaves with uncertain unknown affinity were found. The first taxon includes leaves with lanceolate laminae, a marked midrib and parallel, undivided veins arising from the midrib at an almost perpendicular angle that have been assigned to the genus *Taeniopteris* and occur only in assemblage A. A leaf morphotype, named Morphotype 1 is represented by leaves with a lamina that bifurcates symmetrically at least once, more rarely twice, forming ribbon-like segments with entire margins. Each segment is characterized by a central, wide midvein (or rachis) covered by some parallel wrinkles, whereas no secondary veins are visible on the lamina. Morphotype 2 is represented by big elongate leaves characterized by thickening in the basal area, serrated distal margin and distinct longitudinal and parallel veins. Both morphotypes occur in assemblage A and are scarcely represented (<5%; Fig. 3).

Palynological samples from Le Fraine are dominated by dispersed amorphous organic matter (< 70–90% of all the organic matter). Most of the amorphous kerogen has an undefined origin, although it originated probably from plant remains. A smaller portion can clearly be attributed to phytoclasts (i.e. altered wood fragments, cuticle fragments and conifer pitted tracheids). Fungal hyphae and spores occur as well, although exclusively in the lower assemblage. The very dark colour and the bubbly appearance of the sporomorphs indicate their poor preservation, which is likely attributable to diagenesis. Nonetheless, one sample collected from the Tregiovo village section (ca. 16 m from the base of the section, Trep 104), is better preserved (Fig. 2). Apertures, taeniae, ornamentation and the reticulate structures of sacci are clearly visible (Fig. 2). This sample gave us better insights in the diversity of the Kungurian microflora from Tregiovo. Palynoassemblage A (Fig. 2) is characterized by high number of undetermined sporomorphs (about 43%). Bisaccate pollen are the most abundant group, ranging from 45% to 60% (Tab. 1). Recognizable taeniate pollen grains range in abundance from 2.4% to 3.4% (Tab. 1) and include mainly *Lueckisporites* Potonié et Klaus, *Protohaploxypinus* Samoilovitch, *Protodiploxypinus* Samoilovitch, and cf. *Striatopodocarpites* sp. (Tab. 1). Non taeniate pollen are slightly more abundant, ranging from 0.63% to 5.8% (Tab. 1) and including *Illinites* Kosanke, *Gardenasporites* Klaus, *Limitisporites* Leschik, *Alisporites* sp., *Platysaccus* sp. and *Falcisporites* Leschik. Monosaccate pollen (<1%) are represented by *Potonieisporites* Bhardwaj and *Nuskoisporites* Potonié et Klaus. Poliplicate pollen are extremely rare (< 0.1%; Tab. 1). No

Fig. 4. Overview of the Tregiovo flora: A) *Sphenobaiera* sp.; B) dwarf-shoot of *Dolomitia* sp.; C) dwarf-shoot type A; D) shoot fragment of *Quadrocladus* sp.; E) undetermined conifer cone; F) shoot fragment of *Feysia* sp.; G) shoots of *Hermitia* sp.; scale bar 1 cm.

		PRODUCING PLANT GROUPS	REFERENCES	"LE FRAINE" SECTION A(%)	"LE FRAINE" SECTION B(%)	TREGIOVO VILLAGE SECTION (%) TREP02	TREP07	TREP17	TREP104	TREP25	TREP27
BISACCATE	**Taeniate**	Volziales, Majonicaceae (*Lueckisporites*); Glossopteridales, Peltaspermales (*Protohaploxypinus*); Unknown (*Protodiploxypinus*);	Balme, 1995; Clement-Westerhof, 1974, 1984	2.12	7.58	6.15	10.51	20.90	30.55	19.94	5.92
	Non taeniate	Voltziales, Ullmanniaceae (*Illinites, Gardenasporites, Alisporites; Limitisporites*); Corystospermales, Peltaspermales (*Alisporites, Falcisporites*); Unknown (*Platysaccus*)	Balme, 1995; Clement-Westerhof, 1974	2.35	11.01	0.31	0.00	4.82	16.08	0.00	0.31
	Indet.			51.02	43.59	56.92	59.32	53.05	42.77	65.73	85.36
	Total bisaccate			55.49	62.17	63.38	69.83	78.78	89.39	85.67	91.59
MONOSACCATE		Voltziales, Utrechtiaceae, Emporiaceae (*Nuskoisporites, Potonieisporites*)	Balme, 1995; Clement-Westerhof, 1974	0.63	0.66	0.31	1.69	5.14	0.96	2.81	0.31
POLIPLICATE		Peltaspermales (*Vittatina*)	Balme, 1995	0.08	0.87	0.31	0.00	1.29	0.32	0.28	1.87
SPORE		Various mosses, lycophyte, sphenophyte and fern families		0.00	0.51	0.00	0.00	0.00	0.32	0.00	0.00
PALYNOMORPHS INDET.				43.81	35.79	36.00	28.47	14.79	9.00	11.24	6.23

Tab. 1. Abundance of the palynological groups present respectively in the palynoassemblages A and B from Le Fraine section and palynoassemblages B from Tregiovo village section.

spores have been found. Palynoassemblage B (Fig. 2; Tab. 1) has around 35% of undetermined sporomorphs. Undetermined bisaccate pollen grains are the most abundant group, ranging from 41 to 45% (Tab. 1). The second most abundant group is represented by non-taeniate bisaccate pollen grains, which range from 6 to 16%, including basically the same genera that occur in assemblage A, such as: *Illinites*, *Gardenasporites*, *Falcisporites* and *Limitisporites*. Taeniate bisaccate pollen are less represented in palynoassemblage B (6–9%), and include *Lunatisporites*, *Lueckisporites*, *Protohaploxypinus* and *Protodiploxypinus* (Tab. 1). Poliplicate pollen are represented only by *Vittatina* Wilson, with <2.5% (Tab. 1). Similarly, monosaccate pollen grains are rare and basically represented by the genus *Nuskoisporites*. Spores are extremely rare, and never exceed 1%. Palynoassemblage B is better preserved in the Tregiovo village section. Here, bisaccate pollen are dominant as well (55–90%) including non-taeniate forms like *Falcisporites* and *Gardenasporites* and taeniate ones like *Striatisporites* and *Lueckisporites* (Tab. 1). Monosaccate pollen grains such as *Nuskoisporites* and poliplicate pollen grains are more abundant in the Tregiovo village section than in the Le Fraine section, whereas spores are very rare.

Rock samples from the Le Fraine section have a high organic matter content (1.2–2% TOC). The isotopic values of the organic matter range from –23.4‰ to –20.1‰ VPDB. The isotopic values are higher in the lower part becoming gradually lower along the section recording a negative trend. The most negative $\delta^{13}C_{org}$ values are recorded in the upper plant horizon (Fig. 5). The difference in $\delta^{13}C_{org}$ between the two plant horizons is about 1.7‰. The average values of the Tregiovo village section (−22‰ VPDB) are very close to the average $\delta^{13}C_{org}$ values of the upper part of "Le Fraine" (−21.7‰ VPDB), confirming that the Tregiovo village section corresponds to the uppermost part of the Tregiovo Formation.

Discussion and conclusions

A multidisciplinary study in the "Le Fraine" and Tregiovo village sections allowed us to improve our understanding of local palaeoenvironmental and palaeoclimate conditions in the framework of a more global context. Laminated pelites of the Tregiovo Formation deposited in subaqueous environment as testified by normally graded laminae and the common occurrence of freshwater fossils (conchostracans) are common. However, common mud-crack structures and tetrapod footprints imply also frequent subaerial exposure events. This facies association was interpreted as representing a playa-lake depositional system where ephemeral lakes likely dried up frequently, possibly seasonally. The overlying lithozone is characterized by the presence of carbonate intraclasts, flat pebbles and spheroids of microbial origin. The intercalation of these carbonates with laminated pelites suggest their lacustrine depositional environment. The lithozone with microbial carbonates contains little or no evidence of subaerial exposure, supporting a stable lacustrine environment rather than a playa lake in this phase.

The increasing aridity recorded during the Permian at low latitudes favoured the spread of conifers and other gymnosperms, including certain groups of seed ferns, due to their more drought-tolerant character with respect to other groups of Pennsylvanian–Cisuralian plant communities (e.g., DiMichele et al., 2008). The walchian conifers originated during the Pennsylvanian in drier extrabasinal environments, whereas the voltzian conifers appeared later becoming widespread from the late Cisuralian onwards, and consequently to the aridification, colonized also the lowlands (e.g., Looy et al., 2014). The

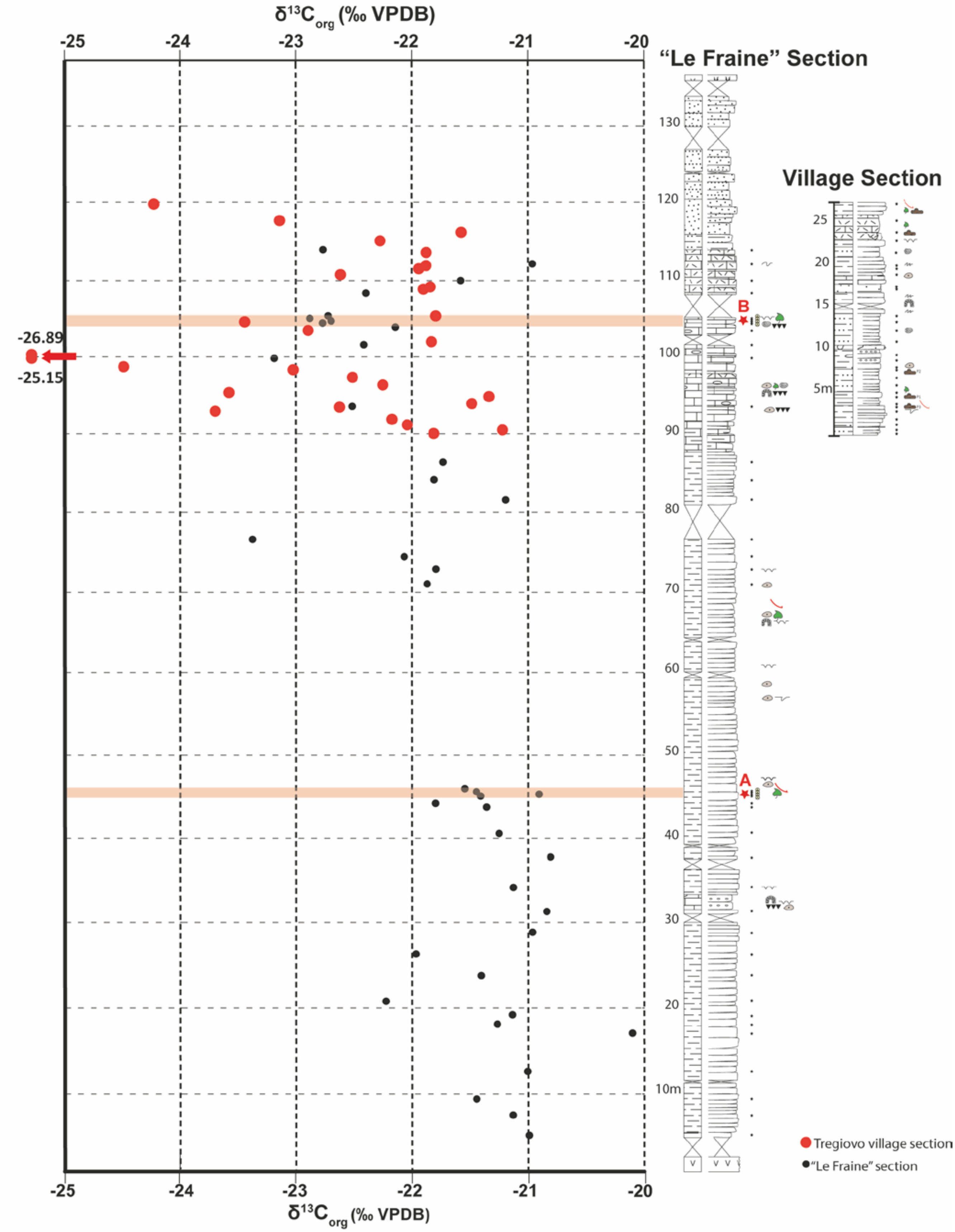

Fig. 5. $\delta^{13}C_{org}$ isotopic values measured along Le Fraine and the Tregiovo Village sections. The light orange band indicates respectively the palaeobotanical assemblages A and B. The proposed correlation is based on lithostratigraphy. Symbols legend as in Fig. 1B.

plant assemblages of Tregiovo reflect very well this aridification process. Walchian and voltzian conifers occur together in both Tregiovo assemblages (A and B). The finding of broad-leaved conifer branching systems, generally rare in the Cisuralian but dominant in the Tregiovo assemblages (>50%), is of particular interest and shows how they were more widespread during this time period than previously known. Moreover, the occurrences of *Dolomitia* and *Pseudovoltzia*-like dwarf-shoots in the Tregiovo plant assemblages allows to date back to the middle Kungurian the appearance of these two genera, adding important information on the evolution of conifers and on the transition from walchian to voltzian conifers in Euramerica.

The large number of plant fossils from the "Le Fraine" section (more than one thousand), together with material from the type section (20 specimens), make Tregiovo one of the largest and best documented Kungurian floras of the eastern Pangea palaeotropics. Plant material collected from the "Le Fraine" section showed how the floral composition changed through time, with a decrease in conifers and parallel increase in ferns and/or seed ferns from the lower assemblage A to the upper assemblage B. Conifers indeed are more abundant in assemblage A (86%) and decrease in assemblage B, parallelly to the increase in abundance of the ferns and/or seed ferns group, which range from 6% in assemblage A to > 30% in assemblage B. The group of ferns and/or seed ferns is mainly composed of the seed fern *Peltaspermum*, and the genus *Sphenopteris*, which includes pteridophyllous foliages with strongly lobed and dissected pinnules. The coriaceous nature of the reproductive organ and the fronds would rather suggest a xerophytic affinity for these plants.

Despite the poor preservation of the Le Fraine sporomorphs, likely attributable to the growth of pyrite cubes as result of sulphate-reducing bacterial activity and burial diagenesis, the sporomorphs from Tregiovo village section, in particular from the sample Trep 104, are well preserved and their analysis allowed to assess the potential preservational bias in all other samples. The palynological analyses of the Tregiovo assemblages allowed us to compare the palynoflora composition with the macroflora and test whether the latter was affected by any collecting or taphonomic biases or not. Moreover, since sporomorphs and macrofossils are subjected to different taphonomic processes the use of both datasets permitted a more complete understanding of the fossil flora. The palynological analysis shows that spores are very rare in both assemblages, according to the scarce occurrence of spore-producing plants (e.g., *Annularia* sp.) in the macroflora and indicate the xerophytic character of the assemblage. Nonetheless, we cannot exclude a selective degradation of spores. In palynoassemblage A and B nearly all determined palynomorphs are bisaccate pollen grains (Tab. 1), which belong to gymnosperms such as conifers, ginkgophytes, cycadophytes and seed ferns. Moreover, in palynoassemblage B an increase of palynomorphs attributable to ferns and/or seed-ferns (e.g., *Vittatina*) has been observed. The palynological analysis thus not only shows a strong correlation with the macroflora, excluding the presence of any significant collection or preservation bias, but also confirms the xerophytic character of both assemblages.

The $\delta^{13}C$ of Permian terrestrial organic matter ranges between −22.9‰ and −25.5‰, representing a strong signal of C3 photosynthetic plants. The values of $\delta^{13}C_{org}$ obtained from the "Le Fraine" section and from the Tregiovo village section, which range from −20.1‰ to −26.5‰ VPDB, are also within the interval of C3 plants. Thus, we considered the $\delta^{13}C$ of the finely dispersed organic matter contained in the bulk rock samples ($\delta^{13}C_{org}$) as representative of the $\delta^{13}C$ of terrestrial plants. The negative trend recorded along the Le Fraine section represents a well-dated portion of continental $\delta^{13}C_{org}$ record of the Kungurian. It may reflect the same isotopic trend that characterized the Palaeozoic global $\delta^{13}C$ curve. The decrease of $\delta^{13}C_{org}$ that characterized the Permian starting with the Guadalupian, could correspond to a decrease of organic matter burial in terrestrial sediments (Berner et al., 2003; Peters-Kottig et al., 2006), but also to other causes such as i) tectonic and climatic processes linked to the consolidation of Pangea, which could have reduced the organic carbon burial (e.g., Faure et al., 1995; Kidder and Worsley, 2004); ii) increase of weathering, which could have increased the erosion of coal beds resulting in the release of ^{12}C (Peters-Kottig et al., 2006); or iii) release of CH_4 from clathrate deposits (de Wit et al., 2002), which has a very negative $\delta^{13}C$ of ~ −60‰). In sight of this, the negative trend recorded at the "Le Fraine" and the Tregiovo village sections could correspond to the global negative trend, which had started in the late Cisuralian (Kungurian) and lasted until the Permian–Triassic boundary (Peters-Kottig et al., 2006). Nonetheless, we cannot exclude that the change in floral composition could be due to local environmental factors such as water stress, which would also have influenced the mean of bulk $\delta^{13}C_{org}$. Several authors (e.g., Peters-Kottig et al., 2006; Dal Corso et al., 2011) demonstrated that plant material (e.g., woods, cuticles, amber, coalified tissues) of different taxa may show significant differences of $\delta^{13}C_{org}$ values. Water stress/low relative humidity can affect the $\delta^{13}C$ of plants as well, causing a general increase of up to 3–6‰ (Arens et al, 2000). The isotopic shift at Tregiovo may thus simply reflect a change in the taxonomical composition of plants contributing to the bulk organic matter, such as the decrease of conifers and the parallel increase in ferns and/or seed ferns in the assemblages B, or local environmental factors. However, the trend towards more negative $\delta^{13}C_{org}$ by values, with an amplitude of >1‰, is comparable with that registered other continental deposits that are roughly coeval from North China and South Africa and was recorded in marine carbonate as well. Thus, although local ecological factors, change in the floral composition and water-stress may have had their effects, the negative trend $\delta^{13}C$ recorded at Tregiovo could well reflect the global decrease of $\delta^{13}C$ during the Kungurian.

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Age and duration of Olson's Gap, a global hiatus in the Permian tetrapod fossil record

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The Guadalupian (Middle Permian) is characterized by a worldwide change in the global assemblages of tetrapod vertebrates, with the extinction of the eupelycosaur-grade synapsids and the radiation of the therapsid synapsids, a change also evident in the tetrapod footprint record (e.g., Lucas, 2004; Voigt and Lucas, 2018). In evaluating the timing of this change, Lucas (2004) recognized a global gap or hiatus (named "Olson's gap") between the youngest Early Permian eupelycosaur-dominated tetrapod assemblages (which are in North America) and the oldest Middle Permian therapsid-dominated tetrapod assemblages (which are in Russia) (Fig. 1). Nevertheless, there has been some debate about the existence of Olson's gap in the vertebrate palaeontological literature, and the age and duration of the gap can now be more accurately determined based on advances in marine biostratigraphy, particularly of the Russian section. Here, we review those advances to present a more accurate estimation of the age and duration of Olson's gap than was published by Lucas (2004, 2006, 2017, 2018).

Lucas (2004) explained in detail why the youngest North American eupelycosaur-dominated Permian tetrapod assemblages (from the San Angelo, Flowerpot and Chickasha formations of Texas-Oklahoma) are late Leonardian (Kungurian) in age. In brief, this is because marine strata intercalated in the San Angelo Formation yield Leonardian fusulinids, and overlying strata at the base of the Blaine Formation (and the correlative San Andres Formation) yield ammonoids of Leonardian age. Furthermore, the oldest age of the San Andres Formation in the Permian basin of West Texas-southeastern New Mexico, which is correlative to the Blaine Formation of north-central Texas-Oklahoma, is approximately middle Kungurian (*Neostreptognathodus prayi* conodont zone: Kerans et al. 1993).

The oldest Guadalupian tetrapod assemblages for which marine biostratigraphic constraints exist are from Russia. So, the questions are, which is the oldest and how old is the oldest Middle Permian therapsid-dominated assemblage in the Russian section? Lucas (2004) considered Golyusherma to be the oldest of these assemblages, and it is of Early Kazanian age in the Russian Permian chronostratigraphy (Golubev, 2001) (Fig. 1). However, the therapsid-dominated tetrapod assemblage of localities from the copper-bearing sandstones in the vicinity of Perm City (Kutorga, 1838; Efremov, 1954; Efremov and Vjushkov, 1955) are now known to be older than the Golyusherma locality. They are in the Sheshmian interval (upper Ufimian) (Zhdanov, 2015) and thus the oldest therapsid-bearing strata in the Russian section (Fig. 1).

Lucas (2004) suggested that Olson's gap is equivalent approximately to Roadian time, based on the then current correlation of the Kazanian with the Wordian (e.g., Kotlyar, 2000). However, biostratigraphic studies of the ammonoids (Leonova et al., 2002; Leonova, 2007; Barskov et al., 2014) and conodonts (Chernykh et

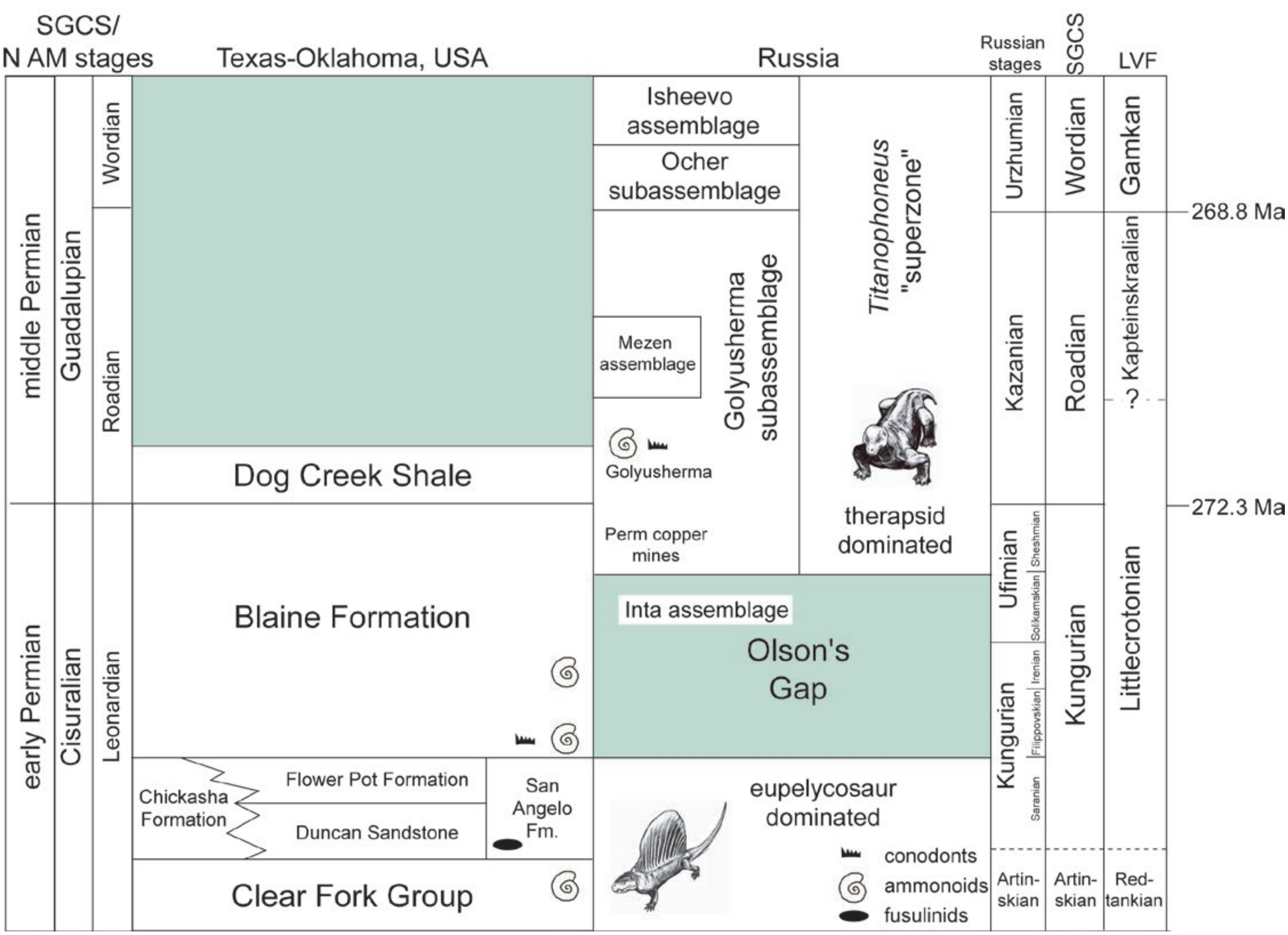

Fig. 1. Olson's gap is shown here as the hiatus between the youngest Lower Permian eupelycosaur-dominated tetrapod assemblages of Texas-Oklahoma, USA, and the oldest Russian Permian therapsid-dominated tetrapod assemblages. See text for discussion of marine age constraints on the correlation. Modified from Lucas (2004, 2018).

al., 2001; Larochkina, 2013; Davydov et al., 2018) have demonstrated that the Kazanian is older than Wordian; it correlates to the Roadian. Furthermore, the Russian Stratigraphic Committee moved the top of the Lower Permian (Cisuralian) Series of the Russian Permian chronostratigraphic scale upward to encompass the entire Ufimian (Resolution, 2006; see Lozovsky et al., 2009 for commentary on this; and note that Lucas, 2018 still considered the upper Ufimian [Sheshmian regional stage] to be Roadian). Thus, the Russian concept of Kungurian now encompasses five regional stages (ascending order): Saranian, Filippovskian, Irenian, Solikamskian and Sheshmian (the latter two comprise the Ufimian: Fig.1). This was not a new correlation of the Ufimian, but instead based on the fact that the base of the Roadian (base of the Guadalupian) is likely correlative to the base of the Kazanian. Some Russian stratigraphers eliminated the Ufimian and included the Solikamskian in the upper Kungurian and the Shesmian in the Kazanian (e.g., Klets et al., 2001; Chuvashov et al., 2002; Kotlyar et al., 2004), but the Russian Stratigraphic Committee did not support these suggestions. However, whether or not the upper interval of the Ufimian (Sheshmian) is actually Roadian, as it was considered by various workers, cannot be determined with certainty based on current biostratigraphy.

As noted above, in the American Southwest, the base of the San Andres Formation, the western equivalent of the Blaine Formation, is in the conodont zone of *Neostreptognathodus prayi* (Kerans et al., 1993). If this is the oldest age of the Blaine Formation in conodont biostratigraphy, then the base of the Blaine is about the same age as the Filippovskian of the Kungurian, which is in the conodont zone of *N. prayi* (e.g., Henderson, 2018). Therefore, the San Angelo tetrapod assemblage from Texas and equivalent tetrapod assemblages in Oklahoma (the youngest eupelycosaur-dominated tetrapod assemblages in North America) are older than the Filippovskian, which means that Olson's gap is equivalent to much of the Kungurian (as it has been redefined in the Russian section), encompassing the Filippovskian, Irenian and Solikamskian (Fig. 1).

The only tetrapod assemblage that clearly is in Olson's gap is the Inta assemblage from the Pechora basin in Russia (Fig. 1). This assemblage is essentially an endemic amphibian assemblage that resembles North American Early Permian amphibians in its stage of evolution, but cannot be otherwise correlated based on tetrapod biochronology, alone (Lucas, 2004).

Therefore, current marine biostratigraphic constraints indicate Olson's gap is a substantial interval of Kungurian time (Fig. 1). However, the duration of Olson's gap in numerical age terms is very difficult to evaluate.

Equating Olson's gap to the Roadian, Lucas (2004) suggested it was 2-4 million years long. However, its equivalence to much of the Kungurian suggests it may be of longer duration, perhaps as much as 4-6 million years. Nevertheless, there are no reliable numerical constraints tied to useful marine biostratigraphy within the Kungurian, and the beginning of Kungurian time has only been indirectly estimated at about 283.5 $\pm$ 0.5 Ma (Henderson et al., 2012; Ramezani and Bowring, 2018). The age of the beginning of the Roadian is under discussion, with estimates ranging from ~ 273 to ~ 277 Ma (Wu et al., 2017; Davydov et al., 2018). Depending on which date is chosen, the Kungurian is either ~10 or ~6 million years long. Chronostratigraphically, Olson's gap looks like it represent most of Kungurian time (Fig. 1), and this suggests it could be at least 4 million years long. However, better numerical age control within the Kungurian will be needed to provide a more accurate estimate of the duration of Olson's gap in millions of years.

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Uncovering *Tapinocaninus pamelae* (Synapsida: Therapsida): the most complete dinocephalian skeleton from the lowermost Beaufort Group of South Africa

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Dinocephalian therapsids comprise an important component of Guadalupian terrestrial tetrapod biodiversity of Pangaea. The taxonomically most diverse dinocephalian faunas are from the *Eodicynodon* and *Tapinocephalus* assemblage zones (Beaufort Group) of South Africa (King, 1988; Modesto and Rybczynski, 2000; Rubidge, 1993). However representatives are also known from the Madumabisa Formation in Zimbabwe (Boonstra, 1946; Lepper et al., 2000; Munyikwa, 2001), the Ruhuhu Formation of the Songea Group in Tanzania (Simon et al., 2010), the Madumabisa Mudstone Formation of the Mid Zambezi Basin in Zambia (Sidor et al., 2014), the Rio do Rasto Formation of the Paraná Basin in Brazil (Cisneros et al., 2012; Langer, 2000), the Ocher and Ischeevo deposits from the Kazanian of Cis-Uralian Russia (Tchudinov, 1983) and from the Xidagou Formation at Dashankou, Yumen in western Gansu, China (Cheng and Ji, 1996; Cheng and Li, 1997). In addition to being the largest therapsids from the Guadalupian, dinocephalians were also the first large tetrapods to live on land in Gondwana (Rubidge, 1995, 2005; Rubidge et al., 2019), shedding light on the early evolution of gigantic body masses in basal synapsids.

Over the years, most dinocephalian research has focused on the cranial skeleton, while the postcranium has received only cursory attention in the literature (see Rubidge et al., 2019 for a historical review). Recently Rubidge et al. (2019) provided a detailed analysis and description of the postcranial skeleton of the tapinocephalid dinocephalian *Tapinocaninus pamelae*, based on the superbly preserved and prepared holotype (NMQR 2987) and a closely associated specimen (NMQR 2986) from the South African Karoo Supergroup (Figs. 1, 2). This almost complete skeleton of *Tapinocaninus* from the lowermost Beaufort Group of South Africa provides, for the first time, an accurate vertebral count for all the axial regions of a dinocephalian as well as inferences on limb posture and locomotion based on the very well preserved appendicular skeleton.

The discovery and preparation of *Tapinocaninus*

To date four dinocephalian families have been recognized from the South African Karoo Supergroup: Anteosauridae, Styracocephalidae, Tapinocephalidae and Titanosuchidae (Rubidge et al., 2019). Anteosauridae are considered the most basal clade while the Tapinocephalidae are more derived

Fig. 1. The superbly preserved and prepared holotype of *Tapinocaninus pamelae* (NMQR 2987) at the Evolutionary Studies Institute (ESI), University of the Witwatersrand. Marco Romano for scale.

(Kammerer, 2011), with *Tapinocaninus* being the most basal tapinocephalid genus (Rubidge, 1991). The material on which the Rubidge et al. (2019) description of the *Tapinocaninus* skeleton is based was found in 1985 by John Nyaphuli, of the National Museum, Bloemfontein. The original finding was represented by skulls and articulated skeletal material of two dinocephalian (specimens NMQR 2986 and 2987) of similar size, found very close together in a fine grained sandstone of the *Eodicynodon* Assemblage Zone on the farm Modderdrift in the Prince Albert district of the Western Cape Province of South Africa.

The very difficult and challenging excavation of the huge specimens, embedded in very hard surrounding matrix, was conducted over several field seasons between 1985 and 1989. Recovered material was initially mechanically prepared from 1985 to 1990 by preparators of the National Museum in Bloemfontein, and from 1990-2005 the process was continued by the Bernard Price Institute for Palaeontological Research (now Evolutionary Studies Institute) at the University of the Witwatersrand in Johannesburg (see Rubidge et al., 2019).

The superbly prepared holotype provided the basis for the new detailed description of the post-cranial skeleton of *Tapinocaninus* by Rubidge et al. (2019), enhanced by new digital technologies, including the use of 3D photogrammetric models.

Fig. 2. Bruce Rubidge (right) and Marco Romano holding the 'monster' head.

The post-cranium of *Tapinocaninus*: a mix of 'primitive' and derived features

In addition to remarkably well preserved cranial material originally described by Rubidge (1991), the holotype of *Tapinocaninus* has an almost complete and articulated vertebral column, and a very well preserved appendicular skeleton including: two clavicles, two scapulae, and an interclavicle for the pectoral girdle; two humeri and a right ulna for the forelimb; parts of the ilium, both ischia, a left femur, and a complete right hind zeugopodium for the pelvic girdle and hindlimb; differently, the cleithrum, radius, pubis and both anterior and posterior autopods are missing (see Rubidge et al., 2019).

This new study highlights that the axial skeleton of *Tapinocaninus* is characterized by 36 vertebrae comprising seven cervical, 20 dorsal, two sacral and seven caudal. Unlike the situation in *Tapinocaninus,* the celebrated mounted specimen of *Moschops* (AMNH 5552), the only other relatively complete postcranial skeleton of a tapinocephalid dinocephalian, is likely a composite of several skeletons. The articulated skeleton of *Tapinocaninus* has only seven caudal vertebrae, with the most posterior one being very small and most likely the terminal caudal vertebra (Rubidge et al., 2019). The study thus stressed that probably all tapinocephalids were characterized by a very short tail, a condition found amongst therapsids only in Dicynodontia which have 12-15 caudals (King, 1988; Angielczyk and Rubidge, 2013), and in contrast to the condition in *Anteosaurs* characterized by very long tail comprising up to 60 caudal vertebrae (Orlov, 1958).

A very distinct feature characterizing the cervical and more anterior dorsal vertebrae of *Tapinocaninus* is the presence of well-defined and deep rounded excavation on the lateral surface of the neural arch at the anterior base of the neural spine (deep fossae). Similar rounded lateral fossae are not known in other therapsid taxa, apart from the cervicals of *Anteosaurus magnificus* and *Moschops*, and the cervicals and anterior dorsal vertebrae of *Titanophoneus* (Rubidge et al., 2019). Similar fossae are also known in 'pelycosaurs', occurring along the vertebral column of

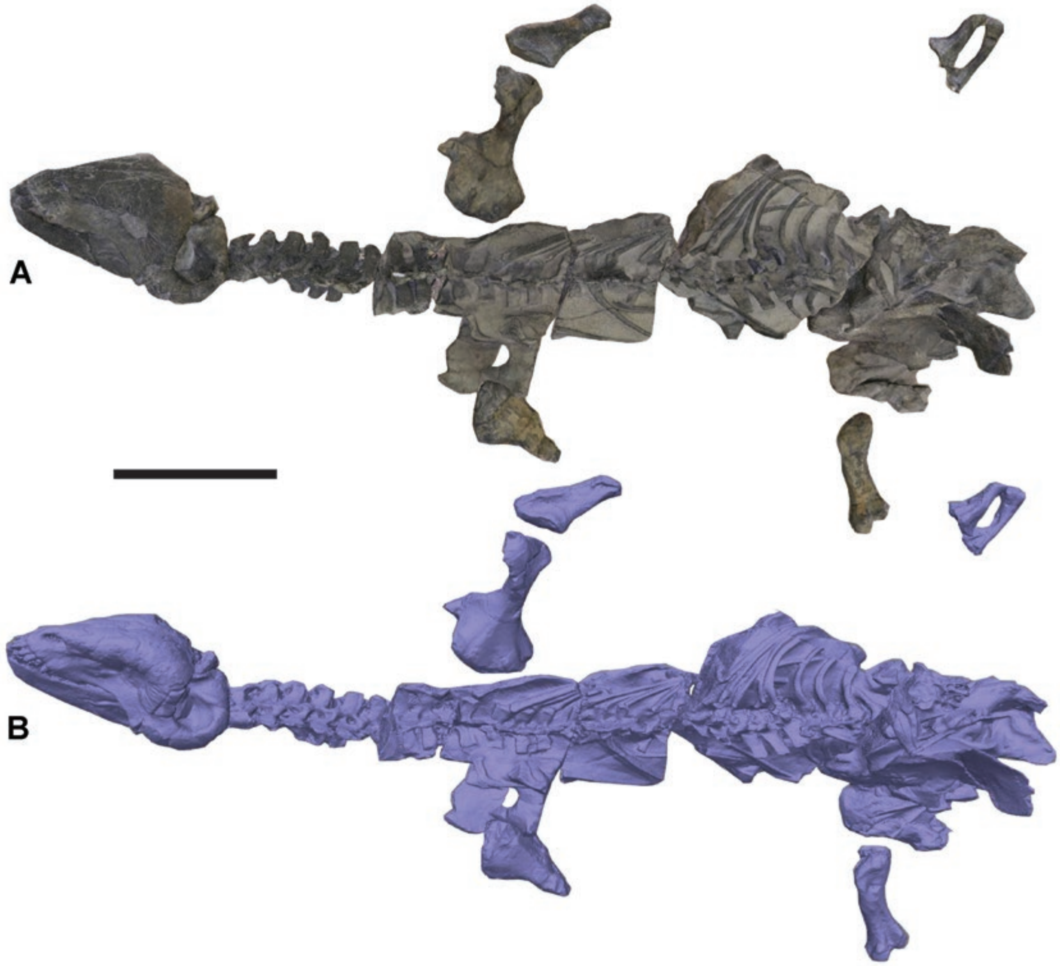

Fig. 3. 3D photogrammetric model of *Tapinocaninus pamalae* (modified from Rubidge et al., 2019, fig. 1). A, textural mode of the skeleton in dorsal view; B, solid model of the skeleton in dorsal view. Scale bar equal to 40 cm.

some taxa (see Romer and Price, 1940; Reisz, 1986), with the lateral fossae of sphenacodontines and secodontosaurines being the deepest and best defined (Reisz, 1986). Reisz (1986) considers the fossae at the base of neural spine to represent a derived character which evolved several times within "Pelycosauria". Considering that amongst therapsids this feature is present only on the cervical and anterior dorsal vertebrae of some basal dinocephalians (Rubidge et al. 2019), this condition very likely represents a plesiomorphic character for therapsids.

Appendicular skeleton structure and inferred posture

In *Tapinocaninus* the glenoid is postero-ventrally oriented suggesting that the pectoral girdle was more upright with respect to the condition characterizing sphenacodonts (Rubidge et al., 2019); with this conformation the humerus would have moved up and down rather than parallel to the substrate surface (Gregory, 1926). Conversely, amongst sphenacodonts the screw-shaped glenoid and laterally directed humeral articulation indicates a primitive sprawled limb position for the forelimbs (Romer and Price, 1940; Reisz, 1986). Differently, *Tapinocaninus* is characterized by a straight rather than a screw-shaped glenoid, and the articulating surface of the humeral head is not oriented terminally as in "pelycosaurs" (Romer and Price, 1940; Reisz, 1986), but is dorso-laterally directed as in dicynodonts (King, 1988). Thus, according to Rubidge et al. (2019), the overall structure of the humerus indicates a more upright posture than the condition characterizing sphenacodonts, but still with a certain grade of sprawling as observed in some dicynodonts (King, 1981).

The presence of an only slightly developed olecranon in *Tapinocaninus* is further evidence of a more upright posture with respect to sphenacodont grade synapsids (characterized by a well-ossified and developed olecranon), since a well-developed olecranon in the ulna allows a consistent insertion of the triceps muscle typical of sprawling tetrapods. Also the femur of *Tapinocaninus* is not characterized by a terminal position of the femoral head as in sphenacodonts, but is medially inflected. In general, the slightly curved shaft also observed in *Moschops* (Gregory, 1926), and the medially inflected head, confirms the more upright hind limb posture previously suggested by Boonstra (1966) for dinocephalians.

The combination of all these lines of evidence confirms that in *Tapinocaninus* the humerus had a more upright position compared to the condition characterizing 'pelycosaurs'. Early dicynodonts had a more sprawling posture (King, 1981), when compared with the more erect forelimb inferred for gorgonopsians (Kemp,

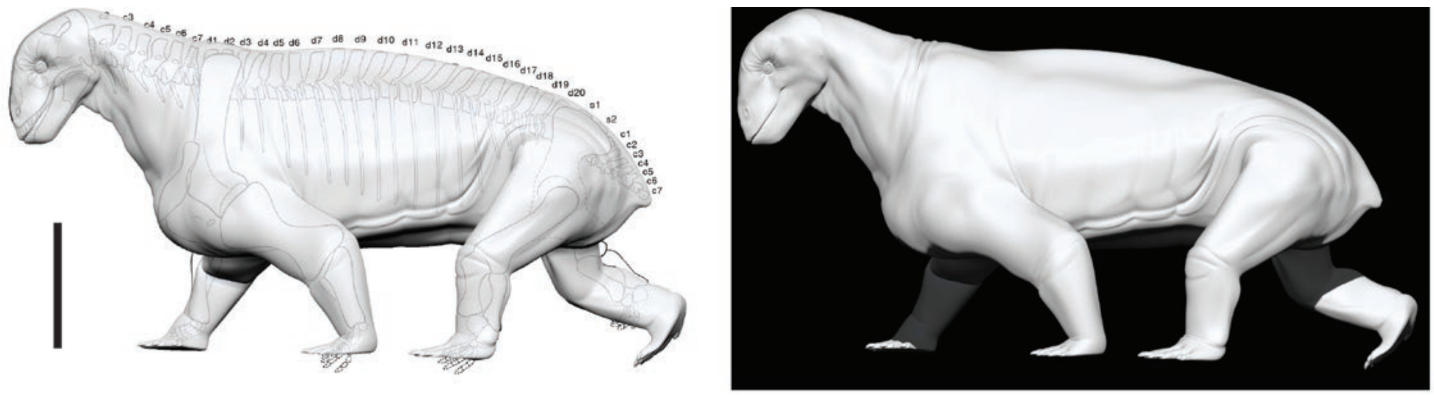

Fig. 4. Body mass reconstruction of *Tapinocaninus* based on skeletal proportions provided by Rubidge et al. (2019, fig. 10). Scale bar equal to 50 cm

1982), cynodonts (Jenkins, 1971), biarmosuchians (Sigogneau Russell, 1989) and therocephalians (Fourie and Rubidge, 2009). Differently, the hindlimb had a more upright posture, as suggested by the only slightly sloping distal articulation of the femur with the tibia and the medially inflected femoral head (see Rubidge et al., 2019).

With regard to overall body size and mass, the description of the post-cranium by Rubidge et al. (2019) demonstrates that the gigantic body size of tapinocephalids was already evolved in the most basal member of the clade. The orientation of articular surfaces of both the humerus and femur, along with the overall long bone morphology, indicating an "intermediate" general posture between a sprawling and erect stance, have been interpreted by Rubidge et al. (2019) as a possible structural response towards a more upright limb orientation, in order to accommodate biomechanical support for a large body size.

Future directions: *in-vivo* reconstruction and volumetric body mass estimate

The next step in the study of *Tapinocaninus* is the reconstruction of an *in-vivo* 3D model of the taxon, to give an idea of the life appearance of the animal in a classic Guadalupian environment and to calculate a putative body mass for the therapsid based on model volume and a range of densities for living tissues. Despite the significance of the huge size reached by dinocephalians, to date no detailed body mass estimations are available for the group, which, as already stressed above, represent the earliest large terrestrial tetrapods from Gondwana (Fig. 5). To accomplish this we produced a 3D photogrammetric model of *Tapinocaninus* based

Fig. 5. Two males *Tapinocaninus* facing each other in a typical Guadalupian South African environment. Artistic reconstruction by Emiliano Troco, oil on canvas 50x60 cm.

on the holotype skeleton using the software Agisoft PhotoScan (Fig. 3), and we used mounted skeletons of the dinocephalians *Ulemosaurus* and *Moschops* to reconstruct the missing autopods (Romano and Rubidge, under review). The software used to reconstruct the photogrammetric model is Agisoft PhotoScan Standard Edition, version 1.4.0 (Educational License). Agisoft PhotoScan enables automatic generation of point clouds, polygonal models, georeferenced true orthomosaics, textured and DSMs / DTMs from still images. High-resolution Digital Photogrammetry is based on Structure from Motion (SfM) (Ullman, 1979) and Multi View Stereo (MVS; Seitz et al., 2006) algorithms. This has an accuracy of at least 1 mm for close-range photography for the obtained models. Photogrammetry has become a useful tool in vertebrate paleontology, ichnology and geology *sensu lato*, allowing a wide range of new approaches and dissemination of data (e.g. Castanera et al., 2013; Citton et al., 2015, 2017, 2018, 2019; McCrea et al., 2015; Cipriani et al., 2016; Romano and Citton, 2016; Petti et al., 2018; Romano et al., 2018a, 2018b).

In collaboration with the Italian artist Fabio Manucci, the photogrammetric model was modelled in ZBrush, software for digital sculpting and painting, which also enabled separation of individual bones and body portions and digital modification and arrangement of the posture of the skeleton to perfectly fit the skeletal reconstruction of Rubidge et al. (2019). Using the software we modelled and sculptured the soft parts around the 3D photogrammetric model of the skeleton (Fig. 4), while the surface area and the volume were calculated using the software 3D Studio Max. Application of a living tissue density range of between 0.9 and 1.15 Kg/1000 cm^3 to the model, we reconstructed a body mass close to 900 Kg for *Tapinocaninus* (Romano and Rubidge, under review). Application of traditional regression formulae, based on long bone circumference (Campione and Evans, 2012), by contrast provides higher values of 1694.5 Kg and 2015.8 Kg. Similar overestimations using classical regression formulae have already been empirically demostrated in the literature, for example amongst stegosaurs (Brassey et al., 2015) and titanosaurian sauropods (Bates et al., 2015).

The study has demonstrated that volumetric body mass estimates are the most precise, and are recommended if mounted or relatively complete skeletons are available. The 'intermediate' posture inferred for *Tapinocaninus*, more upright than the sprawling condition characterizing sphenacodontid 'pelycosaurs' (Rubidge et al., 2019), could represent a structural response to a large body mass, which, for the first time in synapsids, reaches weights close to a ton (Fig. 5).

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No longer in the Mesozoic. The Permian world as a cradle for the origin of key vertebrate groups

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Ever since W. Smith and G.G. Simpson, the fossil record has been used to provide a fundamental timescale for, respectively, stratigraphers and evolutionary biologists. An accurate identification of First Appearance Datum (FAD) of key taxa is of fundamental importance for the development of a solid biostratigraphic framework. Similarly, the precise dating of the origin of taxa is of great relevance to both palaeontologists and evolutionary biologists, who investigate trends and rates in the evolution of life.

Notoriously, however, the fossil record cannot be read literally. It is full of gaps (Raup, 1972), it is highly dependent on rock outcrops availability and sampling (Smith and McGowan, 2007), and on the overall specific features of the rock record (e.g. Peters, 2005). Furthermore identifying the oldest fossil representative of a clade is notoriously difficult because: (i) they emerge within a single point in time and space, (ii) the earliest representatives will invariably lack fossilizable apomorphies of the living members of the clade; and (iii) fossils are usually incomplete and so it can be difficult to determine whether the absence of clade-specific diagnostic character reflects the nature of the organism or of its fossilization history (Donoghue and Benton, 2007). As stratigraphers know well, estimates of the FADs consistently underestimate global taxon ranges (Cody et al., 2008). In fact, the true distribution of FADs and LADs is unknowable (Sadler, 2004), and our identification of FADs are actually best estimates based on data from multiple locations.

However, in recent years, understanding the time of origin of major clades became a task increasingly more precise and easily available with the wide implementation of time calibrated relaxed clock approaches (see Drummond et al., 2006). In the beginning, molecular clock analyses became a powerful tool to estimate divergence times based on a given molecular data set and presuming a constant rate of evolution for a particular region of the DNA (locus). However, this assumption of constant rates could not be met when multiple loci and much broader phylogenetic data sets started to be compiled. Subsequent model improvements that allowed for rate variation across sites (molecular characters), accounting for different models of evolution for different molecular partitions (representing different clusters of loci evolving at similar rates) as well as relaxing the assumption of constant evolutionary rates across lineages (relaxed clocks) made divergence time estimation increasingly more reliable. Especially in the last decade, relaxed clocks became increasingly more flexible by accounting for different types of relaxed clock models (Lepage et al., 2007): from models where rates at each branch in a phylogeny are completely independent from each other (uncorrelated clocks), to others where the rate at a particular branch is dependent on the rates on the neighbouring branches (autocorrelated clocks), or on the clade where that branch is located (random local clocks). But perhaps the most important advance was the advent of the morphological clock — when the previous clock models are applied to morphological data using the Markovian model of evolution for morphological characters (Ronquist et al., 2012).

Once it became possible to apply relaxed clock models to morphological data only, or even combine morphological and molecular data to be analysed together, morphological data gathered for decades in the form of cladistic data sets could suddenly be assessed by likelihood based statistical approaches to understand the time of origin of major clades. Such analyses include estimates for entirely extinct lineages, for which molecular data is not available. As an example of the latter, we recently published (Simões et al., 2018) a large reptile data set, including both morphological and molecular data from both living and extinct species to understand the time of origin of the major reptilian clades (Fig. 1). The oldest known fossils for marine reptile such as sauropterygians (Jiang et al., 2014) and ichthyosaurs (Motani et al., 1998) and archosaurs (the lineage leading to crocodiles, dinosaurs and birds; Butler et al., 2011), are found in the Triassic, although recent trace fossil evidence suggests that some of this groups, notably the archosaurs, could have originated in the Late Permian (Bernardi et al., 2015). However, by using relaxed clocks that are able to co-estimate species relationships, evolutionary rates and divergence times we were able to prove that their origin is least a few million years older than the oldest fossils. We in fact identified the time of divergence for lepidosaurs (lizards, snakes, and tuataras), archosaurs, protorosaurs (early archosauromorphs), and many lineages of marine reptiles, including sauropterygians, ichthyosaurs and thalattosaurs was deep into the Permian.

This result matches the expectation that lineages are generally detected only when there are enough individuals available for at least some to be preserved as fossils (Ho and Phillips 2009). At the point of divergence of most lineages, however, clades are not yet abundant enough to generate fossils, and enough time must pass before their earliest representatives are a diverse enough to be the fossilized and subsequently recovered.

The latter corollary of diversification processes on divergence time estimates makes it imperative that more precise models of fossilization and fossil sampling are incorporated into relaxed clock approaches. Furthermore, it highlights the importance of an integrated approach to the fossil record. Knowledge of preservation biases, recovery rates and fossilization rates are therefore paramount to an accurate modeling of evolutionary change.

The fossil record is imperfect, but the integration of fossils and clocks could provide a more reliable timescale for the evolution of life which is crucial to both geologists and evolutionary biologists.

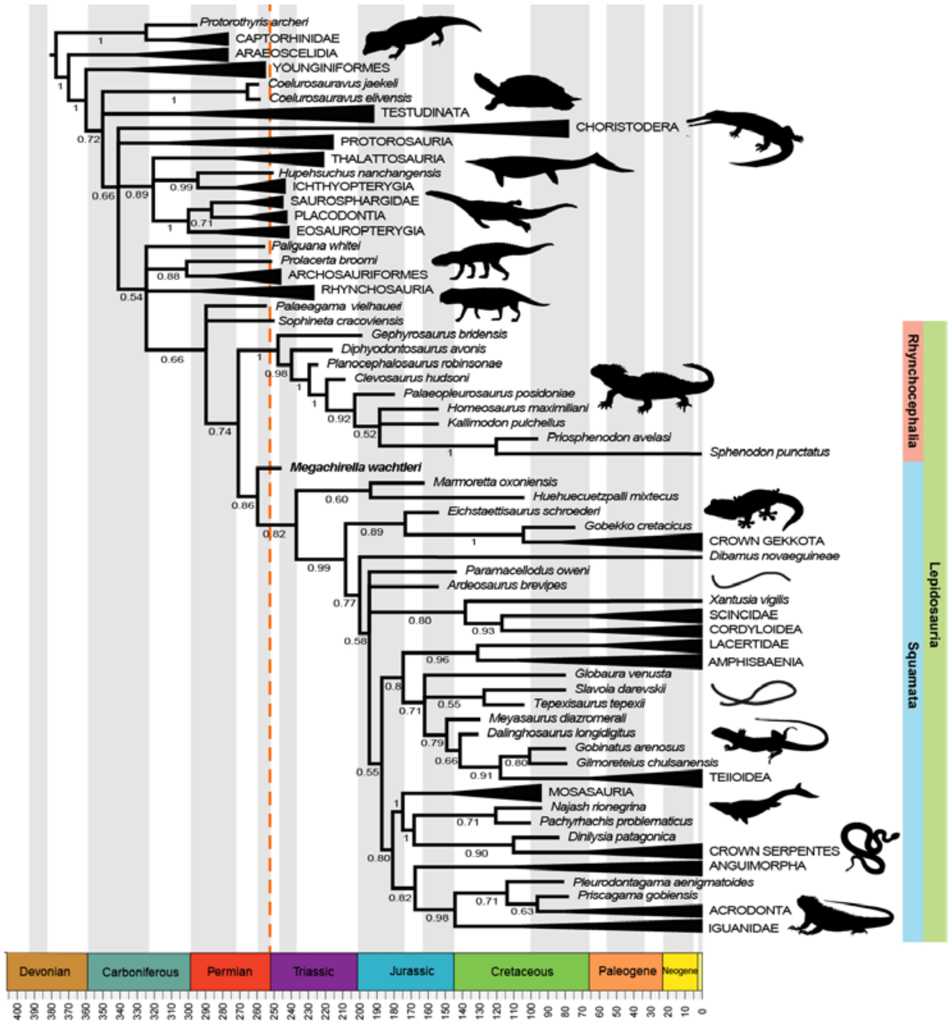

Fig. 1. Divergence time estimates using relaxed combined morphological and molecular clocks show that most diapsids lineages originated before the PTB, indicating that the Triassic was a period of radiation, not origin, for several diapsid lineages (modified from Simões et al., 2018).

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The present state of the Capitanian-Upper Permian bivalve stratigraphic scale of Northeast Russia in the light of the latest new fossil findings, dating of zircons, and δ^{13}Corg chemostratigraphy

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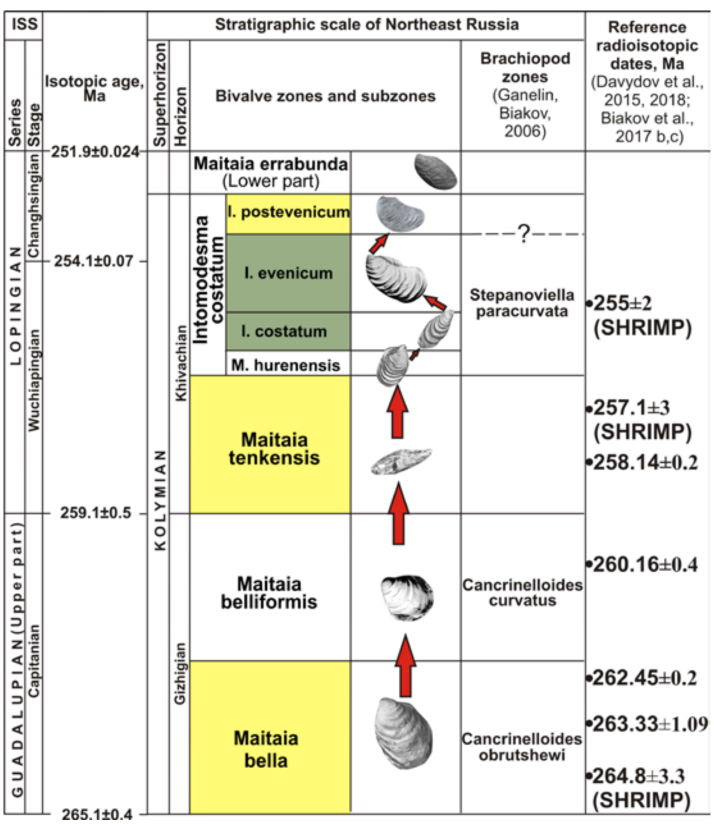

Fig. 1. Correlation the Capitanian-Upper Permian part of the bivalve stratigraphic scale of Northeast Russia with International stratigraphic scale.

The bivalve biostratigraphic scale is an important component of the Permian Regional Stratigraphic Scale (RSS) of the Northeast Russia. This RSS is the single complete stratigraphic sequence of Permian marine sediments in Russia and allows to correlate the sections not only in Northeast Asia, but also in all the regions of the eastern part of the Boreal Superrealm – North of the Siberian Platform, Taimyr, Novaya Zemlya and Transbaikalia (Ganelin and Biakov, 2006).

Bivalves are one of the most characteristic groups of Permian high boreal biota. They dominate the benthic communities and are very common in all types of sediments. Therefore, the bivalve biostratigraphic scale is very important for intra- and interbasin correlations.

Most of the bivalve scale (the upper part of the Lower – Upper Permian) is based on the phylogenetic sequence of *Inoceramus*-

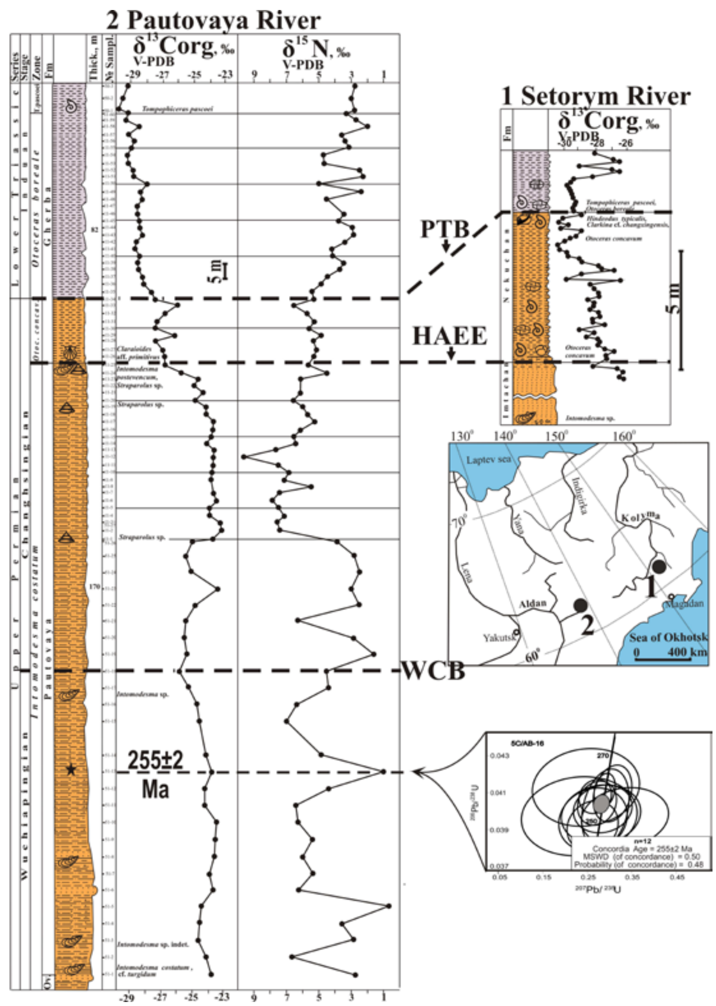

Fig. 2. Correlation of Permian -Triassic boundary deposits of the Balygychan basin at Pautovaya river (1) and South Verkhoyansk region at Setorym river (2). Ov., Ovod Formation; *O. boreale, Otoceras boreale*; *T. pascoei, Tompophiceras pascoei*. Map: *1*, Pautovaya river section, right bank of Kolyma river, Balygychan basin, Kolyma–Omolon region; *2*, Setorym river section, upper reaches of East Khandyga river, South Verkhoyansk region. The asterisk indicates the position of the dated tuff. HAEE – Hight-Arctic extinction event, PTB – Permian-Triassic boundary, WCB – Wuchiapingian-Changhsingian boundary.

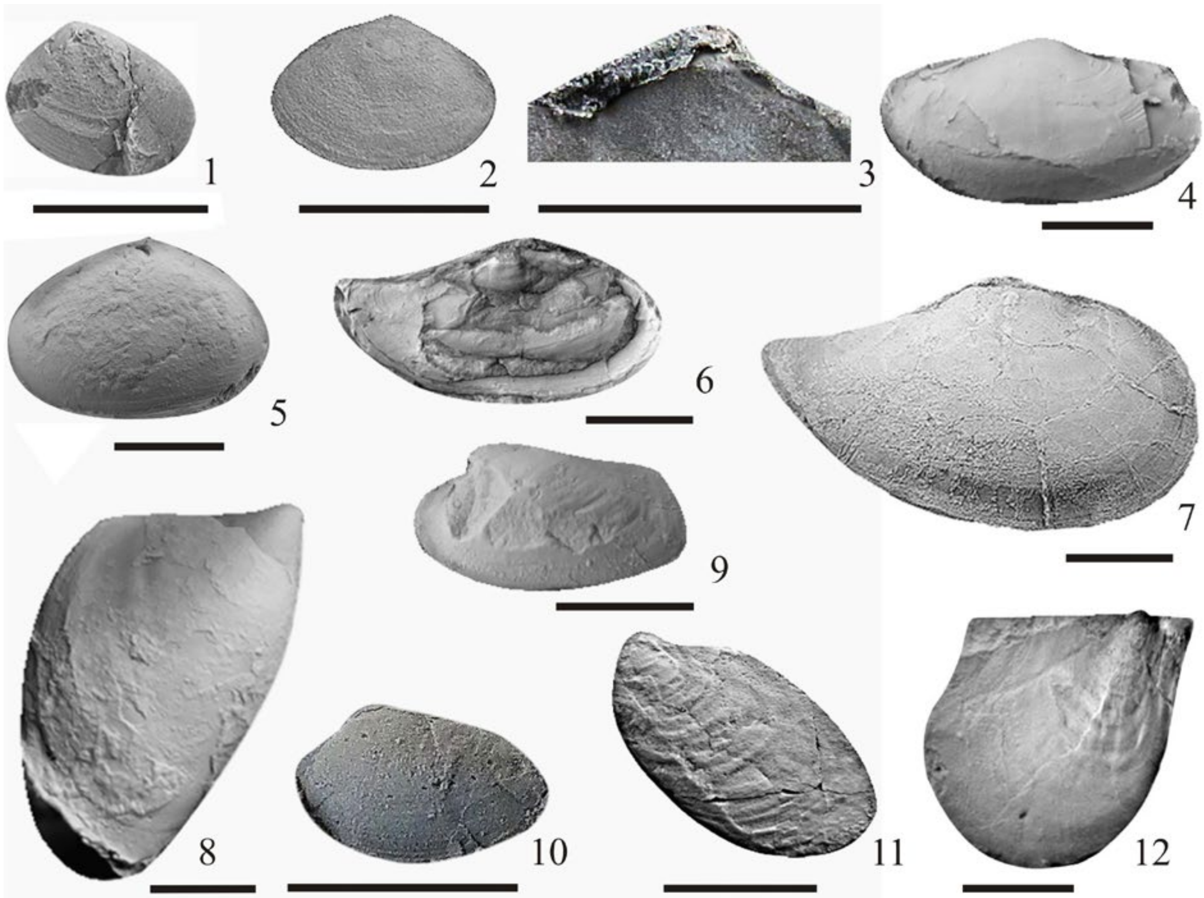

Fig. 3. The most characteristic Uppermost Changhsingian bivalves from the Levyi Suol section, South Verrkhoyansk region. 1–3, *Palaeonucula aldanensis* Kurushin; 4, *Malletia* ? sp. 1; 5, *Sarepta* ? sp.; 6, 7, *Dacryomya* sp.; 8, *Myalina* aff. *putiatinensis* (Kiparisova); 9, *Unionites* cf. *canalensis* (Catullo); 10, *Malletia* ? sp. 2; 11, *Maitaia* cf. *errabunda* (Popow); 12, *Pteria* cf. *ussurica* (Kiparisova). Scale bar 5 mm.

like bivalves (Biakov, 2010). The analysis of the morphogenetic changes in this group through the section and the reconstruction of its historical development makes it possible to avoid lacunae in the zonal scale and the use of evolutionary trends for the identification of bivalve zones particularly for the inter- and transregional correlations. The index species of these zones represent separate elements in the evolutionary succession of the most characteristic taxa of *Inoceramus*-like bivalves: *Aphanaia, Kolymia, Maitaia*,and *Intomodesma* (Fig. 1). At the same time, a high level of endemism of northeastern Asia Permian fauna (almost complete absence of conodonts and fusulinids) makes it impossible to directly correlate most of the regional Permian divisions in northeastern Asia with the Permian stages of the International Stratigraphic Scale (ISS). This is especially true of the Capitanian and Upper Permian. Because of this, the transregional correlation of Permian deposits is still one of the most debatable issues in the regional geology of northeastern Asia. Therefore, it is necessary to use non-biostratigraphic methods for correlation of the Northeast Russian sections and ISS.

The U-Pb TIMS and SHRIMP dating of zircons from tuff interlayers carried out in recent years made it possible to obtain several important reference levels in the Middle and Upper Permian part of the RSS (Davydov et al., 2016, 2018; Biakov et al., 2017a, b) (Fig. 1). This opens up new opportunities not only for calibrating the bivalve biostratigraphic scale, but also for its correlation with the ISS.

Another important element of the correlation of the sequences is the δ^{13}Corg chemostratigraphy, the study of which for the first time made it possible to trace the Wuchiapingian-Changhsingian boundary and PTB (Biakov et al., 2017b, c) (Fig. 2). Recently, study of the ^{87}Sr / ^{86}Sr ratio in biogenic carbonates of the Middle and Upper Permian has been carried out (Biakov et al., 2019, in press). These studies allowed us to identify the late Capitanian Sr minimum, stated in a number of sections of the world (e.g. Kani et al., 2013; 2018).

For a long time, it was believed that the uppermost (Upper Permian) sediments were absent in northeastern Russia and there was a hiatus between the Permian and Triassic. The recent discovery of an upper Changhsingian bivalve assemblage made it possible to get information on the youngest Permian bivalves of the Boreal region and more reliably substantiate the Changhsingian Stage in Northeast Asia (Biakov et al., 2018) (Fig. 3).

Thus, in recent years, many important materials have been obtained on Permian biostratigraphy, isotope dating, and chemostratigraphy of northeastern Russia. These studies make it possible to closely approach the use of ISS stages in the east of the Boreal Superrealm.

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Permian-Triassic boundary stratigraphy of the East European platform. The State of the Art: no evidence for a major temporal hiatus

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In Russia, the Upper Permian is united in the Tatarian Series, which consists of the Severodvinian and Vyatkian stages (Fig. 1). The Vyatkian is subdivided into the Lower and Upper substages. The Upper Vyatkian of the East European Platform (EEP) is represented by the Nefyodovian Regional Stage and the Zhukovian Regional Stage. The Nefyodovian is distinguished by the range of the *Wjatkellina fragiloides–Suchonella typica* ostracode Assemblage Zone (AZ) (Zhamoida and Prozorovskaya, 2006; Kotlyar, 2006), and the Zhukovian is distinguished by the range of the *Suchonellina perelubica–Suchonella rykovi–S. posttypica* ostracode AZ (Kukhtinov and Voronkova, 2012). The Zhukovian is overlain by the Vokhmian Regional Stage (Kotlyar et al., 2018), which corresponds to the *Darwinula mera–Gerdalia variabilis* ostracode AZ (Lozovskiy and Shik, 2011). The lower boundary of the Triassic is traditionally placed at the base of the Vokhmian (Lozovsky and Esaulova, 1998; Lozovskiy and Shik, 2011). A significant transformation of the East European continental biota occurred at the Zhukovian–Vokhmian boundary (Lozovsky and Esaulova, 1998).

It was traditionally believed that the Permian–Triassic boundary (PTB) on the EEP was characterized by a major gap in sedimentation (Lozovsky and Esaulova, 1998; Henderson et al., 2012). The idea of a temporal hiatus was formed by the end of the 1930s (Mazarovich, 1941; Efremov, 1952). It was based on the following geological features of the PTB beds (Mazarovich, 1941): (1) thick strata of sandstones with large lenses of extraformational sandstones and conglomerates with gravel and pebbles of Uralian metamorphic rocks appear for the first time at the base of the Triassic in different areas of the platform. (2) The East European Triassic lies on the different horizons of the Permian with features of strong erosion of the Permian deposits. (3) The late Permian and Triassic continental biotas differ sharply; there is almost no similarity between them.

Extensive geological and palaeontological material of the Upper Permian and the Lower Triassic of the EEP was assembled by the end of the 20th century. On these bases, arguments of the gap at the PTB were refuted (Golubev, 2004). In recent years, new data have been obtained indicating the chronostratigraphic continuity of the East European sequence. Many sections were studies in which the Zhukovian–Vokhmian boundary is placed inside a lithologically unified stratum — the Vokhma Formation (Golubev et al., 2012; Sennikov and Golubev, 2012; Sennikov et al., 2014; Lebedev et al., 2015; Scholze et al., 2015, 2019; Balabanov et al., 2016). Magnetostratigraphic studies of these sections showed that the Zhukovian–Vokhmian boundary is located in the normal magnetozone NPT (Fig. 1) (Golubev et al., 2012; Balabanov et al.,

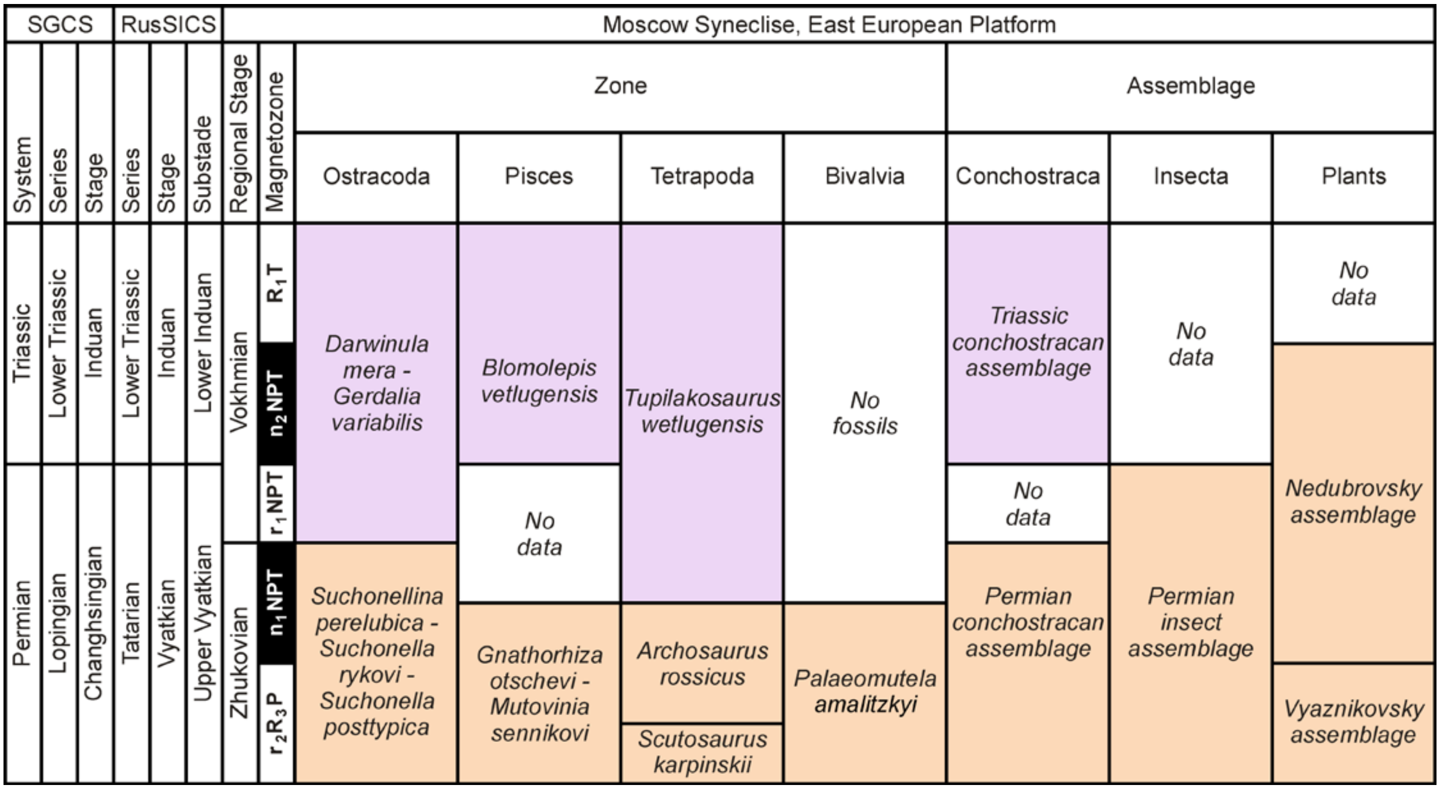

Fig. 1. Permian-Triassic boundary stratigraphic chart of the East European platform. Zone and assemblage ranges are based on an original data and on a synthesis of the literature (Arefiev et al., 2015, 2017; Aristov et al., 2013; Golubev et al., 2012; Karasev et al., 2018; Molostovskaya et al., 2018; Sennikov and Golubev, 2012; Scholze et al., 2015, 2019). Abbreviations: RusSICS – Russian Standard Interregional Chronostratigraphic Scale; SGCS – Standard Global Chronostratigraphic Scale.

2016). Similarly, the lower boundary of the Triassic in the GSSP Meishan section (China) is in a normal magnetozone (Yin et al., 2005). In some sections of the EEP, there is a subzone of reversed polarity (r_1NPT) in NPT magnetozone (Lozovsky and Esaulova, 1998; Arefiev et al., 2015). Based on ostracods, the n_1NPT magnetozone is in the Zhukovian and r_1NPT and n_2NPT magnetozones are in the Vokhmian (Fig. 1). The remains of tetrapods *Tupilakosaurus wetlugensis* Shishkin are found in the n_2NPT magnetozone (Golubev et al., 2012; Sennikov and Golubev, 2012). This indicates the early Induan age of these strata (Novikov, 2015).

Minimum δ^{13}C values occur in the lowermost Vokhmian, including r_1NPT magnetozone (Arefiev et al., 2015, 2017). This negative δ^{13}C excursion is evidence of the presence of the end-Permian mass extinction event horizon in the Permian–Triassic sequence of the EEP and corresponds to δ^{13}C negative excursion in Bed 25 of the PTB stratotype in Meishan (Cao et al., 2002). Thus the lowermost Vokhmian correlates with the uppermost Changhsingian (Fig. 1). The uppermost part of the Changhsingian can be recognized only in those sections on the EEP where δ^{13}C geochemical studies have been performed. In the sections for which the isotope-geochemical and magnetostratigraphic data and *Tupilakosaurus* remains are absent, the lower boundary of the Triassic is placed at the base of the Vokhmian (at the base of the *Darwinula mera–Gerdalia variabilis* AZ).

The n_1NPT magnetozone is characterized by Permian biota (Golubev et al., 2012). The tetrapods *Uralerpeton tverdochlebovae* Golubev and the ostracods *Suchonella typica* Spizharsky (Molostovskaya, 2010; Golubev et al., 2012) occur here and in the directly underlying Zhukovian deposits. The tetrapods and ostracods are representatives of phylogenetic linages *Chroniosaurus dongusensis* → *Chroniosaurus levis* → *Jarilinus mirabilis* → *Chroniosuchus paradoxus*, *Chroniosuchus licharevi* → *Uralerpeton tverdochlebovi* (Golubev, 1998, 2000, 2017) and *Prasuchonella nasalis* → *P. sulacensis* → *P. stelmachovi* → *Suchonella blomi* → *S. auriculata* → *S. typica* (Molostovskaya et al., 2018) respectively. These phylogenetic linages were reconstructed based on huge material from the numerous Severodvinian and Vyatkian sections of the EEP. They testify to the chronostratigraphic continuity of the pre-Vokhmian interval.

Newest biostratigraphic data from the sections near Gorokhovets town in Vladimir Region show a high degree of similarity between the Permian and Triassic nonmarine ostracode assemblages (Naumcheva, 2018). The first ostracods of the Triassic assemblage appear in the Zhukovian, and some typical Permian species continue to exist in the Vokhmian. A gradual, smooth renewal of the ostracode fauna, without major extinctions and occurrences, is observed during the transition from the Zhukovian to the Vokhmian in Gorokhovets sections. This confirms the absence of a meaningful temporal gap in the studied sequence and it is indicative of the chronostratigraphic continuity of the PTB interval on the EEP.

In contrast to the ostracods, many groups of the continental biota are sharply renewed at the Zhukovian–Vokhmian boundary. The tetrapod (Sennikov and Golubev, 2017), fish (Lozovsky and

Esaulova, 1998) and conchostracan (Scholze et al., 2015, 2019) faunas almost completely change, bivalves and gastropods disappear (Lozovsky and Esaulova, 1998), but early Vokhmian flora and insect fauna maintain similarity with the Nefyodovian and Zhukovian assemblages (Aristov et al., 2013; Arefiev et al., 2015; Karasev et al., 2018). Thus, the end-Permian reorganization of the East European biota was not a one-stage event. It comprised several phases and began with a tetrapod community crisis (Sennikov and Golubev, 2017) in the n_1NPT subchron (Fig. 1).

In Zhukovian–Vokhmian time, the nature of sedimentation was changing on the EEP. The Nefyodovian and Zhukovian deposits are represented by variegated carbonate-sandy-clayey alluvial-lake rocks. The Vokhmian Formation is composed mainly of red-colored sandy-clayey alluvial sediments with numerous carbonate-gley paleosol (e.g., Golubev et al., 2012). Landscape restructuring took place against a background of changes in the palaeoclimatic conditions. Significant cooling is reconstructed on the EEP at the Zhukovian–early Vokhmian time (Arefiev et al., 2016). It is possible that the change in the East European biota in the late Zhukovian and early Vokhmian time is associated with the restructuring of the East European geosystem. However, these changes coincided with the global end-Permian environmental crisis. Therefore, it cannot be excluded that the causes of these changes were global abiotic factors and not local ones.

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Report of the Chinese-Pakistan working group: The Permian-Triassic boundary sections of the Salt Range

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Abbottabad, Khyber Pakhtunkhwa, Pakistan

Supported by the Second Tibetan Plateau Scientific Expedition program, a research group composed of a Chinese party with S.Z. Shen, H. Zhang, Y.C. Zhang, J.T. Chen, F. Liu, Q.F. Zheng, D.X. Yuan, M. Luo, L. Yao, H.P. Xu and Z.S. Hou, and a Pakistan party with Muhammad Qasim, Amjad Ali Bukhari and Aneela Aurang Zeb (Figs 1-2) visited the sections in the western part of the Salt Range, near Mianwali in west Pakistan.

It took 9 days for the joint field excursion named 'Geological Field Trip of the Salt Range: Zaluch Nala and Chhidru Nala sections for the study of Paleozoic stratigraphy and environment', from March 11 to 19. The Permian and Triassic strata in these sections crop out in several valleys along the Salt Range. During the field trip, we sampled in great details for conodonts, foraminifers, brachiopods, palynology, ichnofossils and corals as well as sedimentology, and geochemistry. The sedimentary succession consists of the Middle-Upper Permian Amb, Wargal and Chhidru formations and the Lower Triassic Mianwali Formation. Those samples will be processed upon arrival.

The main goals are:

1) to establish a refined conodont and foraminifer biozonation for the Middle-Upper Permian and Lower Triassic of the Salt Range through a detailed sampling and a direct comparison and correlation with the biozonation of the Tibet and South China regions.

2) to compare the faunal diversity and paleobiogeography between the Salt Range and southern Tibet in order to understand the paleogeography of northern Indian Plate margin during the Permian time.

3) to study the brachiopod evolution throughout the Lopingian and near the Permian-Triassic boundary (PTB), focusing on the

Fig. 1. Group photo of the participants in the field excursion.

Fig. 2. Researchers spent their lunch time thrashing out geological problems in the field.

Fig. 3. The PTB in the Chhidru Nala Section.

Fig. 4. The researchers conducted field communications with local university teachers and students.

palaeocology and functional morphology of the fauna and the possible change in brachiopod biomineralization which are one of the best tools to understand the ocean chemistry in this critical time interval (e.g. Garbelli et al., 2017).

4) to study geochemistry of the bulk rock, conodont apatite and brachiopod calcite throughout the Lopingian in the Salt Range, Pakistan.

5) to investigate the sedimentology, sea-level changes and paleoenvironmental background during the Permian-Triassic transition as well as the Guadalupian-Lopingian transition in the Salt Range, Pakistan.

The Salt Range sections are well-known to Permian specialists around the world from the detailed study published by Pakistan-Japanese Research Group (1985), which is a classical research in this region both in contents and methodology, and is followed by many researches on the conodonts (Wardlaw and Pogue, 1995; Wardlaw and Mei, 1999), brachiopods (Waterhouse, 2010), corals (Kato and Ezaki, 1986), geochemistry (Baud et al., 1996; Hassan et al., 1999), depositional environment change (Mertmann, 2003), and palynology (Jan and Stephenson, 2011; Hermann et al., 2012; Schneebeli-Hermann et al., 2012; Schneebeli-Hermann et al., 2015).

The outcrops are of high standard, with the Permian developed above Precambrian, including salt deposits, developed in a complex anticlinorium over which the Permian is repeated by folding with thrusts (Waterhouse, 2010). After a whole day's driving, we reached the Zaluch Nala Section by walk for ~20 minutes from the car. We measured three subsections in the Zaluch Nala Section for correlation and comparison with each other, all of these subsections contain either the PTB or the Guadalupian-Lopingian boundary (GLB). The Chhidru Nala Section crops out a continuous Upper Permian to lowermost Triassic succession (Fig. 3), where we measured the entire section from the PTB at the top of a mountain down to the Guadalupian Amb Formation in the valley at the foot of the mountain.

We gained a great deal of new discoveries during this field work: (1) from the systematic point of view, we found well-preserved and diversified brachiopods in the Kalabagh Member, the top unit of the Wargal Formation; (2) from the Wargal Formation, we found abundant well-preserved solitary and massive colonial rugose corals in the Sarai Member (Capitanian Stage) and massive fasciculate rugose corals in the Sakesar and Kalabagh members (Wuchiapingian Stage); (3) abundant physical and biological sedimentary structures developed across the PTB and the Guadalupian-Lopingian boundary (GLB), which would provide adequate evidence for the interpretation of sedimentary processes, sea-level changes and paleoenvironments during the Permian-Triassic transition and the Guadalupian-Lopingian transition in the Salt Range, Pakistan; (4) multi-disciplinary discussion was carried out on formation and paleoenvironmental background of the dolostone around the PTB.

The field work was of great success thanks to detailed observations, constructive discussion (Figs 2, 4), and harmonious collaboration. We would especially thank Dr. Muhammad Qasim and other Pakistan colleagues for their helpful guidance in this field trip.

All the observations, discussion, and samplings in the field will allow us to obtain new insights into the Permian stratigraphy and the PTB events, which we would be happy to share with the Permian community as soon as the laboratory analyses and the preparations are performed.

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Rivista Italiana di Paleontologia e Stratigrafia Vol 125, 1. In memory of Maurizio Gaetani.

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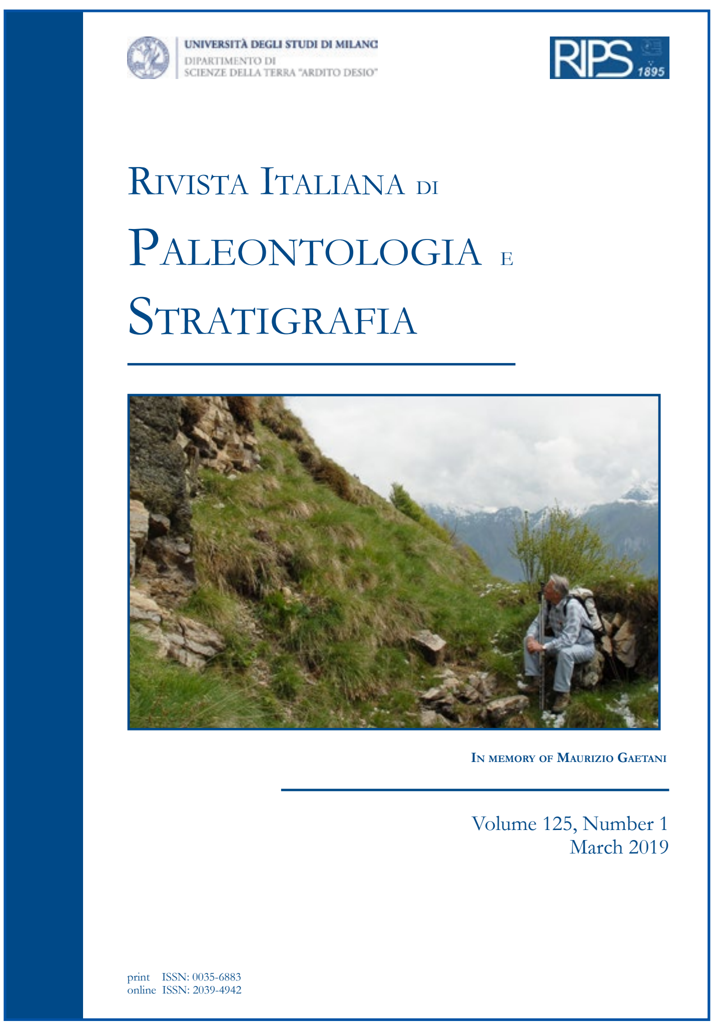
The first issue of volume 125 (2019) of Rivista Italiana di Paleontologia e Stratigrafia is dedicated to the memory of Maurizio Gaetani (1940-2017), editor of this journal for many years and eminent palaeontologist and stratigrapher.

The journal is open access and all the articles are directly accessible at https://riviste.unimi.it/index.php/RIPS/issue/archive.

Many friends, colleagues and scholars of Maurizio Gaetani have contributed to this volume, which contains 14 papers about the wide geological interests of Maurizio, from paleontology to paleogeography, from stratigraphy to diagenesis, from paleomagnetism to regional geology. We have selected four of these papers for the audience of Permophiles, as they focus on the Permian and Early Triassic.

Valerio Gennari and Roberto Rettori describe a new taxon of biseriamminoid foraminifer, *Globigaetania an*gulata Gennari & Rettori, 2019, from the Middle Permian Gnishik Formation and Arpa Formation of NW Iran, along the Zal and Poldasht stratigraphic sections. The new taxon is characterised by globivalvulinin coiling, wall, and aperture types, and by the presence of supplementary nodular structures and angular chambers in the adult stage. The description of *Globigaetania angulata* sheds light on the evolution of the Palaeozoic biserial microgranular foraminifera.



John Powell and co-authors describe the Upper Permian to Lower Triassic succession of the Dead Sea in Jordan, which records the transition between the alluvial Umm Irna Formation and the shallow water Ma'in Formation. The Permian-Triassic boundary is either at the sequence boundary between the formations or in the shallow marine beds overlying the boundary. The Himara Member marks the initial Triassic marine transgression and passes upward to the Nimra Member characterized by an increase in bioturbation and biodiversity and representing the recovery phase. Among the fossils, conodonts are abundant, and allowed revision of the conodont apparatus.

Giovanni Muttoni and Dennis Kent presents a synthesis of the discussion about the transformation from Pangea B to Pangea A in the Permian, starting from the conundrum that if palaeomagnetic data from northern Italy are more compatible with data from Africa than from Europe, and thus Adria was part of Africa, then the palaeolatitude anomaly of Adria relative to Europe imply a huge crustal misfit of Gondwana relative to Laurasia when they are forced into a classic Wegenerian Pangea. Various solutions have been proposed that involved placing Gondwana to the east relative to Laurasia, with a dextral shear occurring in the Tethys between these supercontinents. The dextral shear (of about 2300 km) is interpreted to have been a discrete event during the Permian between a configuration termed Pangea B (with the northwestern margin of Africa against southern Europe) to a configuration termed Pangea A-2, similar to the classic Jurassic Pangea A-1.

Marco Balini and co-authors describe the structural and stratigraphic setting of the Lower to Middle Triassic sedimentary succession of the Aghdarband window in Kopeh-Dag, NE Iran. Based on the study of six stratigraphic sections in the Sefid-Kuh Limestone, Nazar-Kardeh Formation and Sina Formation, the authors revise the lithostratigraphy and ammonoid and conodont bio-chronostratigraphy and reconstruct the sedimentary evolution of the basin. They also propose a new palaeogeographic reconstruction for the Aghdarband Basin in the Triassic, located along the southern Laurasia margin in a back-arc position in close connection with Mangyshlak (West Kazakhstan) and Tuarkyr (Turkmenistan).

OBITUARIES

Michaela Bernecker, 1963-2017, a remarkable teacher, scientist and friend

Foreword and Michaela Bernecker's career. Oliver Weidlich

The untimely death of Michaela Bernecker on 3rd November 2017 at her home in Al Hail, Sultanate of Oman, robbed an excellent friend and valuable colleague. She possessed enthusiasm in carbonate geology and had the remarkable ability to teach students. For her students at the German University of Technology, GUtech, she was Doctor Michaela, for her friends and colleagues she was simply ‘Micha’.

Academic career at Friedrich-Alexander University Erlangen (Germany)
In 1983 Micha started to study geology at the Friedrich Alexander University, Germany. After her undergraduate degree, she got interested in microfacies analysis using thin sections and joined Eric Flügel’s famous reef research group at the Paleontological Institute. Her diploma thesis was about Paleocene azooxanthellate cool-water coral mounds which are exposed in the world-class limestone quarry of Fakse, Denmark; the scientific results were presented 1989 at the ‘Sediment Congress’ in Innsbruck and 1990 published in Facies. Her passion for teaching started when she performed a paleontological student excursion to Denmark while she worked on her diploma thesis.
In 1989, immediately after submission of her diploma thesis, she got excited when Eric Flügel offered her the possibility to study Triassic carbonates from the Oman Mountains. Micha’s enthusiasm for Arabic culture and carbonate sedimentology where significant drivers for her to plan the project. She visited Oman 1990 with a tourist visa having a validity of 2 weeks. In that time, she managed in Oman to convince the Ministry of Petroleum and Minerals to support the PhD project logistically by providing long-term-visa (NOC) and allowed the export of samples for further scientific analysis. In the field she worked with Oliver Weidlich, a start of a scientific life close collaboration. Occasionally, Erich Flügel came to visit her as a PhD student and they published together papers or abstracts on Oman Permian and Triassic reefs.
In her PhD thesis Micha focused on (micro)facies and paleoecology of Triassic carbonates of autochthonous and allochthonous carbonates of the Oman Mountains and her achievement was published in Facies on " Upper Triassic reefs of the Oman Mountains".
After her PhD in 1995, Micha decided to continue her academic career and started to work for habilitation thesis, which was at that time the final academic step on the way to a professorship in Germany. In Oman she continued her own researches, collecting samples with Oliver Weidlich, Erich Flügel, Senowbari-Daryan and Leopold Krystyn.
She broadened her research and chooses the taxonomy and paleoecology of Triassic and Tertiary scleractinians Apart from her own sample collection, Micha visited famous collections in Copenhagen and London and got connected with world-class taxonomists. She received her habilitation document (facultas docendi) from Friedrich-Alexander-University

2006 and became ‘Privat-docent’ (venia legendi) in 2007. Unfortunately, her taxonomic and sedimentological work of her habilitation thesis remains unpublished

Assistant and Associate Professor Professorships

Micha became Assistant Professor in Eric Flügel’s team 1995. During the next seven years she was very much focused on student education and became a relevant member of his microfacies course, which is a renowned interdisciplinary carbonate course for students and industry colleagues outside Friedrich-Alexander-University until today. During her teaching time in Germany she organized an excursion for FAU students (Fig. 1) and offered mapping to students.

Fig. 1: Excursion with FAU students, Jebal Akhdar, 2007 (photo O. Weidlich).

In 2008 her vision to permanently work in Oman became realty when she accepted an offer as Associate Professor at the newly founded Department of Applied Geosciences at the Faculty of Sciences of the German University of Technology in Oman (GUtech) affiliated to RWTH Aachen University (Fig. 2).

Fig. 2: The GUtech campus at Athaibah, Muscat, Sultanate of Oman, open in 2007.

She had opportunity to teach in the field in the Oman Mountains (Fig. 3) and to bring GUtech student for a field trip in Germany (Fig. 4).

Fig. 3: Micha with part of her classroom teaching Geology in the Oman Mountain (photo C. Ducassou).

Fig. 4: Micha with GUtech students on excursion in southern Germany

Within the awarded and permanent GUtech campus built in Halban, 50 km West of the Airport, open in September 2012, Micha helped to develop the institute and became Head of the Geosciences Department in 2013. (Figs. 5, 6 and 7). The last merit of her activity was the approval of the Master Programme for Applied Geology by the Ministry of Higher Education of the Master.

Fig. 5: The GUtech new building in Halban, open Sept. 2012.

Fig. 6: Micha (on the right) with some of her GUtech colleagues at an Academic event (photo C. Ducassou).

Fig. 7: Micha, on the right, head of the GUtech Applied Geology Department, with her close colleagues (photo Wilfried Bauer).

In February 2017, she was proud to offer an opportunity to the GUtech high performance student (Fig. 8) of scholarships for the International Course on Carbonate Microfacies 2017 to be held at the University of Erlangen in Germany (Muscatdaily.com).

Fig. 8: Feb. 2017, one of the Micah's official last photo, with two of her high performance student (Muscatdaily.com).

Scientific activities

Despite the high workload as lecturer and academic administration duties Micha managed to publish about 90 papers and congress presentations. Out of these most relevant are papers describing Paleocene azooxanthellate cool-water coral mounds, the detailed maps of sawed

quarry walls of spectacular patch reef(s) exposed near Adnet, Austria (Fig. 8 left) and facies observations of Triassic carbonates of the Oman Mountains.
Micha loved to attend scientific congresses in Europe, the Middle East and Far East to present her results. (It can be said that) She liked GeoArabia Meetings in Bahrain (were her favorite) (Fig. 8 right). She animated students to attend meetings and helped them to win prizes.

Fig. 8 left: Micha doing fieldwork in Adnet quarry, Austria; right: Micha in front of her poster at the Geoarabia meeting in Bahrain 2008.

Other papers written with coauthors deal the taxonomy of Triassic invertebrates. Apart from the aforementioned topics Micha was interested in sedimentological aspects of alkaline lakes, as Lake Lisan.
Micha was a member of many geoscientific organizations, including AAPG, SEPM, IAS and Paläontologische Gesellschaft. Choosing very early taxonomy and paleoecology of Triassic and Tertiary scleractinians she participated in 1993 to the first European Regional Meeting of the International Society for Reef Studies in Vienna. In 1995, she became member of the Fossil Cnidaria and Porifera Association and she went and gave talk to the 7th International Fossil Cnidaria Symposium in Madrid. Each four years she actively participated to this Cnidaria International Symposium. With her 2003 experience in the organization of the 2nd International Symposium on Deep Sea Corals at FAU, Erlangen (Germany), she became very happy to be selected to organize the last one (12th) International Symposium on Fossil Cnidaria and Porifera at GUtech, Halban, in 2015, in Oman.

Activities apart from Academia

Public outreach From the beginning Micha acknowledged the relevance of communicating scientific results to the public with exhibitions and public talks. She dpresented corals in exhibitions in the 1980s - early 1990s at Friedrich-Alexander-University and at Wintershall in Barnstorf. Geological Society of Oman (GSO) invited Micha as presenter for public events in the capital area.

Consultancies Apart from her mission as scientist and lecturer, Micha provided services to Wintershall Holding GmbH (German oil and Gas Company), Oolitica (carbonate consulting company and Carmeuse (important producer of pure limestone and dolostone)

Over a period of 10 years Micha's house was always was open for colleagues working in Oman. These colleagues, principal collaborators and friends feel a deep sense of loss. As modest and helpful human being she will not be forgotten and has the best claim to be regarded as a remarkable teacher, scientist and friend.

From FAU to GUtech, some of the Michaela participation on Permian-Triassic studies.

Aymon Baud

We meet first with Michaela Bernecker (Micha) during the 1993 "Carboniferous to Jurassic Pangea conference" in Calgary with both presentations and posters on Oman Permian and Triassic geology. Leading a research team on Permian and Triassic stratigraphy and sedimentology in Oman, our next meeting was in 2001, again during a Pangea Symposium. At this time it was in Muscat, as part of the International Conference on the Geology of Oman. Micha was invited to give a talk on "Second-order cycle development of the Arabian platform and Hawasina seamounts: Permian and Triassic outcrop data from central Oman".

In 2004, during the International Geological Congress in Florence she participates at two sessions: one, as our team on "Late Permian-Early Triassic events" and the other on "Paleocene/Eocene thermal maximum".

In January 2005 we meet again in Muscat during the 24th Meeting of the International Association of Sedimentology on "Scenic sedimentology" and Micha gave a talk on the Paleogene shelf of Oman.

Our next common meeting was during May 2005 at the Triassic conference on Chronostratigraphy and biotic recovery in Chaohu, China. Micha came with Oliver Weidlich, having a presentation on " Carnian to Rhaetian isolated platform and reef development in the Neo-Tethys." and she take part to the fieldtrip on the Lower Triassic of the Nanpanging basin (Fig. 9 left and right).

Her starting professorship in 2008 at GUtech, Muscat, opened some new opportunities for the organization of international geological meeting in her Permian-Triassic field of researches.

Contacted for the new International Geological Correlation Program 572 of the UNESCO on the recovery of ecosystem following the end Permian great extinction, she accepted with enthusiasm to prepare with me, a day conference followed by a fieldtrip on significant Permian-Lower Triassic outcrops in the Oman mountains, from shallow to deep water. Announcement was sent in the start of 2009, Micha and I edited the guide book and the very successful second IGCP 572 conference take place February 21, 2010 at the GUtech meeting room (Fig. 10). Micha was Chairwomen of the morning session and she participated actively to the five days of field examination (Figs. 11, and 12).

Fig. 9, The Chaohu (China) Triassic conference, May 2005, left: Micha at Chaohu; right: at a field stop near Guando.

Fig. 10: Micha (in dark) at the starting IGCP 572 meeting in GUtech conference Hall, 21.02.2010.

Fig. 11, IGCP 572 Fieldtrip, Feb. 2010, left: Micha taking note in the field; right: departure of the fieldtrip, Micha in the sun.

Fig.12: Seating on the Sumeini lower Triassic platy limestone, friend discussion with Micha.

In 2011, Micha was asked to be member of the scientific committee of the International Conference on the Geology of the Arabian Plate and the Oman Mountains scheduled to open January 7, 2012 at Sultan Qaboos University. With Oliver Weidlich, she gave a talk on " The

Oman Exotics: evidence for the development of isolated carbonate platforms in the Tethyan Ocean" and a poster on "Postdepositional deformation of carbonates and injection of fluidized mud: Field observations from the Saiq Formation, Eastern Oman Mountains". After the congress, she was in charge of the post-congress fieldtrip at Barr Al Hikman, on "Modern Carbonates & Sabkhas".

Preparing with three colleagues during 2014 the 12th International Symposium on Fossil Cnidaria and Porifera, she sent invitation to all interested scientists. Micha asked Oliver Weidlich and me to organize a pre-conference fieldtrip on the "Permian limestones with sponges and corals in the Ba'id area". Giving her the guidebook on time for printing in GUtech, I luckily leaded this one day trip, valued by participants. With more than fifty members, the meeting was very successful as the two days field trip that she organized on "Permian/Triassic reefal limestones in the Hajar Mountains" and you make me happy when asking me to prepare a stop on the Permian-Triassic boundary outcrop on the Saiq Plateau.

Outside the above mentioned official meetings, from 2009 up to last year, I take visit to GUtech each year, starting or ending Oman field researches and Micha always warmly welcome me, my friends and my colleagues and, when asked, she helped us to find field equipment or to store it, as to store geological samples.

Micha, you were an open, noble and esteemed colleague. We will not forget you.

Acknowledgments

Thanks to Céline Ducassou for her help finding living pictures of Michaela and thanks also GUtech colleagues and administration for their always welcome.

Oliver Weidlich and Aymon Baud

Michaela Bernecker publication list

A- Articles, journals & books

1) Michaela Bernecker alone or first in collaboration:

Bernecker, M. (1996): Upper Triassic reefs of the Oman Mountains: Data from the South Tethyan margin.- Facies **34**, 41-76, Erlangen.

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Vladlen Lozovsky (1936-2018)
In Memoriam

On June 19, 2018, after a long illness, well known stratigrapher Vladlen Ruvimovich Lozovsky, Professor of the Department of Paleontology and Regional Geology at the MGRI-RSGPU (Russian State Geological Prospecting University named after Sergo Ordzhonikidze), passed away. Born March 28, 1936, in Kharkov, Russia, Vladlen was the son of a mother who worked as a radiotechnologist, and a father who was a senior engineer at the People's Commissariat of the Coal Industry. During the Second World War, Vladlen evacuated with his mother to Prokopyevsk, and, following his father's death in May 1943, he moved to Moscow. After graduating from high school in 1954, Vladlen entered the Moscow Geological Prospecting Institute named after Sergo Ordzhonikidze. Studying in the Faculty of the Geological Survey, Vladlen graduated with a specialty as a mining engineer-geologist.

After completing his studies, Vladlen was sent to work at the All-Union Hydrogeological Trust (later named, in 1962, the Second Hydrogeological Department of the Ministry of Geology of the USSR), where he worked as a geologist, engineer-geologist, and, from 1960, as the senior geologist of the Kostroma Expedition Party. In that position, Vladlen was responsible for the integrated geological and hydrogeological survey of three sheets of the State Geological Map of the USSR at a scale of 1:200,000, which he prepared for publication and defended at the editorial board of VSEGEI (A. P. Karpinsky Russian Geological Research Institute).

In the early years of his career, Vladlen became interested in Triassic stratigraphy, which determined the direction of his scientific activity for the rest of his career. In 1966, he entered the postgraduate department full time at the Department of Regional Geology and Paleontology of the MGRI. There, under the supervision of Professor M. V. Muratov, a corresponding member of the USSR Academy of Sciences, Vladlen defended his Ph.D. thesis "Triassic deposits of the axial zone of the Moscow syneclise" in 1969. After graduating, Vladlen was sent to the research sector of MGRI, where he worked as a Junior Researcher, and later rose to the position of Senior Researcher in 1971. At MGRI, Vladlen was engaged in research on the tectonics of Northern Ciscaucasia, and conducted research work on the project "USSR Paleotectonics in the Major Epochs of Coal Accumulation." Based on that work, Vladlen co-authored five paleo-tectonic maps of the final report of this project.

In 1970, Vladlen also began to work in the Department of Regional Geology and Paleontology of the MGRI, first as an Assistant, and, then, in 1976, as Senior Lecturer. Beginning in 1982, he started his duties as an Assistant Professor, and, in 1993, he rose to Professor of the Department. In that role, Vladlen lectured and conducted laboratory classes in the courses "Stratigraphy," "Historical geology," "Regional geology of the USSR," "Historical geology of the USSR," "Geotectonics," and the "Geology of Africa." He also supervised course design, advised graduate students, participated in the Moscow Region and the Crimean educational geological practices, and led student scientific excursions. Together with V.G. Ochev, Vladlen developed a draft educational practice for students of the MGRI at the Zhirnovsky Research and Education Test Site (Volgograd Region), which previously was traditionally used only by the Geological Department of the Saratov State University (SSU). The collaboration of MGRI and SSU was implemented in an experimental mode in 1993 under the direct guidance of Vladlen. He was responsible for the student exchange program between the MGRI and the Bergakademie Freiberg, East Germany, in the 1970s and 1980s, and, in 1971, Vladlen guided a four-week-long student excursion and mapping course of German students on the Russian platform and in the Crimean Peninsula. One of us (Schneider), as one of the German students, very well remembers his excellent logistical and teaching talents, and especially his friendly affection for the students. Later, after 2000, he supervised the MSc and PhD thesis of a German student in Moscow, which became a stepping stone for the current research on Permian-Triassic conchostracan biostratigraphy.

In 1974, the Higher Attestation Commission of the Soviet Government (VAK) approved Vladlen as a senior researcher in the specialty "stratigraphy and paleontology." In 1992, he defended his doctoral thesis on the theme "Early Triassic stage of development of Western Laurasia." In 1993, by the decision of the Higher Attestation Commission, he was awarded the academic degree of Doctor of Geological and Mineralogical Sciences. In 1994, by the decision of the State Committee of the Russian Federation for Higher Education, Lozovsky was also awarded the academic title of Professor in the Department of Regional Geology and Paleontology of the MGRI.

In addition to his native Russian, Vladlen was fluent in French and conversant in English. In 1977-1980, he was sent to the People's Revolutionary Republic of Guinea (now the Republic of Guinea), where he worked as a teacher in the Mining and Geology Department of the Polyakhnichesky Polytechnic Institute. There, he taught courses in "Paleontology," "Historical geology" and "Aeromethods in geology." Vladlen also managed educational geological practice and degree design for students, and from 1978 he headed the Department of Geology. For his successful work in training national personnel, he was thanked by the Advisor for Economic Affairs at the USSR Embassy in Guinea.

In 1986-1988, Vladlen was in the Republic of Mali, where he worked as a teacher in the Geological Department of the National School of Engineering in Bamako. There, he lectured and conducted practical classes on the courses "Paleontology," "Stratigraphy," "Structural geology" and "Geological mapping," and also oversaw geological practice.

In addition to his extensive teaching and his research work, Lozovsky always actively participated in service work. Over the years, he was elected as a trade union professor, a member of the Geological Survey Faculty, a member of the MGRI trade union committee, a Vice-chairman of the General Institute for Socialist Research, he was responsible at the MGRI for the work of the Red Cross, and from 1988 he oversaw the research of the Department of Regional Geology and Paleontology.

As an outstanding educator, Vladlen always paid particular attention to and showed great goodwill to younger researchers, and sought to provide his younger colleagues with maximum support. Until the last days of his life, he was open to constructive communication with students and colleagues. It was always possible to consult with him, to receive a thorough response to your work, to feel the support of the master, and to benefit from his inexhaustible optimism.

Vladlen was one of the leading experts in Permian and Triassic stratigraphy, a stratigrapher of global stature. He was an active participant in numerous international scientific meetings in the USA, Germany, China and other countries. Vladlen was also a corresponding member of both the Permian and the Triassic subcommissions of the International Commission on Stratigraphy. In 1970, Vladlen was elected to the Permanent Commission of the Stratigraphic Commision on the Triassic System, led by the Permian and Triassic Section of the Regional Interdepartmental Stratigraphic Committee RMSC. He developed a stratigraphic scheme of the continental Triassic deposits of the Moscow syneclise, published more than 100 scientific articles, including five monographs, some of which were published abroad.

Vladlen's numerous scientific contributions to our knowledge of Permian and Triassic stratigraphy focused on the Moscow syneclise, but also revealed his global grasp of the relevant data and issues. His 1992 article "The Permian-Triassic boundary in the continental series of Laurasia and its correlation with the marine timescale," published in the *International Geology Review*, was, for decades, the consummate synthesis of the Permo-Triassic section in the Moscow syneclise and its global correlation, and has only been modified by new data collected during the last few years. The correlation of Permian and Triassic nonmarine strata with marine strata was a particular focus of Vladlen's research, and he devoted much time to studying the position of and geological events associated with the Permo-Triassic boundary. In 1991, he initiated a working group of the International Subcommission on Permian Stratigraphy of the International Union of Geological Sciences on the interregional to global correlation of continental beds at the Permian-Triassic boundary. This working group laid the foundation for the current working group on Nonmarine-Marine Correlation of the International Carboniferous, Permian, and Triassic subcommissions.

Not afraid of scientific controversy, Vladlen co-authored an article published in 2009 in the journal *Stratigraphy and Geological Correlation* that took exception to the then recent decision of the Russian Interdepartmental Stratigraphic Committee to eliminate the Ufimian Stage by subsuming it into the upper Kungurian. Some of Vladlen's last papers argued the case for an asteroid impact at the Permo-Triassic boundary. He also criticized the concept of Olson's gap, a global hiatus in the Permian tetrapod fossil record advocated by one of us (Lucas), referring to it instead as "Olson's bridge." One of Vladlen's last papers, published in 2017 in a volume dedicated to his longtime friend and colleague V. Ochev, wrestled with the correlation of the Permo-Triassic boundary from the marine Meishan GSSP to the Moscow syneclise and into the Germanic basin.

Beyond his research, Vladlen was also the co-author of textbooks, manuals and teaching materials in various disciplines, including some published in French. Furthermore, he devoted much time and effort to preparing exhibits in the geological and paleontological museum of the MGRI. Even after retirement, Vladlen worked together with V.M. Zeisler on the modernization of a number of museum exhibits, including those devoted to geological practice.

Everyone who came into contact with Vladlen Lozovsky, in the process of his many-sided career, will remember with gratitude his sensitivity, honesty, vitality, attentive and benevolent attitude towards others, and amazing work capacity. Until the last days of his life he wrote scientific articles, reviews and prepared memoirs. Vladlen was also a keen connoisseur of classical music (after graduating from the cello class at the Gnessin School), and he loved nature very much. One of us (Schneider) well remembers a "concert" organized by him in the students mapping camp Prochladnoye on the Crimean Peninsula, where the German students sang German folk songs. His favorite song was the very melancholy "Wenn alle Brünnlein fließen… (When all the wells are flowing…)." One of us (Lucas) also remembers a sweltering August day in Moscow in 1996, beating the heat with gin and tonic at Vladlen's Moscow apartment, while he carried on a conversation in Russian with a parrot he had brought back from his sojourn in West Africa—Vladlen, ever the great teacher, had taught that bird to speak Russian quite well, indeed.

The name Lozovsky is perpetuated in the names of a number of fossil organisms. In particular, new forms (genus and species) of Early Triassic amphibians, archosaurs and lungfish, as well as Cretaceous rhinholytes are named in his honor. In the minds of the geological community--his colleagues, friends and numerous students--Vladlen Lozovsky will long be remembered as a great teacher, a disciplined and insightful researcher, and a wonderful person.

Spencer G. Lucas, Igor Novikov and Joerg W. Schneider

Professor Tuncer Güvenç (1935-2018)

Tuncer Güvenç in the Dikenlidere Valley, Alanya, Turkey, 2009

Prof. Tuncer Güvenç, an eminent expert on Turkish and global Carboniferous and Permian stratigraphy and biostratigraphy died on 06 July 2018 aged 83 years. Tuncer was a corresponding and voting member of the international commissions, subcommissions and working groups in the field of Carboniferous and Permian stratigraphy.

He graduated from Sorbonne University with a BS degree in geology (1959), followed by MS (1960) and PhD (1965) degrees. His graduate work concentrated on stratigraphic and micropaleontologic features of the Carboniferous-Permian successions of the Taurides from the southern Turkey. Soon after gaining his PhD, Tuncer came back to Turkey to work in his grantor institute MTA (institute of Mineral Research and Exploration) in Ankara in 1966 where he undertook significant field mapping and biostratigraphical studies in particular relating to the Carboniferous and Permian successions. During 1970-1973, Tuncer's first academic career began in Middle East Technical University (METU) (Ankara) and Aegean University (İzmir) as part-time lecturer. In 1973, Tuncer moved from the MTA to join the Aegean University as Lecturer in Geology. After three years career in Aegean University, in 1976 Tuncer established Aegean University Marine Sciences and Technology Institute (İzmir) and continued his career here until 1982. After six year scientific career in this institute he moved to Ankara and begun to work in Polmak Drilling Company as a general manager and board member. In 1986, Prof. Tuncer Güvenç moved from the Polmak Drilling Company to join Hacettepe University (Ankara) as Lecturer in Geology. Tuncer spent the rest of his academic career at Hacettepe University Department of Geological Engineering. Tuncer retired in 2002, but remained extremely active and productive. Tuncer Güvenç was a distinguished scholar and intellectual who excelled in his teaching, research and administrative activities. He took part in several international research programs and projects during his career. Due to his scientific competence, he worked as consultant at different state agencies too. He was a very kind person and he used to share his knowledge and provide support and advice to students and colleagues.

As a paleontologist, Tuncer worked on Paleozoic calcareous algae and foraminifera, but, perhaps his largest contributions were on calcareous algae. He was interested in a broad range of topics related to morphology, taxonomy and biostratigraphic significance of Carboniferous, Permian and Triassic calcareous algae. Many of the new taxa described by Tuncer and his collaborators were used to build landmark understandings of the evolution and biostratigraphy of this fossil group. Tuncer's outstanding publication record began with his first paper published in 1965 in the Bulletin de la Société Géologique de France on Carboniferous fossil algae of Anatolian Platform. He subsequently published more than fifty high-quality scholarly articles. Tuncer started to work on a revision of the Paleozoic Calcareous algae before the beginning of his illness. His first purpose was to complete the revision of the genus *Gymnocodium* (Pia) and the family Gymnocodiaceae (Elliot) and giving the description of two new genera of Gymnocodiaceae from the Permian of Anatolia. Sadly, before completing his last work, he passed away.
Professor Tuncer Güvenç will be missed by his former students, friends and colleagues in different institutions and universities.

Cengiz Okuyucu
His former PhD student

ANNOUNCEMENTS

First Workshop on the DeepDust Drilling Project - March 6-10, 2019

Nearly 60 geoscientists gathered for a workshop sponsored by the International Continental Drilling Program (ICDP) to discuss the potential to core the Permian. Primary science topics include Permian continental climate— particularly capturing the icehouse-greenhouse transition, run-up to the Great Dying, and development of the Pangaean megamonsoon. Additional topics include probing the extent and nature of the deep microbial biosphere— both the modern deep biosphere and the Permian microbial biosphere as preserved in evaporites. Auxiliary topics include aspects of astrobiology, Mars-analog studies, and orogenic processes. Potential drilling sites discussed include the deep Anadarko Basin (Oklahoma), capturing western-equatorial Pangaea, and a western European target to capture eastern equatorial Pangaea. The U.S. site includes preservation of both a thick Permian section and adjacent paleo-upland, with archives expected to comprise predominantly continental and shallow-epeiric deposits including paleo-loess and evaporites. Such archives provide the potential for high-resolution continental records, including insights into long-standing issues regarding the acme and ultimate collapse of Earth's penultimate icehouse, and the perplexing and extreme hydro-climate and temperatures of mid-late Permian equatorial Pangaea.

For more, visit https://www.icdp-online.org/projects/world/global-coverage/deep-dust/

SUBMISSION GUIDELINES FOR ISSUE 68

It is best to submit manuscripts as attachments to E-mail messages. Please send messages and manuscripts to Lucia Angiolini's E-mail address. Hard copies by regular mail do not need to be sent unless requested. To format the manuscripts, please follow the TEMPLATE that you can find on the new SPS webpage at http://permian.stratigraphy.org/ under Publications. Please submit figure files at high resolution (600 dpi) separately from text one. Please provide your E-mail addresess in your affiliation. All manuscripts will be edited for consistent use of English only.

Prof. Lucia Angiolini (SPS secretary)

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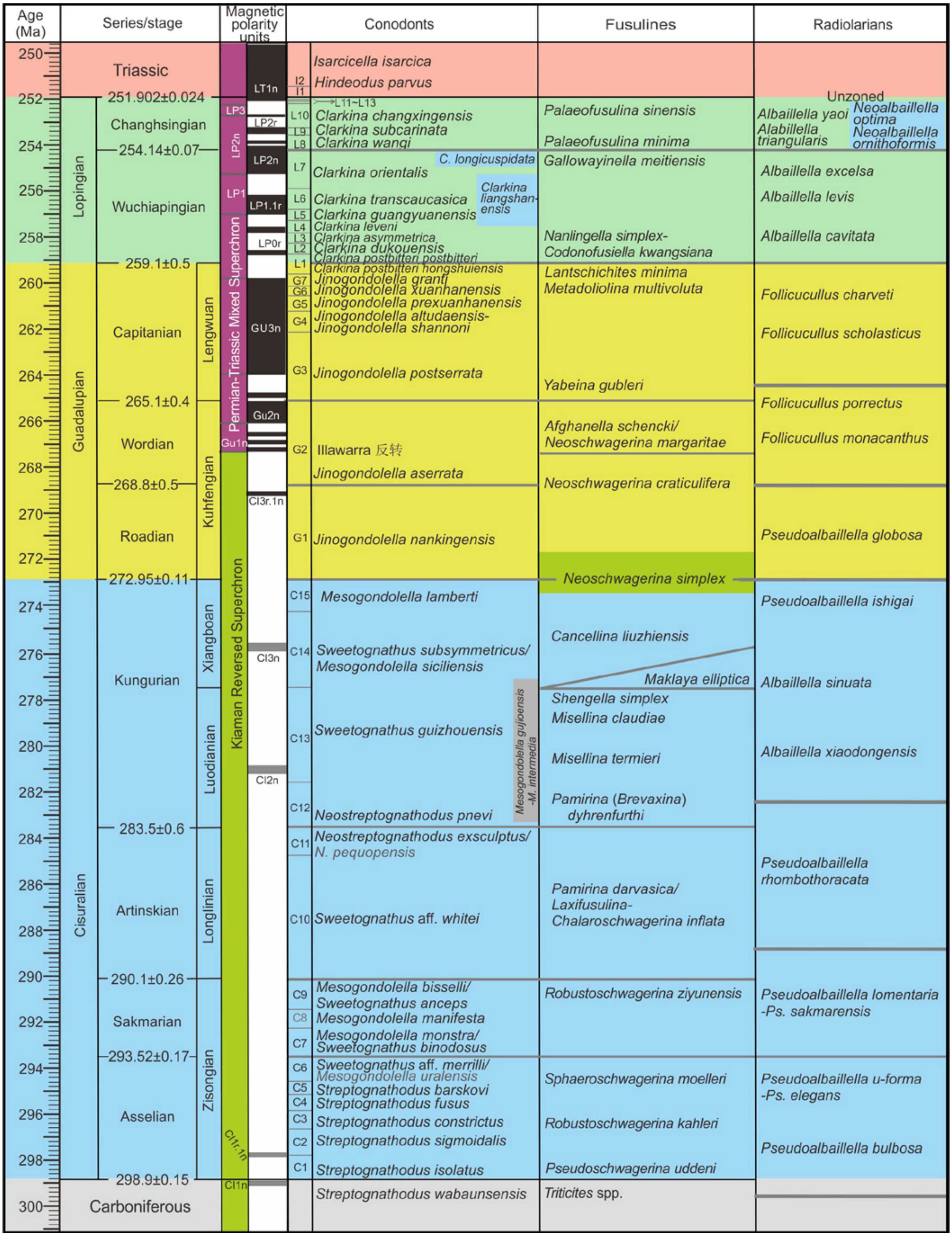
The deadline for submission to Issue 68 is December, 31th, 2019.



High-resolution integrative Permian stratigraphic framework (after Shen et al., 2019. Permian integrative stratigraphy and timescale of China. Science China Earth Sciences 62(1): 154-188).