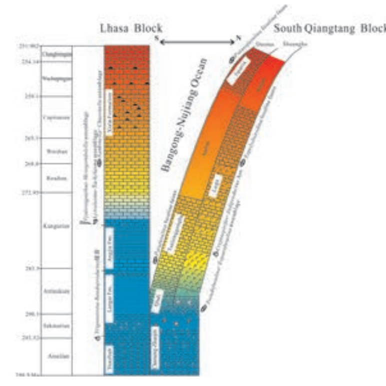
Permophiles

International Commission on Stratigraphy



Newsletter of the Subcommission on Permian Stratigraphy
Number 68
ISSN 1684-5927
January 2020

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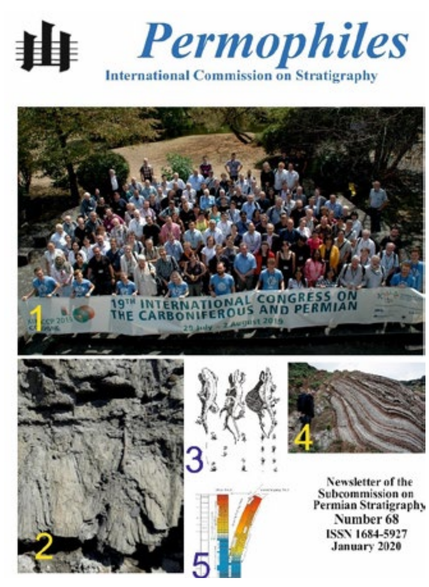

Fig. 1. Participants of the 19th ICCP 2019, Cologne. Herbig, this issue.

Fig. 2. Cone-in-cone calcite. Kershaw, this issue.

Fig. 3. Permian track makers. Lucas, this issue.

Fig. 4. Cala Viola north of Alghero, NW Sardinia. Bachmann, this issue.

Fig. 5. Permian sequences of South Qiangtang Block and Lhasa Block. Zhang et al., this issue.

Notes from the SPS Secretary

Lucia Angiolini

Introduction and thanks

This is the last issue that I will organize and edit as Secretary. I did the job for eight years, sometimes struggling to secure contributions; and at other times (as now) struggling with several academic duties to find time to get it finished. However it was really an extraordinary and interesting job. I hope that the next SPS secretary will have the same interest, the same passion, for preparing Permophiles.

Thanks Shuzhong for those great eight years working together, despite the geographical distance between us!

My warm thanks also go to the contributors of this issue: Charles Henderson, Spencer Lucas, Stephen Kershaw, Mingtao Li and co-authors, Yichun Zhang and co-authors, Shuzhong Shen ad co-authors, Mike Stephenson and Dorit Korngreen, Michael Brookfield, Joerg Schneider and co-authors, Hans-Georg Herbig, Gerhard Bachmann, and Daniela Germani.

I would like to thank Claudio Garbelli for his assistance also in 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.

Previous SPS Meetings

A SPS business meeting was 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" was scheduled for Tuesday 2 July and was followed by the SPS business meeting (see report of Daniela Germani, this issue and minutes below). During the session, Shuzhong Shen kindly gave the certificate of support of participation in STRATI to Alexander Biakov, Massimo Bernardi and Marco Romano.

A second important meeting was organized at the 19th International Congress on the Carboniferous and Permian (XIX ICCP 2019), in Cologne, July 29th -August 2nd, 2019 (see report of Hans-Georg Herbig, this issue). SPS supported the participation of Valeriy Golubev in ICCP 2019.

Minutes of SPS Business meeting, 2 July 2019, Milano

People attending: Jay Zambito, Tea Kolar-Jurkoviez, Marco Romano, Ausonio Ronchi, Yukun Shi, Yuri Zakharov, Aymon Baud, Olga Kossovaya, Alexander Biakov, Charles Henderson, Bob Nicoll, Mike Stephenson, Xiangdong Wang, Shuzhong Shen, Lucia Angiolini, George Sevastopulo.

The chair of SPS Prof. Shuzhong Shen opened the business meeting announcing that it is time to compile a list of candidates to cover the positions of chair and vice-chair for the next term (2020-2024) by the end of Strati 2019 congress. He asked the voting members to suggest the names of possible candidates to Charles Henderson, who is in charge of the nominating committee for the next executive.

The second point of discussion was the replacement of voting members, based on the fact that some of them are no longer active or do not participate in the discussion and in the voting procedures. This should be done taking into account both the scientific activity, level of interest and participation, and the geographic distribution of the members.

As a third point, Shuzhong Shen focused on Permian GSSPs. Three are still to be defined and these are the priority but the Sakmarian base GSSP has been successfully ratified and established in Russia with a good definition and its publication is in progress. He asked the Russian colleagues about the erection of a monument at the location of the GSSP. A geological park has been organized on the site, but not a monument.

The Artinskian base GSSP needs now to be moved forward: conodont, fusulinid and high precision age data are already available.

For the Kungurian base GSSP, a section has been excavated, but the possible candidate is based on few data, and only on conodonts. Ammonoids are present, but just in a single horizon. Also, the policy for sample collections and export should be clarified. So this is probably the GSSP which is in need of much more work.

Then, Shuzhong Shen recommended a larger presence of voting members at the next business meeting at the 19th International Congress on the Carboniferous and Permian (XIX ICCP 2019), in Cologne, July 29th -August 2nd, 2019.

The chair announced a very important project on Big Data led by M Stephenson with the support of IUGS, called Deep-time Digital Earth. The main goal of the project is to build a timeline for all geoscientists globally applicable and integrated with all available data.

Finally, there has been some discussion about the Wordian GSSP, as a recent campaign of field work failed to reproduce conodont data as in the original definition. Also, there are problems in separating the Roadian from the Wordian, so there may be a possibility to lump the two. More work and discussion is needed to clarify the situation.

Minutes of SPS business meeting, 30 July 2019, Köln

A SPS business meeting was successfully held during the 19th International Congress on Carboniferous and Permian in Köln, Germany. Among the current 17 voting members of the SPS, 9 of them attended this meeting and discussed several issues relating with SPS and Permian GSSPs.

The first thing SPS Chair Shuzhong Shen noted was that three current voting members have served eight years for the SPS and will be replaced by new voting members. The Chairman requested all the current voting members to vote for their candidates as soon as possible. Following the ICS regulation, Charles M. Henderson has been invited by the Shuzhong Shen to be the Chair of the nominating committee. Hopefully, new voting members will be welcomed before the next IGS meeting in India in March. Additionally, if any current voting member(s) of the SPS is not active on Permian research, e.g., reporting their studies to Permophiles, or involved in subcommission activities, then they will be replaced by new members.

Secondly, we have made progress on Permian GSSP work. However, we are also facing a lot of problems which need to be solved.

Cisuralian Series

Recently, the Sakmarian GSSP was ratified in the Usolka section located near the health resort Krasnousolsky (Republic of Bashkortostan of Russia). The alternated non-fossiliferous clastic beds between the carbonates of the Usolka section make this GSSP imperfect in terms of its complex lithologies and biostratigraphy. Thus, it is hard to judge if the FO of the marker, that is the first occurrence of the conodont *Mesogondolella monstra*, is the FAD or not. However, the continuous conodont lineages of both *Mesogondolella* and *Sweetognathus* have shown the general continuity of the section. Quite a few geochronological ages dated in this GSSP section allow us to control the defined boundary level and realize the correlation well.

The Sakmarian GSSP has been established in a Geopark approved by UNESCO. A monument has been established accordingly (see Galina Kotlyar's report in this issue). A fieldtrip to the Sakmarian GSSP should be organized soon as well. As the GSSP should be internationally accessible. Russian colleagues were requested to negotiate with their government for providing convenience to foreign researchers who are going to transport samples out of Russia.

In the Artinskian GSSP candidate section (Dal'ny Tulkas Section), which has been excavated by Russian colleagues, we were not yet able to get consistency for index species to define the GSSP. Valery Chernykh proposed *Sweetognathus* aff. *whitei* as the boundary marker, because Charles Henderson has already documented that *Sweetognathus whitei* occurs in a much lower stratigraphic position in North America than in the Southern Urals and he thought *Sweetognathus* aff. *whitei* in southern Urals is synonymous with the species *Sw. asymmetrica* which was named based on the specimens from the lower part of the Chihsia Formation in South China. In this horizon, the fusulinid Misellina claudiae has been reported. If Charles Henderson's opinion is correct, *Sweetognathus* aff. *whitei* cannot be used as an index species for the stage. Thus, the taxonomy of the potential Artinskian boundary marker in the Southern Urals needs to be studied further. Also, the lithology and exposure surfaces make this section not ideal. The excavated trench of this section, which will be covered again in a short time, makes this section not a best choice for a GSSP as well. However, the priority of the Artinskian GSSP is to select a proper boundary marker. In this case, the conodont specialists Valery Chernykh and Charles Henderson, who have discrepancies on the taxonomy of the potential boundary markers, will be requested to propose their solution(s) for the biostratigraphic criterion of the Artinskian Stage together or separately (Note: Charles will write a paper on this issue shortly). Otherwise, the Dalny Tulkas section is good because it contains multiple datable ash beds, ammonoid

The Kungurian GSSP candidate section (the Mechetlino Quarry Section) in the Southern Urals, Russia also has been excavated deeply by our Russian colleagues. The index species *Neostreptognathodus pnevi* has been widely confirmed in North America and possibly South China. However, there are no additional markers to support the correlation values of the FO of the index species *Neostreptognathodus pnevi*. Although some well persevered ammonoids were found from this section, they were collected from a single bed, thus making correlation poor. No geo-chronological data, and unreliable chemostratigraphic data, also make this candidate section not ideal as a GSSP section. However, this section is the only candidate section for the Kungurian GSSP. The attending members discussed this issue actively and all agreed that a multidisciplinary method should be applied for the GSSP candidate sections of the Kungurian Stage if there are more potential sections. In fact, the South Chinese Luodian section has high potential to be the Kungurian GSSP, as well as the Rockland section in North America. The SPS Chair Shuzhong Shen, therefore, requested all the voting members to present their Kungurian candidate sections with detailed litho-, bio-, chemo-, cyclo-, stratigraphic data, geochronological data and any other possible information to the next Permophiles issue in 2020. After that, all voting members can fully evaluate their potential in all aspects by organizing workshop(s) and/or field excursion(s) to the candidate sections.

Guadalupian Series

The GSSPs of the three Guadalupian stages have been rati¬fied for more than 20 years. However, no official articles with illustrations of the index species from the GSSP sections have been published. After the investigations by SPS Chair Shuzhong Shen and his colleagues, some problems related with those GSSPs have arisen.

At the Roadian GSSP section, Stratotype Canyon in Texas, USA, Shuzhong Shen's group collected conodont samples from the ratified FAD level of the index *Jinogondolella nankingensis*, but they did not recover any specimen of the index species. However, some specimens resembling *Jinogondolella nankingensis* were found from 10 m below the ratified boundary level. Furthermore, serrated conodont specimens, which were used to define the base of the Guadalupian Series, were found from ~150 m below the ratified boundary level in the Bone Spring Formation. That information will be published and will raise more issues on the GSSP of the Guadalupian Series (the GSSP of the Roadian Stage).

The Wordian-base GSSP at Guadalupe Pass (Texas, USA) is facing a more serious problem because Shuzhong Shen and others couldn't find any conodonts from samples at the exact GSSP boundary level defined at the Getaway Ledge outcrop. Bruce Wardlaw probably recovered conodonts from another section (the 'TV tower section') nearby the GSSP. That 'TV tower section' has become private land, and so it is not accessible now. That could be the reason why no conodont specimens were found. Fortunately, Galina Nestell mentioned that another section with complete biostratigraphic succession was found by her group. Those sections could replace the current GSSP or serve as an auxiliary section for the GSSP. Of course, data of those sections should be presented to the SPS members for ful evaluation and discussion.

The Capitanian-base GSSP at Nipple Hill (Texas, U.S.A) has good exposure and is highly productive for conodonts. However, there is only ~0.5 m of strata above the GSSP. Luckily, Shuzhong Shen and his colleagues discovered another section called Frijole section with a complete succession from middle Wordian to the upper part of Capitanian. The Frijole section, ~2 km distance and within sight of the current GSSP Nipple Hill, is plausible for carbon chemostratigraphy, conodont biostratigraphy and geochronological dating from several ash beds. In fact, Shuzhong Shen and his colleagues have already obtained precise dates close to the Wordian/Capitanian boundary and preliminary conodont data. The Frijole section could serve as a better GSSP for the Capitanian Stage. Those results will be published soon. The Capitanian-base GSSP will be discussed as well.

The Terrestrial Working Group leader Joerg Schneider reported the work of his group and promised that the results will be published soon (Schneider et al., in press, https://doi.org/10.1016/j.palwor.2019.09.001). He also proposed that separate correlation charts of both marine and non-marine Permian stratigraphy should be established. The SPS Chair agreed to this proposal and invited Joerg Schneider to prepare the terrestrial correlation chart of Permian stratigraphy. Shuzhong will also be in charge of the update of the marine correlation chart of Permian stratigraphy. Both charts will be under the same international timescale and will provide more utilities for Permian stratigraphic work.

The pdf file package of the special volume "The Permian Timescale" published by Geological Society, London (GSL) in 2018 will be provided by Spencer Lucas via Dropbox. Members can ask Spencer Lucas for a copy.

Forthcoming SPS Meetings

A forthcoming SPS business meeting is scheduled at the 36th International Geological Congress, 2-8 March 2020, Dehli, India.

Permophiles 68

The present issue is very rich, detailed and varied in contributions and, thus, it is really interesting and valuable for the Permian community. Also, this issue contains some very interesting discussions, with Permian students presenting different interpretations of the same, or similar, data. This is what Permophiles should do: besides presenting contributions on scientific topics which are most interesting, it should become the forum for Permian discussions.

This issue starts with Spencer Lucas and Charles Henderson "haranguing each other" as said in the accompanying email by Spencer. He replies to Harangue #5 of Charles, explaining his criticism on the arbitrarily chosen primary signals for GSSPs and why he favours boundaries based on natural events. Other important topics discussed by Spencer Lucas are the concepts of "immutable chronostratigraphic boundaries" and of LO and HO. Charles Henderson replies, underscoring that they both agree on several points, for instance the necessity to improve the GSSP process, but commenting on what they disagree.

This debate is followed by the sixth harangue of Charles Henderson which deals with several important topics concerning revisions of the Geologic Time Scale and the need to use it, because this is the way to stabilize it.

Stephen Kershaw provides a very detailed description and interesting discussion of fibrous calcite cements of "beef" and cone-in-cone types. The goal of his contribution is to advise caution in interpreting these cements as extinction-related environmental processes. He addresses three papers recently published on this subject, comparing the features of burial diagenetic cements and of contemporaneous precipitates associated with mass extinction, providing his interpretation. In sending his contribution, Stephen asked Shuzhong and myself to involve the authors of the three papers in this debate, in order to publish in Permophiles 68, a comprehensive discussion.

Mingtao Li, Haijun Song, Li Tian, authors of Li et al. (2018), accepted the invitation, providing their reply to the stimulating discussion of Stephen Kershaw and presenting arguments for their original interpretation as seafloor carbonate precipitates.

Yichun Zhang and co-authors and co-authors provide data and future perspectives on the palaeobiogeographical analyses of very complex tectonic settings as the Qinghai-Tibet Plateau (QTP) of China composed of different blocks/terranes amalgamated by several suture zones. Detailed stratigraphic and paleontological studies and precise correlations are needed to reconstruct the evolution of the Cimmerian blocks in the Permian.

Shuzhong Shen and co-authors report about the search for a replacement for the Penglaitan section, the base-Lopingian GSSP, which will be soon be permanently flooded due to the building of a dam along the Hongshui River. The authors introduce the promising studies they are doing on the possible candidate for this replacement, the Baixiangdong section in Liuzhou.

Mike Stephenson and Dorit Korngreen report about a palynological study of the Arqov and Saad formations of the Negev, Israel, in Avdat-1 borehole. Through this study, they tested the utility of the OSPZ Arabian palynological zones and carried out a comparison with the assemblages of the Umm Irna Formation of the Dead Sea, Jordan.

Michael Brookfield discusses the depositional setting and timing of the Tesero Oolite, a thin, shallow marine bed at the Permian-Triassic boundary in the Southern Alps through a comparison with the Quaternary Bahama bank, differently interpreted as a ramp vs. a platform in the literature, supporting his own view.

Joerg Schneider and co-authors present comprehensive reports of the many activities of the Late Carboniferous – Permian – Early Triassic Nonmarine-Marine Correlation Working Group, starting from the exhaustive article published by Schneider et al. (2019) to the several congresses and meetings where the working group was able to present and discuss new data and achievements.

Following on this, Hans-Georg Herbig report about the 19th International Congress on the Carboniferous and Permian (XIX ICCP 2019) held from July, 29th to August, 2nd, 2019 at the University of Cologne, Germany, attended by 200 participants from all over the world.

Finally, Gerhard Bachmann presents the report of the 15th International Permian-Triassic Workshop, that took place on May 13–18, 2019 in Sardinia, whereas Daniela Germani reports about the 3th International Congress on Stratigraphy STRATI 2019, held in Milano on July 2-5, 2019.

At the end of the issue, Galina Kotlyar reports about the monument erected for the base Sakmarian GSSP at Usolka, and Spencer Lucas presents an interesting paper published open access in Bollettino della Società Paleontologica Italiana 58 (2019).

Future issues of Permophiles

The next issue of Permophiles will be the 69th 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 69 is 31th July, 2020. Manuscripts and figures can be submitted via email address (yczhang@nigpas.ac.cn) as attachments. PLEASE NOTE THE NEW ADDRESS FOR SUBMISSION!

To format the manuscripts, please follow the TEMPLATE

Notes from the SPS Chair

Shuzhong Shen

First of all, I would congratulate the newly-elected executive committee of the Permian Subcommission on Stratigraphy. Lucia Angiolini has been elected as the chair, Mike Stephenson as the vice-chair and Yichun Zhang has been nominated as the SPS secretary. We thank Charles Henderson for the chair of the nominating committee to organize this new election. The new SPS executive committee will take the position after the 36th International Geological Congress in March, 2020, in New Delhi, India. I am sure the new committee under the leadership of Lucia Angiolini will move the Permian GSSP work and timescale refinement forward efficiently. Both the International Union of Geological Sciences (IUGS) and International Commission on Stratigraphy (ICS) hope all Subcommissions finish the GSSP work as soon as possible.

The official paper on the GSSP for the base of the Sakmarian Stage is currently under revision after a first round of review. I hope the paper can be published shortly on Episodes. We still have two GSSPs to be defined in the Permian. The Kungurian-base and Artinskian-base GSSPs are the priority for the next steps of SPS. However, controversy is still present in terms of the index species to define the base of the Artinskian Stage. The Mechetlino Quarry section has been greatly improved recently following the recent online publication on the Kungurian Stage by Chernykh et al. (2019, Palaeoworld, https://doi.org/10.1016/j.palwor.2019.05.012). More data are available for this section which becomes much better as the candidate of the Kungurian-base GSSP.

Unfortunately, the Lopingian-base GSSP will be flooded this year probably permanently because a dam for a power station is being built in the downstream of the Hongshui River in Guangxi Province. The Ministry of Water Resources of China supported the Chinese team and some measures were taken to save the GSSP section. Our team tried very hard to find a new section as the replacement or supplementary section for the Lopingian-base GSSP. Great progresses have been made during 2019 (see a report by Shen et al. in this issue).

Two very important meetings were held during last year. The ICS official congress STRATI 2019 was held in July in Milano. It was a great honor for me to be awarded the ICS Medal. I am the first Chinese scientist to win such a great honor in ICS. In addition, the 19th International Congress on Carboniferous and Permian was held in late July-early August in Cologne, Germany. We thank the organizing committee led by Prof. Hans-Georg Herbig to have done a great work for this congress. Two SPS business meetings were held during Strati 2019 and ICCP 2019 as well, 12 SPS voting members and about 20 other colleagues attended the two meetings. I reported the progresses of the Permian GSSPs and we had a lot of discussions on the future work of SPS, in particular, the Guadalupian GSSPs in the Guadalupe Mountains National Park in Texas. A few papers on these GSSPs will be published soon.

Today is the eve of the Chinese Spring Festival, I wish you all the best for the Year of the Rat. Happy Year of the Rat!

SUBCOMMISSION ON PERMIAN STRATIGRAPHY

ANNUAL REPORT 2019

1. TITLE OF CONSTITUENT BODY and NAME OF REPORTER

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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, magnetostratigraphical 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 - interface with other international projects / groups

3a. Current Officers and Nominated Officers for 2020-2024 period:

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

I am currently discussing with the Scientific committee of the Deep-time Digital Earth (DDE) Big Science Program of IUGS to try to get supplementary funding to support an international program for ICS to complete an official numerical multidisciplinary timeline using all possible correlatable data, which can be also updated instantly.

5. CHIEF ACCOMPLISHMENTS IN 2019 (including any relevant publications arising from ICS working groups)

- The official paper for the ratified GSSP of the base-Sakmarian has been submitted to Episodes and it has been reviewed. The revised version will be submitted shortly.
- General proposals for the bases of the Artinskian and Kungurian stages have been prepared.
- A Special Issue has been published (Shen and Rong, 2019. Integrative Stratigraphy and Timescale of China: Science in China Series D: Earth Sciences, 62(1):1-348). One issue of Permophiles (Issue 67, SPS Newsletters) was published.

6. SUMMARY OF EXPENDITURE IN 2019

We supported two voting members and two young scholars to attend the Strati 2019 and ICCP 2019 and held two SPS business meetings respectively during the International Carboniferous and Permian Congress 2019 and Strati 2019. The total expenditure is much more than the amount (US$4500) supported from ICS.

7. SUMMARY OF INCOME IN 2019

$4500 from ICS.

8. BUDGET REQUESTED FROM ICS IN 2020***

We will apply for 5000US$ from ICS for SPS activities in 2020. This will be mainly for: 1) SPS Chair Shuzhong Shen to attend the 36th International Geological Congress (2-8 March, New Delhi, India); 2) Shuzhong Shen attends the Executive Committee Meeting of IUGS held in South Korea in January; and 3) possible expenditure (~$ 500) for the activities to finish the two remaining GSSP work.

9. WORKPLAN, CRITICAL MILESTONES, ANTICIPATED RESULTS AND COMMUNICATIONS TO BE ACHIEVED NEXT YEAR:

- We hope to complete the remaining two GSSPs (base of Artinskian and base of Kungurian) in the next year.

10. KEY OBJECTIVES AND WORK PLAN FOR THE PERIOD 2020-2024

- Establishing the Artinskian and Kungurian GSSPs
- Completing research into the replacement GSSP section of the base-Lopingian
- Propose and assist the ICS Chair to organize the working group under the Deep-time Digital Earth Big Science Program to establish the numerical multidisciplinary timeline. Try to get financial support from DDE program.

APPENDIX [Names and Addresses of Current Officers and Voting Members)

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GSSP-based Chronostratigraphy: Should Boundaries Be Defined by Arbitrarily Chosen Non-Events?

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Introduction

In his latest "harangue," Charles Henderson (Henderson, 2019) has devoted some discussion to several of the points I made in my article critically reviewing the GSSP method of chronostratigraphy (Lucas, 2018). Charles has encouraged me to continue this discussion by commenting on points on which we disagree.

Arbitrary and Natural Decisions

I have been very critical of primary signals for GSSPs that are based on arbitrary decisions simply because arbitrary decisions are not scientific, they are "random, based on personal choice or whim and thus are not based on any system or line of reasoning" (Lucas, 2018, p. 10). In particular, I have heaped much scorn on the arbitrarily chosen points in conodont chronomorphoclines chosen as the primary signals of many Paleozoic and some Triassic GSSPs (Lucas, 2010, 2013, 2016, 2018, 2019). This is because these points are not only chosen arbitrarily, but they are what I would call non-events, and not readily replicated, even among a group of conodont micropaleontologists. Charles defends such arbitrary decisions using as an example the base of the Permian (base of the Asselian Stage) by saying it was close to the base of the traditional Permian base in the Russian section, it underwent careful scrutiny and was voted on by everybody from the working group to the ICS top commissioners. I would, instead, describe this as a bad decision based on unsound science validated by political means.

Incidentally, Charles (p. 6) claims that the word arbitrary, which has the same Latin root as arbiter (judge) can be used in a positive sense to mean "to judge based only on the facts." However, according to the Oxford English Dictionary, the word arbitrary has never been used in that sense; by the 1600s its use in English meant "capricious, ungoverned by reason or rule, despotic."

Charles misrepresents me when he says (p. 7) that "Lucas (2018, p. 10) incorrectly assumes all conodonts exhibit [evolutionary] anagenesis…." I actually pointed out that this is an integral part of the "corporate culture" of conodont micropaleontologists. My example in the 2018 article is from one of the Olympian figures of conodont micropaleontology, the late Willi Ziegler, who perhaps best articulated as an article of faith that conodont evolution takes place solely by phyletic gradualism. I conclude that "there is no scientific rigor behind the concept that all conodont evolution took place by phyletic (largely anagenetic) gradualism" (Lucas, 2018, p. 10). Thus, I do not believe that all conodonts exhibit evolutionary anagenesis nor do I think anybody should believe this, though most conodont micropaleontologists do. Charles is one of the few (perhaps the only!) conodont micropaleontologist who has said in print that conodont evolution could have taken place by processes other than phyletic gradualism.

I agree with Charles (and others) that chronostratigraphic boundaries do need to be chosen. But, we are using chronostratigraphy to divide up Earth history, and a taxonomy of history based on arbitrary decisions is a history lacking information (see my discussion of this point in Lucas, 2018). We do well to divide history by significant natural events that have widely and readily recognized signals and thus provide the strongest possible basis for correlation.

Natural Choices

Like most chronostratigraphers from Murchison to Walliser, I favor boundaries based on natural events, such as the beginnings of major evolutionary radiations or mass extinctions. As just noted, I oppose boundaries based on arbitrarily chosen non-events such as arbitrarily identified changes in a conodont chronomorphocline. Lucas (2018) pointed to natural events such as the Cambrian explosion, the great Ordovician biodiversification event or the Devonian extinctions as the kinds of events to use for chronostratigraphic definition. Charles (p. 7) notes that the Cambrian explosion and great Ordovician biodiversification event "occurred over an interval of time that is still under debate." True, but each of these events had a beginning and we just need to agree on that beginning to have a potential signal for boundary definition. For example, the oldest trilobite or small shelly fossils were classically used signals to define the base of the Cambrian and they are suitable markers of the beginning of the Cambrian explosion. Unfortunately, the Cambrian Subcommission chose instead to go down a rabbit hole by using a trace fossil signal to define the base of the Cambrian (Lucas, 2019).

Charles explicitly favors two kinds of natural events for chronostratigraphic definition—sea-level fluctuations and ice ages. I endorse those as useful natural events, recognizing their inherent diachroneity over large areas. Indeed, as some astute conodontologists have pointed out, conodont LOs and HOs track sea-level fluctuations and thus are inherently diachronous.

I also find it ironic that Charles draws attention to my comments regarding the impracticality (given current knowledge) of using the Russian stage concepts Asselian, Sakmarian, Artinskian and Kungurian in the West Texas Permian basin, where Wolfcampian and Leonardian are very useful regional/local stages. Charles claims that a new re-interpretation of the *Sweetognathus* conodont lineage has made it possible to correlate the Wolfcampian-Leonardian boundary to the base of the Sakmarian (also see Henderson, 2018). But, this remains to be fully documented, and contradicts earlier, also undocumented correlation using conodonts by Wardlaw (2004) of the base of the Leonardian to the base of the Kungurian, and, the more substantiated correlation of the base of the Leonardian to a level within the Artinskian based on conodonts and calcareous microfossils (Holterhoff et al., 2013; Vachard et al., 2015) (see discussion by Schneider et al., 2019). This is a problem NOT solved, but I am happy to report that Charles and I are working together with new conodont data from Texas and New Mexico to better establish the correlation of the Leonardian to the Russian stages.

Chronostratigraphic Hierarchy

The GSSP method of chronostratigraphy embodies hierarchical reductionism by which the bases of the so-called standard stages define the bases of larger chronostratigraphic units coincident with the stage bases. Charles states that the base of the Permian must correspond to a base of the Asselian, which is an arbitrary point in a conodont chronomorphocline, the LO of *Streptognathodus isolatus* in western Kazakstan (and this is highly problematic, as I have pointed out elsewhere: Lucas, 2013). But, I argue that there are no global stages, because a stage such as the Asselian can only be correlated globally with very variable precision, mostly great imprecision (for example, where is the Asselian base in the red beds of north-central Texas?). Indeed, how useful (recognizable) is the Asselian outside of the Uralian basin?

Furthermore, if the base of the stage defines the base of the system, then the base of this larger chronostratigraphic unit has been reduced (I would say trivialized) to a conodont non-event (Lucas, 2019). I would rather define the bases of series, systems, erathems and eonothems by much larger, natural events. Charles says the Permian began with a substantial ice age, so that would be one signal to look at for potential chronostratigraphic definition, and a much better signal than the conodont non-event now being used.

Instability and Imprecision

Charles and I agree that GSSPs that do not work need to be fixed, so there are no such things as immutable chronostratigraphic boundaries (as claimed by many, including former ICS Chairmen). Charles and I also agree that there will always be some degree of imprecision associated with any chosen chronostratigraphic boundary, as all events used to define boundaries have some built in diachroneity on a regional or global scale.

I drew attention to using multiple biostratigraphic datasets such as are used in the Unitary Association (UA) method to "produce a much more robust biozonation than traditional biostratigraphic interval zones". Charles does not think that UA produces a stronger biozonation than interval zones of single taxa, but it has produced much more robust biostratigraphic zonations than single taxon biostratigraphy (e.g., Monnet et al., 2015). I only used UA as an example of the possible way forward. The point is we need something better than GSSPs with primary signals based on single taxon LOs, which are highly diachronous and subject to restricted distributions due to facies changes, taphonomic biases and/or provinciality.

FOs and FADs

Charles does not like my use of HO, LO and FAD, LAD. Let me repeat what I have published about this more than once. Thus, I make an important distinction between biostratigraphic datums and biochronological events. Biostratigraphic datums are the lowest occurrence (LO) and highest occurrence (HO) of a fossil in a stratigraphic section. Biochronological events are the first appearance datum (FAD) and last appearance datum (LAD) of a taxon, its evolutionary origination and extinction, respectively. For biochronological definitions, it is hoped that the LO and the FAD of a taxon coincide, though given the problems of sampling and facies, it is highly unlikely that this will be the case.

This is a clear way to distinguish what we actually know (lowest and highest occurrences of fossils in stratigraphic sections) from what we may know, but cannot be certain we know (actual evolutionary first appearances and last appearances). However, many micropaleontologists who believe they are looking at anagenetic evolution in chronomorphoclines think they are actually seeing evolutionary originations and extinctions, so they do not make the careful distinctions that I do.

Conclusion

I think Charles and I agree more than we disagree, and that we will ultimately simply have to agree to disagree on a few things. We certainly agree that the GSSP method has been tremendously heuristic in driving the collection of many data, biostratigraphic and otherwise. The GSSP method has also pushed forward a much more precise chronostratigraphic scale, though I see some of that precision as illusion. What I advocate, and I hope that Charles agrees, is that we improve the GSSP method to further advance the timescale. Exactly what improvements need to be made remain to be agreed upon.

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GSSP-based Chronostratigraphy: Should Boundaries Be Defined by Arbitrarily Chosen Non-Events? Reply.

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Introduction

The answer to the question in the title is "no". Spencer and I agree on this, and we agree on many other things, including that every effort should be made to improve the GSSP process. But there are a few things upon which we disagree, which I will discuss below.

Arbitrary Decisions

I will concede that the common usage in English of "arbitrary" is the negative definition, but when Ager (1993) and others said "let us make an arbitrary decision" he was not being capricious, nor despotic, and was not suggesting that decisions would be ungoverned by reason. Spencer "heaps scorn" on arbitrarily chosen points in conodont chronomorphoclines as the primary signal to define many Paleozoic and Triassic GSSPs, in part because he considers them to be non-events. As a member of the "corporate culture" of conodont micropaleontology I would never regard the evolution of a species as a non-event. But I agree that the defining FAD should be chosen wisely, and that some points will be more natural than others.

Natural Choices

It was true that many studies on the evolution of conodonts pointed to anagenesis as the primary mode and tempo as indicated by Spencer, but other modes are also considered. For example, the base of the Wuchiapingian is set at the punctuated evolution of Clarkina postbitteri postbitteri in which gene flow was temporarily restricted by the global lowstand of sea-level. This seems like a very natural choice. In fact, many stage boundaries coincide or nearly coincide with transgressive surfaces, and it is within transgressive systems tracts (TST) that conodont evolutionary events seem to be concentrated. Anagenetic changes may predominate within the regressive (RST) or highstand systems tract. Choosing a conodont evolutionary event within a TST is a decision that has wide applicability in many other sections, even if the conodont species is lacking. In fact, red beds typically accumulate at times when accommodation is provided by base-level rise. I have been a long-time advocate, and teach my students, that good biostratigraphic analysis does not ignore the sequence stratigraphy of the rock record. Conodonts are among the very best fossils to consider modes of evolution, largely because they are so common in most marine facies. In many sections, conodonts can be collected continuously and thereby provide a high-resolution record of evolutionary change – change that seems to follow the beat of ancient sea-levels. It is true that sea-level change is inherently diachronous over large regions, but the question "what is the temporal extent of that diachroneity" can only be answered by the detailed and collaborative research associated with GSSP studies. For example, geomagnetic reversals and carbon isotopic shifts might point us in the right direction.

Global Time Scale and Regional Scales

It is my view that all of us should aim to correlate our successions with the international stages of the geologic time scale (GTS) as well as regional stages. There are many reasons why they may or may not correlate. Spencer mentions my "new interpretations of the Sweetognathus conodont lineage that made it possible to correlate the Wolfcampian-Leonardian boundary (WLB) to the base of the Sakmarian". I very recently completed the chapter for the new GTS 2020 book and I revised my correlation of the fusulinid defined WLB to coincide with the RST succession at the base-Sarginian substage (base upper Artinskian). However, my suggestion of base-Sakmarian still stands for the natural event at the end of the late Paleozoic Ice Age (LPIA) that in many locations can be recognized by the termination of eccentricity driven cyclothems. In Texas and in Kansas, this level has been correlated with the WLB (see Henderson, 2018), but it is much older than the fusulinid definition. Conodonts have shown the way toward resolving this issue. I am very excited with some of the work that Spencer and I are doing to recognize the Kungurian in the Blaine Formation of Texas, the Yeso in New Mexico and the Fort Apache Limestone of Arizona. I am happy to report that Spencer has a knack for collecting productive conodont samples, so much so, that he is clearly eligible for conodont corporate membership, if he so desired. Ultimate resolution of the WLB correlation will require access to the private lands of the Glass Mountains where these US stages were defined. There is still more work to be done.

Acronym Challenges

It is true that I disagree with Spencer's use of LO and HO for lowest occurrence and highest occurrence, but my reason is not quite as suggested. We should distinguish between the biostratigraphic first occurrence (FO; Spencer's lowest occurrence or LO) and last occurrence (LO; Spencer's highest occurrence or HO) and chronostratigraphic first appearance datum (FAD) and last appearance datum (LAD). We agree on the use of FADs and LADs. These are both time-rock terms and in my opinion we don't need both first and lowest to identify the first occurrence (FO) of a fossil in a local section (Henderson, 2006). However, the FAD is the true first occurrence as determined by high-resolution collaborative GSSP research; we differentiate this as the first appearance datum.

Conclusion

Spencer and I agree on many points. Both of us are unapologetic field-based geologists who advocate for the need for continuing research on well exposed sections around the world. The collaborative research by many specialists to define GTS stages at different GSSPs is increasing our knowledge of Earth's geologic history. This also improves the GSSP process and we both agree it can only get better. It would be great to hear from others on how the GSSP process can be improved.

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Henderson's Harangue #6

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Introduction

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

How can we stabilize the Geologic Time Scale (GTS)?

The ongoing revisions of the Geologic Time Scale (Gradstein *et al*., 2012 and a new version coming soon in 2020; and see ICS website www.stratigraphy.org) seem to concern many geoscientists – in some cases, researchers would like to use the traditional correlations saying, as an example, "the fusulinids or ammonoids or conodonts are Sakmarian forms and can't possibly be late Asselian". Feel free to substitute your own favourite fossils and time interval. However, determinations of these traditional correlations were made before the Global Stratotype Section and Point (GSSP) process. The fusulinids, ammonoids, and conodonts were not Sakmarian forms – until we had a definition, they were simply forms older or younger than other forms according to the principle of superposition. I agree that the GSSP process is taking a long time, but the GSSP process has been the impetus for amazing advances in stratigraphic analysis, in part because it provided the opportunity for some tremendous collaboration among many colleagues. These new boundaries have been decided by a wide spectrum of geoscientists that considered the global signals of geomagnetic reversals, isotopic shifts, and evolution of many taxa to define interval biozones in multiple sections around the world. They also utilized geochronologic dating, quantitative biostratigraphic techniques, taxonomic procedures like the population concept (Mei et al., 2004), and sequence stratigraphy. Fossils are not distributed randomly in the rock record and proper application of sequence biostratigraphy is essential for good interpretations (Henderson, 2016). I reviewed a paper recently in which some sections included the exact same unchanging facies over all three 3rd-order depositional sequences of the Lower Triassic. Is this even possible?

Are there natural boundaries? I suggest that some are more natural than others (see the discussion and reply by Spencer Lucas and me elsewhere in this issue of *Permophiles*). One such natural boundary in the Permian is the end of the late Paleozoic Ice Age (LPIA), which can be clearly demonstrated by the termination of high amplitude sea-level change associated with 405 Kyr cyclothems. Longer duration 3rd-order sequences dominated the record once the major Gondwanan ice sheet had melted. The recent new definition for the base-Sakmarian means that the last few cyclothems are Asselian. The end of the LPIA-P1 is close to the base-Sakmarian defined by the first appearance datum of *Mesogondolella monstra* at the Usolka section (Chernykh *et al*., in press), but also recognized by sequence stratigraphic signature. In addition, this marks the end of the LPIA since so-called P2-P4 events seem to be local alpine events and not really "ice-ages". This seems like a natural choice and appears to correlate with the base-Lenoxian substage of the Wolfcampian regional stage and maybe the regional Longlinian substage in China. I challenge others to test these correlations.

Dates and rates also change as techniques improve and new ash beds are found. There are only a few ash beds in late Artinskian to early Roadian successions that presumably testify to a level of quiescence associated with completion of Pangea amalgamation. Other intervals are well dated because of significant subduction zone volcanism. We need to keep looking for more ash beds because geochronologic age dates are the ultimate test of our biostratigraphic and chronostratigraphic correlations that provide the framework for the GTS.

I review a lot of papers and increasing, many of them provide fantastic stories of oceanographic changes and extinction effects, but actually lack one significant feature. In many cases, they lack any attempt to truly use the GTS – it is as if some workers have decided they do not want to put in the time or have succumbed to the temptation to dismiss the GTS because other geoscientists keep changing it. How would some of these fantastic stories change if it were demonstrated that they compared events of different ages? It is time to complete the first round of GSSPs so that we can develop new methods to test our decisions. As all techniques continue to develop it is likely that higher resolution will result in only minor revisions to the timescale – not wholesale changes.

Conclusion

I conclude that the answer to my title question is simple. How can we stabilize the GTS? We need to use it!

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Sea-floor carbonate precipitates after mass extinctions - separating depositional and diagenetic fabrics: a discussion

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Introduction

This contribution addresses fibrous calcite cements of "beef" and cone-in-cone types that are widely viewed in literature as burial diagenetic, but in at least recent three papers published in peer-review international journals these cements are interpreted as contemporaneous precipitates associated with mass extinction. Those studies regard fibrous calcite layers as precipitates driven by ocean saturation of carbonate, formed either on or just below the sea floor, following the end-Triassic and end-Permian mass extinctions. Two (Greene et al. 2012 and Heindel et al. 2015) were considered by Kershaw and Guo (2016). A third paper (Li et al. 2018) extended the environment of precipitation of "seafloor carbonate precipitates" (SCPs) to deeper water facies, with a new model of formation.

Beef calcite fibrous crystals are arranged normal to the veins in which they occur, informally called "beef" in British literature because of superficial similarity to muscle fibres in a beef steak. Cone-in-cone calcite fibrous crystals are arranged in stacked cone-shaped masses, forming nested structures very similar to stacks of cone-shaped paper drinking cups in public water dispensers. These two forms of fibrous calcite commonly occur together and are not always distinguishable in the field, so the combined term "beef and cone-in-cone calcite" (BCICC) is useful. I argue that because of great similarity between BCICC and cements described from mass extinction facies, doubt may be cast on validity of their application in interpretations of extinction-related environmental processes. I ***greatly stress*** that the intention of this contribution is to maintain a balanced debate of high-quality science, and ***not*** to criticize other authors, for whom I have great respect. This contribution has two key points described below.

Point A: Post-extinction carbonates: depositional and diagenetic

Features of beef and cone-in-cone calcite

Figures 1-6 show structure and variation of cone-in-cone calcite from the Lower Jurassic of a classic area of southern UK; Fig. 7 is a summary sketch. Cone-in-cone calcite is the main focus in this Discussion; very good photos of beef are published by Zanella et al. (2015). The key points, illustrated in Figs 1-7, are:

i – BCICC layers show antitaxial growth: that is, they grew away from the bedding orientation both up and down, but in some cases grew around concretions in any orientation (Fig. 6);

ii – BCICC layers are inconsistent in thickness and lateral extent in relation to the beds in which they occur; they commonly taper to nothing (Fig. 1, see also Rodrigues et al., 2009, Meng et al. 2017) and may irregularly interrupt bedding (Fig. 3);

iii – Cone-in-cone calcite (CICC) exhibits a history involving replacement of sedimentary fabrics, that must have occurred over some time, not consistent with a short period of precipitation on or just below the sea floor (Figs 2, 4, 5, 7). BCICC growth on concretions (Fig. 6) is also evidence of later formation. The reasons why beef and CICC have different arrangements of crystals, located in the same deposits, are not clear, but beef crystals seem to be veins filling fractures, while CICC may involve crystal growth that replaces and displaces sediment, discussed below (see Watts 1978 for discussion of displacive calcite cements).

iv – Kershaw and Guo (2016) presented primary evidence that the clay-rich micritic limestones, in which BCICC occurs, underwent compaction *before* the BCICC was formed, because of crushed ammonite shells in both the sediment and encased in the fibrous crystal masses.

There is a substantial body of literature on BCICC going back more than 100 years. Several studies regard BCICC as later diagenetic results of hydraulic fracturing and involving hot fluids, with raised organic matter, importing calcium carbonate into the rock for precipitation as BCICC fibres (e.g. Cobbold et al. 2013, Meng et al. 2017, Rodrigues et al. 2009, Zanella et al. 2015, and Figs 1-7 of this discussion). However, there is other work that interprets BCICC as due to early formation, for example: **i)** Saitoh et al. (2015) regarded the texture of fibrous calcite crystals of the Middle Permian at Chaotian, Sichuan, China,

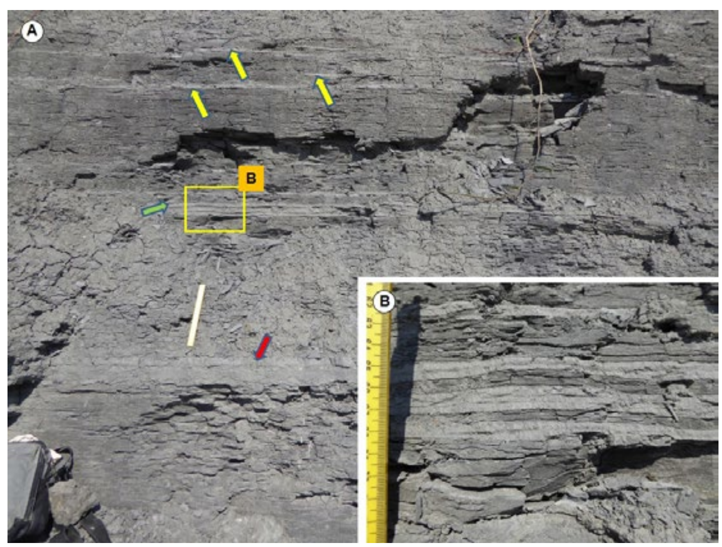

Fig. 1. Field photographs of the vertical cliff section of the Lower Jurassic "Shales-with-Beef" Member at Charmouth, west Dorset County, southern England. **A.** General view showing shale-dominated facies with numerous beef and cone-in-cone calcite (BCICC) bed-parallel veins, forming a cluster in the centre (green arrow). Yellow arrows show sparser veins, some of which taper and terminate laterally. Red arrow shows a single thicker vein. The white scale is 20 cm long. **B.** Enlargement of the yellow box in A, showing the vein cluster, emphasizing that each vein has a structure of a central darker-coloured region with lighter-coloured regions above and below, the significance of which is made clear in Fig. 2.

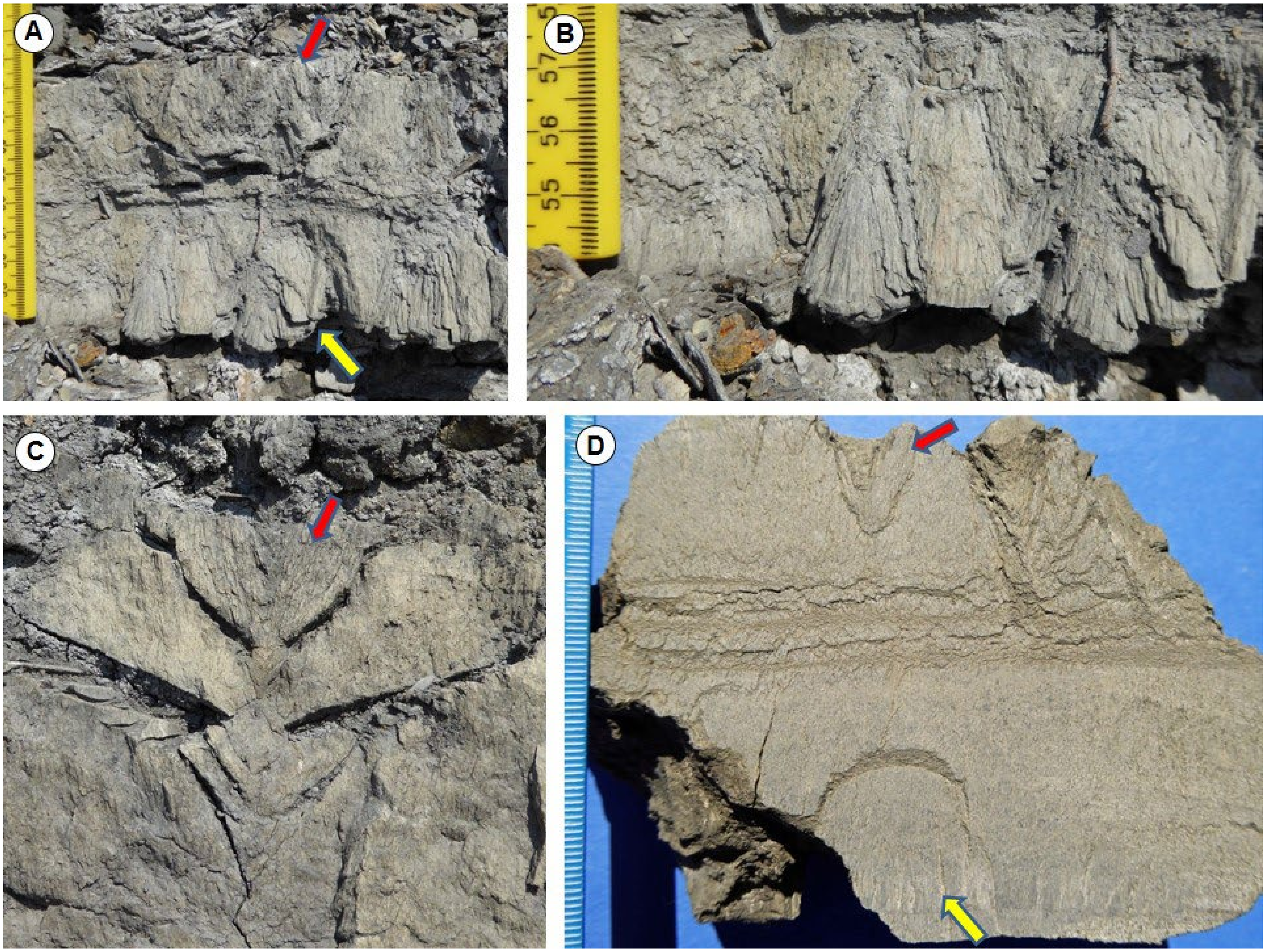

Fig. 2. A-C. Field photographs of details of cone-in-cone calcite layers (same locality as Fig. 1) cut in vertical section. **A.** Section showing the complete thickness of a cone-in-cone calcite vein, with its central part as a distinct layer without an obvious crystalline character, contrasting the highly crystalline structure in its upper and lower parts. Antitaxial growth (downward-expanding cones in the lower layer (yellow arrow), and upward-expanding cones in the upper layer (red arrow)), is a consistent feature. **B.** Enlargement of the lower left part of A, emphasizing the downward-expanding character of cones in the lower part of the vein. **C.** Upper layer of the vein a few cm along strike from the location of A, showing upward-expanding cone structure highly developed to form large cones. Dark recesses in the cone structure were occupied by clays now weathered out (see D). Photo is 8 cm wide. **D.** Cut section of sample showing the entire thickness of a cone-in-cone antitaxial vein from Lyme Regis, a few km from Charmouth, in the Shales-with-Beef Member. The thin undulating darker veinlets are clays, more common in the central portion of the vein, interpreted as concentrations of clays in layers by recrystallisation of the calcite component of the muddy limestone, discussed in the text. Scale in mm.

to have been deposited on the sea floor in deep anoxic ocean waters; **ii)** Tribovillard et al. (2012) interpreted early diagenetic formation in the latest Jurassic in northern France as related to sulphate-reducing processes on the sea floor, associated with synsedimentary faults that may have been conduits for saturated fluids rising to the sea floor from the subsurface. Key to interpretation is the detailed structure of the cements in relation to their associated sedimentary facies.

Kershaw and Guo (2016) drew attention to the character of the CICC variable crystal size where CICC crystals show increasing size from the central part of a limestone bed towards its upper and lower margins (Figs 1, 2, 4). CICC layers terminate at contacts between marly limestone beds and shale. CICC layers may be explained by a combination of addition of calcium carbonate imported into the rock (possibly with additional carbonate from overlying and underlying shales), plus partial recrystallisation of the carbonate component of the marly limestone layers. However, the nature of the crystal mass gives the clear impression that CICC did not form in one event, but instead occurred over time; initially it began at the limestone upper and lower contacts, while the interior of the bed was not altered (Kershaw and Guo 2016, figs 4, 8; and Fig. 7B of this

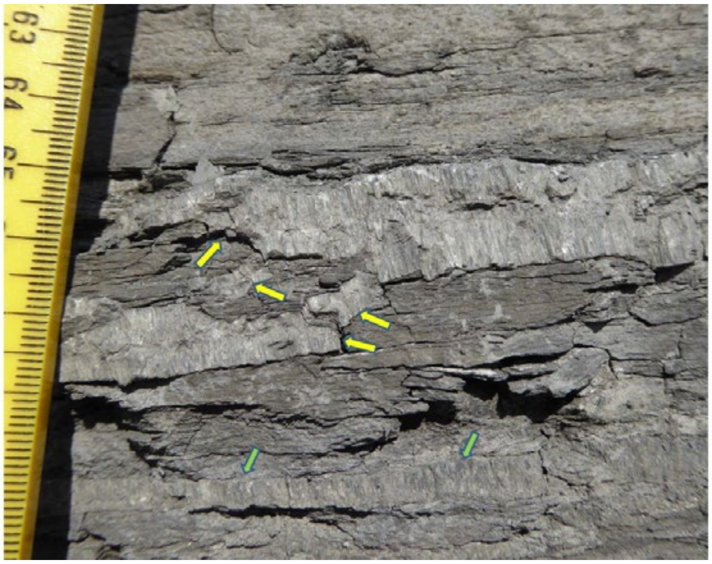

Fig. 3. Vertical cliff section from Shales-with-Beef Member at Charmouth showing partial development of layers of BCICC veins (yellow arrows) and varying vein thickness (green arrows), evidence of their diagenetic, rather than depositional, origin.

discussion). In beds more strongly affected by alteration, the CICC crystals developed downwards from the top of the bed, and upwards from the base of the bed, ultimately converging in the middle (Figs 2, 7 of this Discussion and photos in Kershaw and Guo 2016). The most extensive alteration ended in very large CICC masses (Kershaw and Guo 2016, fig. 13), with pockets of clay trapped between the crystals (Fig. 2C-D, Figs 4, 5). A simple cartoon of increasing alteration is envisaged in Fig. 7 of this Discussion. The control on the process is not clear but may have been stimulated by injected fluids along the upper and lower surfaces of limestone beds in shale-limestone units. Thus the antitaxial crystals did not originate from the middle part of the bed growing outwards but from the outer margins of the bed, developing inwards. Outward expansion of the crystals to form antitaxial cones may be explained by crystal expansion towards the softer overlying and underlying clay beds, where replacive and displacive growth would presumably be less constrained in the direction of the softer clays than towards the centre of the limestone bed. In this interpretation, the outer crystals formed over a longer time period and are therefore bigger.

Fibrous calcite cements associated with mass extinction

Antitaxial growth is visible in fibrous calcite illustrated by Greene et al. (2012, fig. 2E) from the Late Triassic of southern England in material identical to that studied by Kershaw and Guo (2016) from South Wales. Careful examination of their fig. 2E is needed but antitaxial growth is clear enough, compare with Fig. 5 of this Discussion. Likewise, Heindel et al. (2015, fig. 4) also illustrated antitaxial growth with size increase in CICC crystals in upper and lower parts of the bed illustrated. Heindel et al. devoted one section of their paper to a discussion of whether their material is later diagenetic CICC and regarded it as being sufficiently different to support their view of an early formation. Both Greene et al. (2012) and Heindel et al. (2015)

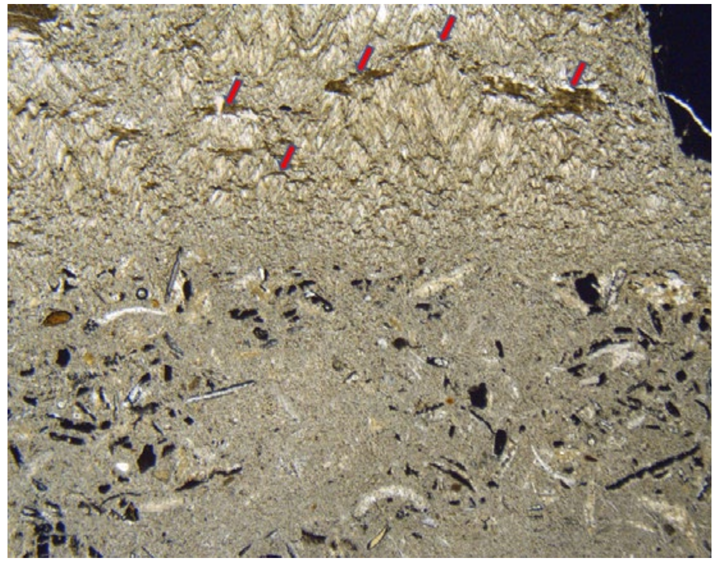

Fig. 4. Vertical thin section of originally muddy limestone from Lower Jurassic Shales-with-Beef Member at Lyme Regis, with cone-in-cone structure at the top of the photo, showing gradational change, diminishing in crystal size downwards into bioclastic-rich micrite. The cone-in-cone part may have grown within shales overlying the limestone bed, concentrating clays into pockets, seen in the upper part of this photograph (red arrows). The gradational change downwards into the limestone is interpreted as partial later diagenetic replacement of the limestone. This idea is developed further in Fig. 5.

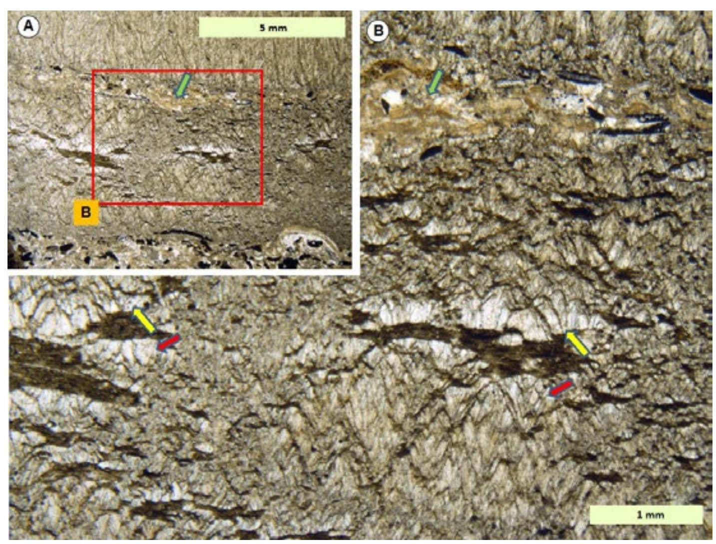

Fig. 5. Vertical thin section of muddy limestone from Lower Jurassic Shales-with-Beef Member at Lyme Regis, showing recrystallisation within the limestone with development of antitaxial structure even in small scale in thin sections (red arrows show upward-expanding and yellow arrows show downward-expanding crystals). The dark areas are clays interpreted as remnant insoluble matter squeezed into pockets by expanding calcite crystal growth. A crushed mollusk shell is shown by green arrow.

viewed this displacive growth as being in soft sediment just below the sea floor, yet the structures illustrated are so similar to later diagenetic CICC that to me remain equivocal. Li et al. (2018, fig. 7A) show antitaxial growth in crystals expanding upwards and downwards from a thin curved shell in the middle of the photograph. In their fig. 7B, it is less clear whether the tiny crystals within the sediment are antitaxial but could be verified by re-examining the thin section used in that photograph. In their fig. 7C, only downward-expanding growth is shown, but the crystals become gradually larger down the photograph, trapping dark matter (presumed clay) between the expanding crystals. This arrangement is a characteristic of later diagenetic CICC, and their fig. 7C is presumably from the lower part of a limestone bed.

Of great value in this debate, Li et al. (2018) provided excellent quality illustrations of their material and I note the following:

a) Li et al. (2018, fig. 5D-E) show very clear thin section photographs in ppl and xpl of fibrous calcite that looks just like beef (compare with Cobbold et al. 2013, fig. 3D-E).

b) Li et al. (2018), fig. 9 (presumably of CICC), shows elemental maps, highlighting that dark matter between calcite crystals is rich in Si and Al (the principal clay elements that are rare in calcite crystals). Ca is low in dark matter of their fig. 9, expected in clays; and Fe, Mn are not distinguishable between calcite crystals and dark matter, a likely reflection of the anoxic conditions in burial that CICC crystals form. These geochemical data would fit well with a formation by progressive formation of CICC that forced the clay into thin layers between CICC crystals.

c) The small variability in CL response reported by Li et al. (2018, fig. 10) may be explained by the lack of diagenetic change that they interpret, but an alternative reason is recrystallisation of sediment into CICC, so the components that carry the CL signal are redistributed more-or-less evenly by the recrystallisation process.

d) It is perhaps significant that SCPs reported in Li et al. (2018) occur in only thin silty limestones as is the case for CICC. In their field photos, fig. 4D looks like beef and their fig. 4E looks like CICC, both occurring on the lower margin of the limestone beds, identical to their occurrence in the limestones of shale-limestone rhythms in the Mesozoic of southern England (Kershaw and Guo 2016; and Figs 1, 2 of this Discussion).

e) Li et al. (2018, p. 63): "Note that contacts between SCPs and

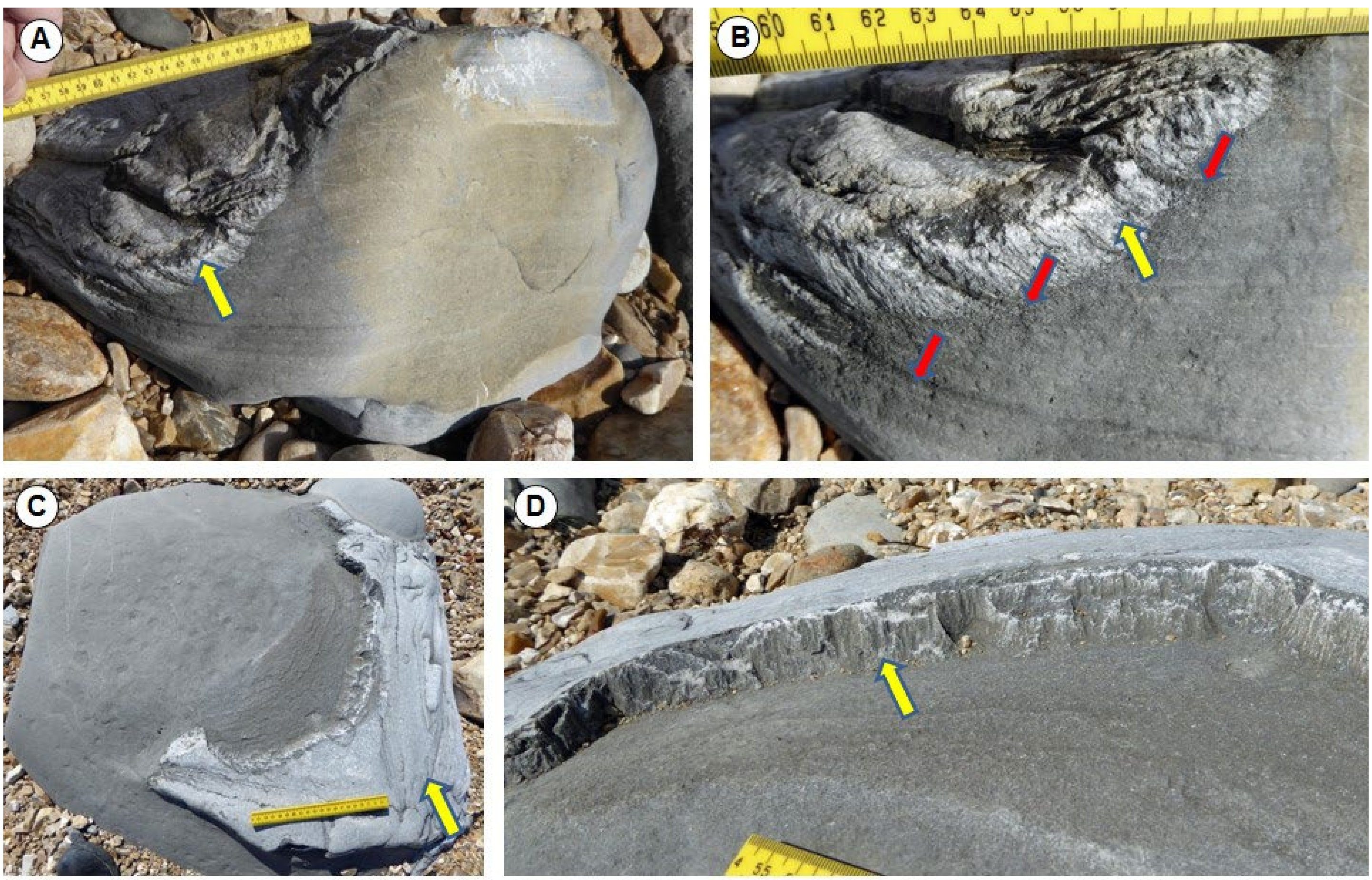

Fig. 6. Field photographs of two concretionary nodules of limestone, **A, B**, **C, D**, loose samples on the beach at Charmouth, eroded from the Lower Jurassic Shales-with-Beef Member. Both nodules are encrusted by BCICC (yellow arrows in all photographs). Concretionary nodules represent early lithification of the muddy limestone layers, then nodule surfaces become sites of BCICC formation, noting that the lithological variation of the marls is reflected in the BCICC structure, which is softer where clay layers are prominent, leaving furrows in the crust in modern weathering (red arrows in B). These pictures are clear evidence of the later diagenetic nature of the BCICC growth.

overlying limestone are gradual, without a truncation or erosive surface. The SCPs average 1–2 cm thick, and extend laterally (fig. 4D, E).”. This description is consistent with the gradient of crystal size through the vertical section of CICC (Fig. 4 of this Discussion).

f) Li et al. (Fig. 11) show oxygen isotopes ranging from -8 to -10, presumably parts per thousand (the graph’s axes are not labelled with units!), similar to Meng et al. (2018, fig. 5), and could represent warmer diagenetic fluids.

Point B: Citation of previous work

We all know the peer-review system in international journals is not perfect and mistakes in citations are possible. Authors must pay very careful attention to accuracy of citations. Unhappily, this process has not worked well in the case of Li et al. (2018); their three citations of my papers are all incorrect, affecting their arguments (and also give the wrong impression of my own results) as detailed below:

Li et al. (2018, p. 60, Introduction, righthand column, second paragraph, lines 1-10: “SCPs that are hypothesized to be the result of upwelling provide a potential model for carbonate supersaturation in shallow settings (Woods et al., 1999). In addition to the upwelling model, microbial activity during early burial diagenesis also plays a significant role in promoting carbonate precipitation (Bergmann et al., 2013; Heindel et al., 2015). These scenarios work well when applied to SCPs that are found in shallow water settings, but the unclear dynamics of carbonate supersaturation in deeper environmental settings make the precipitation of SCP from these facies difficult to understand (e.g. Greene et al., 2012; Kershaw et al., 2012).” SK RESPONSE: Kershaw et al. (2012) did ***not*** discuss the difficulty of understanding deeper water SCPs, because that paper was about microbialites, that are essentially shallow water fabrics. We stated on p. 5 that microbialites have not been described in the deep shelf sites at Shangsi and Meishan. Note also that the

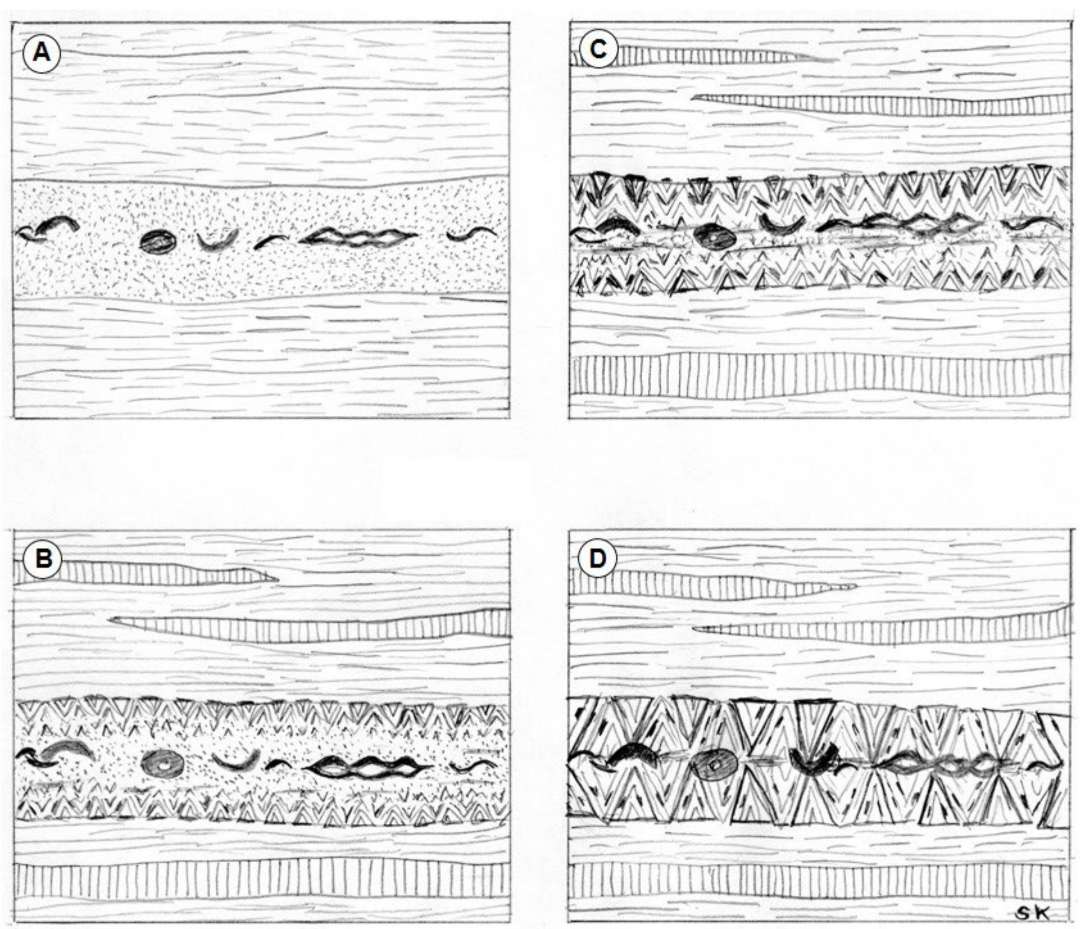

Fig. 7. A cartoon sketch of BCICC, vertical section, each box is *ca* 10 cm wide. **A.** Original sedimentary deposit of shales with a muddy limestone bed. Solid lines in the shale are weaknesses along which beef will form. **B-D.** Increasing degrees of alteration of the limestone bed into cone-in-cone calcite; note that B-D is ***not*** a sequence, these give three end-results of increased alteration. It is not clear why beds of beef and CICC form in close proximity but a possible scenario is that: a) beef formed by hydraulic fracture to form cavities, into which fluids were imported to precipitate the fibrous crystals of beef; b) in contrast, cone-in-cone calcite (CICC) formed by a combination of calcium carbonate imported from fluids via hydraulic fracturing, added to the margins of the limestone bed, together with some recrystallisation of the limestone. Presumably in D, the amount of added calcite and time of alteration is longer than in B.

opening sentence of Li et al. (2018) states that SCPs are "layered and/or fan-like clusters of carbonate crystals", which do not therefore include the microbialites, so the SCP definition could apply only to the crystal components of hybrid microbialites, not to the entire microbialite deposit.

Li et al. (2018, p. 60, Introduction, righthand column, second paragraph, lines 11-14: "Furthermore, diagenetic overprints may also affect palaeoceanographic signals from SCPs and obscure the mechanism that led to their precipitation (e.g. Heindel et al., 2015; Kershaw and Guo, 2016)." SK RESPONSE: Kershaw and Guo (2016) described diagenetic beef and cone-in-cone calcite and discussed its relationship with formation of similar fabrics in papers by Greene et al. (2012) and Heindel et al. (2015). We did ***not*** consider that these fabrics are overprints of seafloor cements, but instead presented evidence and discussion that they formed by import of calcium carbonate into the rock mass, plus diagenetic recrystallisation of sedimentary limestone layers, not seafloor cements. Thus we viewed these fabrics as unrelated in both time and conditions of formation from the depositional environments of sedimentary rocks in which they are found.

Li et al. (2018, p. 65 righthand column, last paragraph, to p. 66 lefthand column, first paragraph, lines 1-4): "The various sedimentary settings of SCPs (Woods, 2009) imply that precipitation and deposition processes could be variable and much more complicated than previously thought (Woods, 2014). Indeed, although the upwelling hypothesis provides us with a perfect model to reconstruct formation processes and associated palaeoenvironmental changes for SCPs from shallow marine settings, the application of the upwelling hypothesis to SCPs from deeper settings, especially basinal facies, is more doubtful (Kershaw and Guo, 2016)." SK RESPONSE: Kershaw and Guo (2016) ***did not*** discuss the upwelling hypothesis in their paper and in fact the word "upwelling" is not used in that paper!

I did not check any other reference citations in Li et al. (2018) and can only hope that errors of reporting are limited to my papers.

Conclusion

The outcome of this discussion is that I regard the interpretations of all three of these studies as "highly unlikely" to be correct. Such terminology is of course probabilistic, leaving open a small degree of "likelihood", a pragmatic approach given the complexity and weirdness of many post-mass-extinction facies. Nevertheless, data and ideas presented in the three recent papers considered in Sections 2, 3 of this Discussion are here reinterpreted differently from those papers. If my reinterpretations are correct, then:

There was no sub-seafloor carbonate factory in shallow marine conditions after both the end-Permian and end-Triassic mass extinctions, so that model is invalid;

Although turbidity currents may well have slipped gracefully down the slope into the deep, after the end-Permian extinction in the area that is now Tibet, they did not deposit calcite precipitates on the deep shelf floor, and so that model, too, is invalid.

More information is given in Kershaw and Guo (2016). The way forward is to search for evidence to attempt to verify or deny my interpretations by further sampling and analysis.

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Reply to Kershaw (this issue). Discussion on separating depositional and diagenetic fabrics in the aftermath of mass extinctions

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We welcome the stimulating and though-provoking discussion of "beef" and cone-in-cone calcites (BCICCs) by Dr. Kershaw. In this discussion, Dr. Kershaw made comments on our paper (Li et al., 2018) and redefined our seafloor carbonate precipitates (SCPs) as BCICCs. According to Dr. Kershaw's terminology, BCICCs are defined based on calcite morphology (a descriptive etymology), whereas SCPs refers to calcite precipitates that were deposited directly on the seafloor (interpretive etymology). We agree that a part of our samples can be classified as BCICCs based on their crystal morphology, but we insist on our interpretation that the samples precipitated directly on the seafloor during syndepositional or early burial stages rather than during later diagenesis as argued by Dr. Kershaw. We bring attention to the following important features:

1. Observed SCPs are restricted to turbidite deposits at the Xiukang section. We have found 11 thin SCP layers in the Lower Triassic of the Xiukang section, all of which are found in turbidite beds. Kershaw (2019) discussed the distributions of SCPs, suggesting that crystals expand towards the softer overlying and underlying clay beds during later burial diagenesis. If this is the case, SCPs should be common in limestones that are embedded with shales, but no SCPs were found in other Early Triassic sections that consist of limestone and shales, i.e., Selong, Tulong, Qubu, Gongpu sections in South Tibet (Garzanti et al., 1998; Li et al., 2019; Shen et al., 2006)and as a consequence Griesbachian assemblages are much better defined than Changxingian ones. The 'Otoceras latilobatum bed', representing the base of the Triassic at Selong, is a condensed biocalcirudite including abundant macrofossils (crinoids, corals, bryozoans, brachiopods.

2. Cathodoluminescence (CL) shows no evidence for late burial diagenetic alteration of the SCPs. All SCPs display a homogenous, dully luminescent pattern as we showed in Li et al. (2018). The CL pattern is a powerful tool for evaluating the degree of alteration that the carbonate rocks have undergone during late burial diagenesis (Machel, 2000). Kershaw (2019) provided a different interpretation for CL patterns of our samples, i.e., recrystallisation of sediment into CICC. He stated that the components carrying the CL signal are redistributed more-or-less evenly by the recrystallisation process. It's worth noting that all our SCPs consisting of coarse crystals presented the same CL patterns (Li et al., 2018). Had our samples experienced intensive recrystallization, as suggested by Dr. Kershaw, there should be no difference in CL patterns between shells and SCPs, but clearly this is not the case (Fig. 1). Moreover, recrystallization would blur boundaries among crystals, which is inconsistent with the smooth and regular boundaries among crystals in our samples.

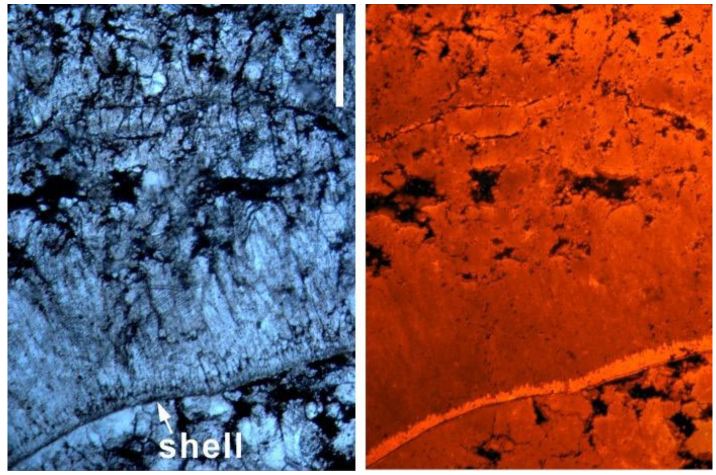

Fig.1. Cathodoluminescence photomicrographs of SCPs on the shell (from Li et al., 2018). Note the different CL patterns of the shell and SCPs. Scale bar is 0.5 mm.

3. EDS mapping of SCPs is well coincident with CL patterns. Fe/Mn mapping show a homogenous distribution of Fe and Mn within crystals (Li et al., 2018). Crystals are separated by Si- and Al-enriched clays that are interpreted as products of late burial diagenesis (Kershaw, 2019). These clays might have been deposited just before the formation of SCPs. Abundant moderately-rounded clasts of calcite crystals in association with radiolarians are present in the matrix, suggesting rework and transportation of SCPs for turbidite activities.

Several imprecise citations in the discussion part of our paper have been pointed out by Kershaw (2019) as well, but these do not have a direct bearing on the conclusions drawn from our data. As we discussed in Li et al. (2018), the occurrence of SCPs along with turbidites is a unique case, so we proposed a new model for its formation. We did not refer any other SCPs or BCICCs to the same mechanism. As many previous studies have shown, the dynamics of SCPs could be variable for different geohistorical backgrounds, paleo-seawater geochemistries, sedimentary environments, and other potentially unknown factors (Grotzinger and Knoll, 1995; Woods et al., 1999; Greene et al., 2012; Heindel et al., 2015).

We gratefully thank Dr. Kershaw for his detailed discussion and careful consideration of our results. Indeed, further investigations are needed to uncover the nature of SCPs or CICCs. We are building a database of the "radial carbonate crystal" to explore its spatial distribution pattern and geological development history. So far, more than 480 publications closely related to this term have been collected and organized by Dr. Li Tian, as of 21st November 2019. We warmly welcome collaboration with other interested colleagues.

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Recent progress and future perspectives in the application of Permian palaeobiogeography in the reconstruction of the palaeogeography of the Qinghai-Tibet plateau and adjacent regions

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Introduction

The Qinghai-Tibet Plateau (QTP) of China is a complex region composed of different blocks/terranes amalgamated by many suture zones (Fig. 1). Every suture zone may represent the positions of previous oceans. It has been widely acknowledged that the rifting and drifting of the Cimmerian continents from Gondwananland has resulted in the narrowing of the Palaeotethys Ocean in the north and the widening of the Neotethys Ocean in the south (Sengör, 1979; Stampfli and Borel, 2002). This model looks simple, but in fact is very complex due to controversies on the evolution of past oceans. Permian faunas and their palaeobiogeography, together with Permian strata in the various blocks in the QTP and adjacent regions, have played an important role in the reconstruction of the palaeogeography because of the pronounced climatic gradient from palaeoequatorial regions to Gondwanaland in the southern hemisphere during the Permian. In the past few years, we have worked on Permian strata and faunas from various sections on various blocks in the QTP including the North Qiangtang Block (NQB), South Qiangtang Block (SQB), Lhasa Block (LB), Tethys Himalaya region of northern Indian Plate, Salt Range of Pakistan, and the Shan Plateau of eastern Myanmar (Sibumasu Block). In this short article, we will introduce the importance of detailed analyses of Permian sedimentary successions and palaeobiogeography in the reconstructions of the position and the evolution of three main Tethyan oceans in the QTP.

Palaeotethys Ocean

The position of the main Palaeotethys sutures in northern Tibet have been the subject of controversy for more than 30 years . Some scholars have considered that the Jinsha (or Jinshajiang) suture zone in northern Tibet is the main Palaeotethys suture zone (e.g., Yin and Harrison, 2000; Kapp et al., 2003). However, more and more evidence has suggested that the Longmu Co-Shuanghu suture zone, that separates the NQB and the SQB, is the main Palaeotethys suture zone (Li, 1987; Zhai et al., 2016). The sedimentary succession and fossil faunas are the best archives of evidence to prove this. Our previous research has demonstrated that the Late Carboniferous and Early Permian in the NQB are dominated by pure carbonates with diverse faunas (Zhang et al., 2009). More importantly, the discovery of an Asselian fusuline *Sphaeroschwagerina* fauna in the NQB contrasts with the glacio-marine diamictites and cold-water faunas in the SQB (Zhang et al., 2016). The different Permian palaeobiogeographic affinity of the NQB versus the SQB has confirmed that the Longmu Co-Shuanghu suture zone is the remnants of the main Palaeotethys Ocean.

Even if the whole North Qiangtang basin and the Qamdo area have typically similar warm-water fauna during the Late Carboniferous to Permian times, their sequences vary a lot in the whole block. They are represented by carbonate platforms, platform margins and rifted basins with widespread volcanic rocks during the Early and Middle Permian times (Niu and Wu, 2016). However, it is very interesting that the Lopingian sequences in many regions in the NQB are represented by paralic facies consisting of sandstones with terrestrial plant fossils and interbedded marine limestones with *Palaeofusulina* fusulines (Fig. 2). Such a facies transition is possibly linked to the continued subduction of the Palaeotethys Ocean beneath the NQB. We are continuing to work on these sedimentary successions to test if the facies changes in different regions are synchronous or not.

Bangong-Nujiang Ocean

The opening time of the Bangong-Nujiang Ocean in the central part of the QTP has been subject to considerable debate (e.g., Baxter et al., 2009; Pan et al., 2012). The Permian palaeobiogeographic distinctions between the SQB and the LB have potential in constraining the opening time of the Bangong-Nujiang Ocean. However, previous palaeobiogeographic studies were not able

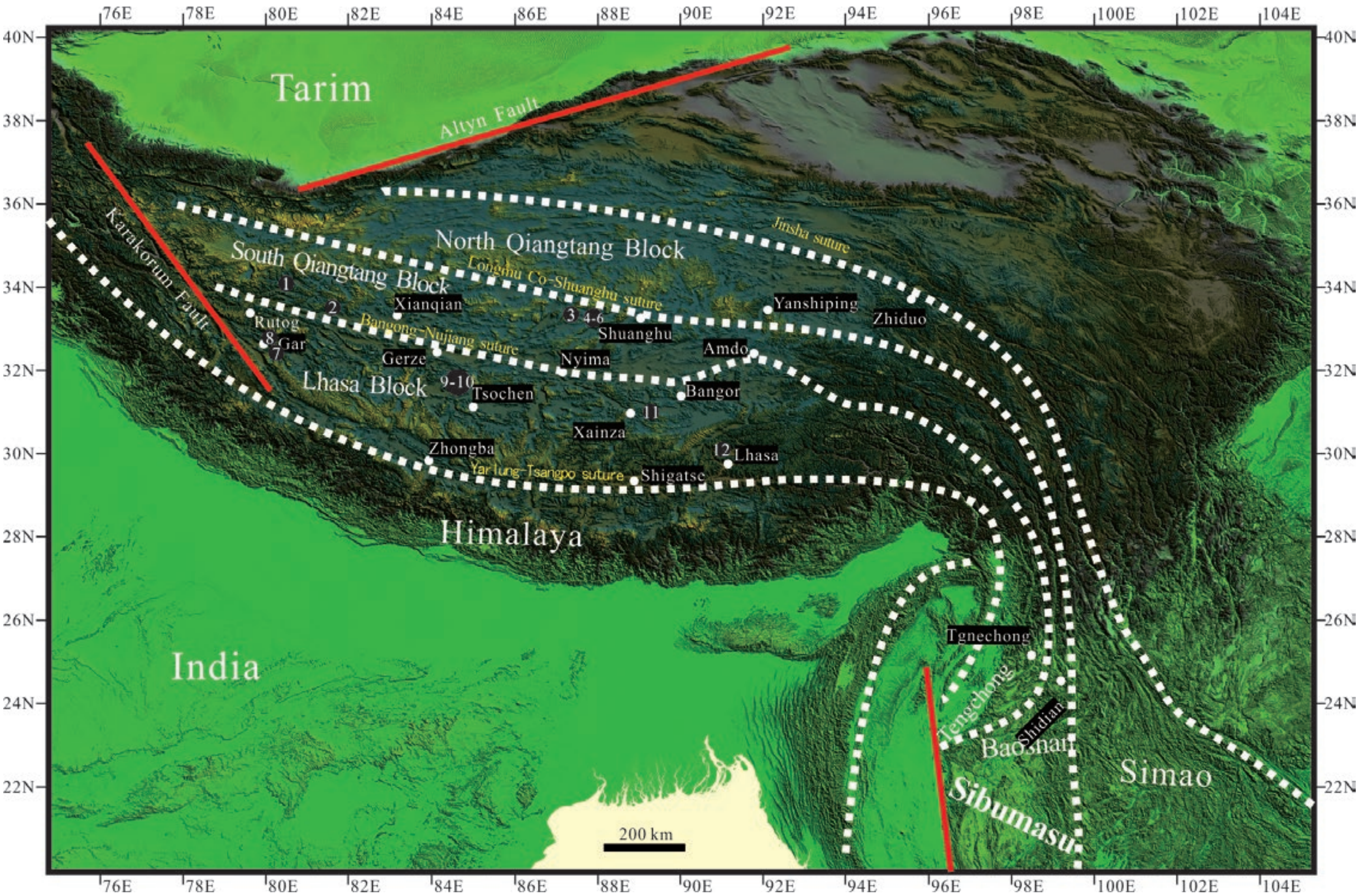

Fig. 1. The tectonic subdivisions of the Qinghai-Tibet Plateaus and adjacent regions

Fig. 2. The similar Lopingian paralic facies in the North Qiangtang basin (A) and the Qamdo area (B)

to recognize the palaeobiogeographic distinctions between the LB and SQB, partly due to insufficient data available from both blocks in northern Tibet (e.g., Shen et al., 2009). Consequently, in the past few years, we have undertaken fieldwork in northern Tibet to find the differences between the Permian stratigraphy and palaeobiogeographic affinity in the LB and the SQB.

Our work provided the following interesting evidence. Firstly, the Permian strata in the SQB differs greatly from those of the LB. There is a long hiatus between the Lower Permian Tunlonggongba Formation and the Upper Permian Jipuria Group in the western part of the SQB. However, this hiatus is not observed in the central part of the SQB. Instead, the Permian strata in the central SQB are dominated by Middle Permian limestones with many basalt layers (Zhang et al., 2012, 2014; Shen et al., 2016). In contrast, the Permian strata in the LB record a stable transition from Lower Permian glacio-marine diamictites to Middle and Late Permian carbonates across the whole block. So, the distinct facies between the SQ and LB suggest they were not connected (Zhang et al., 2019b). Secondly, we found that the Changhsingian strata throughout the LB contain abundant foraminifers such as *Colaniella* and *Reichelina*, but lack the typical warm-water equatorial fusuline genus *Palaeofusulina*. However, *Palaeofusulina* was documented from Lopingian strata in the western SQB. This may suggest that the SQB migrated into the palaeoequatorial regions during the Changhsingian, while the LB was still in a temperate zone during that time (Qiao et al., 2019). Thirdly, more and more research on fusuline faunas showed that an interesting fusuline assemblage *Nankinella-Chusenella* lived in various localities on the LB and the Tengchong Block, but this fusuline assemblage has not been reported from the SQB and the Baoshan Block so far (Zhang et al., 2019a). The contrasting palaeobiogeographic affinity and sedimentary evolution of the LB and the SQB suggest that the Bangong-Nujiang Ocean between them may have been quite wide during the Middle Permian (Zhang et al., 2019b) (Fig. 3).

Another significant issue in the study of the Bangong-Nujiang suture zone relates to its southern extension in west Yunnan and Myanmar. Liu et al. (2016) have suggested that the Myikyina ophiolites are the southern extension of the Bangong-Nujiang suture zone. If this is correct, the Baoshan Block, the Tengchong Block and the Sibumasu Block in southeast Asia should all correspond to the SQB in Tibet. The validity of such a hypothesis requires evidence from palaeobiogeographic analyses. So, in the past few years, field work teams have entered into Myanmar four times with the purpose of reconstructing its palaeobiogeographic affinity during the Middle Permian. Our studies on the fusulines from the Thitsipin Formation in the Shan Plateau have shown the presence of two dominant genera, *Eopolydiexodina* and *Jinzhangia*. Both genera have been widely reported from the Baoshan Block and the central part of the SQB, but they have not been reported so far from the LB and the Tengchong Block. This is supported by our quantitative analysis. Our studies strongly suggest that the Shan plateau of Myanmar can only correlate with the Baoshan Block and the SQB. That is, the Tengchong Block should not be included in the Sibumasu Block. So, the Gaoligong orogen, that separated the Baoshan and Tengchong blocks, should represent the southern extension of the Bangong-Nujiang suture zone.

The further southern extension of the Bangong-Nujiang suture zone in Myanmar and Thailand is another puzzle that has not been resolved. Ridd (2016) has proposed an interesting model predicting that Phuket Island of western Thailand and Shan Scarp of Myanmar belong to the Irrawaddy Block (IB). In order to test this model, we have worked on the Permian sequences in the Shan Scarp terrane of Myanmar. We recorded the conodonts *Vjalovognathus nicolli* and *Mesogondolella idahoensis* from the upper part of the Taungnyo Group and the lower part of the Moulmeim Limestone (Yuan et al., 2020). This conodont assemblage is very similar to the coeval faunas from the lower part of the Xiala Formation in the LB (Yuan et al., 2016). This has indicated a possible palaeogeographic link between the LB and the IB. We will continue to test this model using the palaeobiogeographic affinity of brachiopods and fusulines.

Neotethys Ocean

The Neotethys Ocean in the QTP is represented by the Yarlung Tsangpo Suture Zone. It has also been a contentious issue for more than 30 years, as regards the timing of the rift of the Lhasa Block from the Gondwanan margin. Recently, the discovery of upper Anisian (Middle Triassic) radiolarians within the Yarlung Tsangpo Suture Zone reject the hypothesis of a Late Triassic opening of the Neotethys Ocean (Chen et al., 2019). Many palaeobiogeographic studies of diverse faunas have proved that Middle Permian faunas from the Lhasa Block differ greatly from the equivalent faunas from southern Tibet (e.g., Shen et al., 2009; Zhang et al., 2013). However, it has been argued that the cold-water faunas from southern Tibet gradually changed to warm-water faunas in the LB (Jin et al., 2015). If the LB was attached to Gondwanaland during the entire Permian, a transitional zone, rather than a dramatic change, between the LB and the Gondwanaland should be expected. In order to investigate, in the last few years, we have undertaken fieldwork in various regions in the LB to test if there

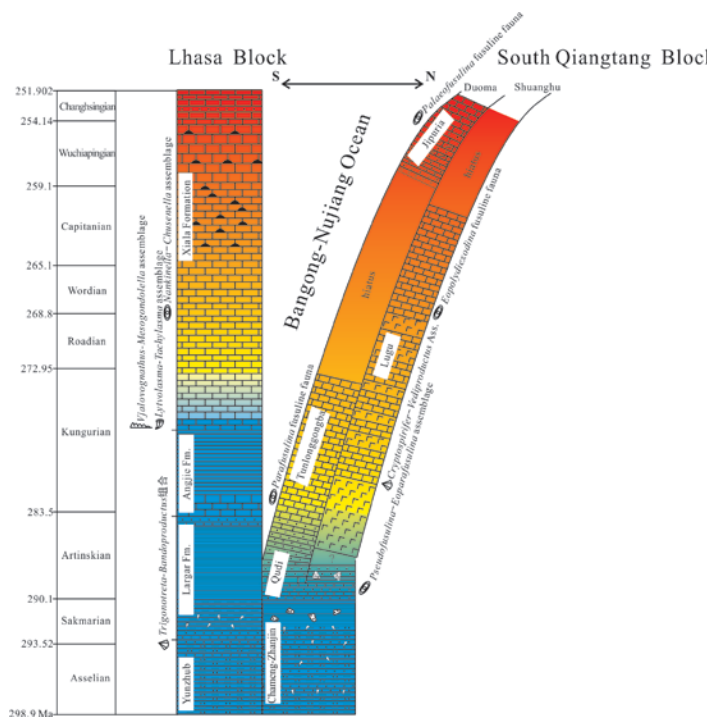

Fig. 3. Contrasting Permian sequences and faunas between the South Qiangtang Block and the Lhasa Block (Zhang et al., 2019b)

is a longitudinal diversity gradient in the throughout the block. Also, fieldwork was done in the Salt Range of Pakistan and southern Tibet with the purpose of examining faunal composition and diversity. We believe that, with the growing knowledge of the stratigraphy and palaeontology of these regions, we will be able to constrain the opening time of the Neotethys Ocean in the near future.

Perspectives

The Qinghai-Tibet Plateau is a complex region preserving the record of the evolution of oceans and continents. Stratigraphic and palaeontological analyses have played a significant role in reconstructing the palaeogeographic settings, also because of the pronounced climatic gradient of the equatorial regions to Gondwanaland. Our works in various regions in the QTB, eastern Myanmar and Salt Range of Pakistan are helpful in reconstructing the palaeogeographic evolution of the peri-Gondwana blocks and the early evolution of the Bangong-Nujiang and Neotethys oceans. However, one of the significant unresolved question in the reconstruction of the palaeogeography is the western extension of the Bangong-Nujiang suture zone in the Karakorum and the Pamir plateau. Because of the displacement of the Karakorum fault, the Permian strata from the Karakorum and Pamirs are not easily correlated with those from the SQB and the LB. For example, the LB may not link with the Karakorum Block due to their distinct Permian sedimentary facies and faunas (e.g., Gaetani et al., 1995; Zhang et al., 2013; Gaetani and Leven, 2014). So, the SQB may have close palaeogeographic affinity with all those three terranes (Karakorum, South Pamir and Central Pamir) or any of these terranes. The Rushan-Pshart suture lies between the Central Pamir Terrane and the South Pamir Terrane (Angiolini et al., 2013, 2015; Zanchetta et al., 2018). But, this suture zone is not found within the SQB so far in northern Tibet. The Permian strata in South Pamir have various facies including platform, slope and basin (Leven, 1967; Angiolini et al., 2015). Interestingly, the Permian strata in the SQB are also dominated by varied facies including platform, slope and seamounts (Zhang et al., 2019b). So, the precise correlations of the Permian sedimentary facies and faunas between the SQB and the terranes west of the Karakorum are significant in reconstructing the rifing and drifting history of the SQB, Karakorum Block, South Pamir and Central Pamir terranes during the Permian. Much stratigraphic work is required in the SQB in the future to address these significant palaeogeographic problems.

Acknowledgement

Our work is supported by the National Science foundation of China (91855205), the second Tibetan Plateau Scientific Expedition and Research (2019QZKK0706) and Strategic Priority Research Program (B) of the Chinese Academy of Sciences (XDB26000000).

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Progress report : location of the replacement section for the base-Lopingian GSSP

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The GSSP for the base of Lopingian Series (also the base of Wuchiapingian Stage) was defined by the FAD of the conodont *Clarkina postbitteri postbitteri* in the lineage from *Clarkina postbitteri hongshuiensis→C. postbitteri postbitteri→C. dukouensis* at the base of Bed 6k at the Penglaitan section in Laibin, Guangxi Province in South China in September, 2005. An official GSSP paper on the GSSP was published by Jin et al. (2006). The Penglaitan section has been so far the most complete section based on conodont succession across the Guadalupian/Lopingian boundary in the world and it has served as the best reference for global correlation for more than 15 years (Jin et al., 2006; Henderson et al., 2012; Shen et al., 2019). Unfortunately, the section outcrops along the Hongshui River and is commonly flooded during summer and most of the spring, but usually exposed during the winter and autumn (Shen et al., 2007). However, the section will be soon be permanently flooded since the Chinese government has established a dam 100 km downstream for a power station in the southern part of Guangxi Province. According to the guideline of Remane et al. (1996), a GSSP section must meet the following requirement, that: “The outcrop has to be accessible to research and free to access. This includes that the outcrop has to be located where it can be visited quickly (International airport and good roads), has to be kept in good condition (Ideally a national reserve), in accessible terrain, extensive enough to allow repeated sampling and open to researchers of all nationalities”. Thus, the

Penglaitan section will no longer qualify as the GSSP section. In order to save the Lopingian-base GSSP, the Ministry of Water Resources and Guangxi Province has supported us to extract a cubic lithologic column of stratigraphic length 50 m including the GSSP interval, to be permanently housed in a museum on the Penglai Islet near to the original GSSP. In addition to the cubic lithological column, two drill cores, each with more than 200 m, were collected for future studies. One will be housed in the museum at Penglai Islet and another has been housed in School of Earth Sciences and Engineering of Nanjing University (Fig. 1).

Meanwhile, a Chinese team has been established to search for a replacement section. The team is led by Prof. Shuzhong Shen of Nanjing University and principal members including Quanfeng Zheng (sedimentology), Dongxun Yuan (conodonts), Hua Zhang (geochemistry), Yichun Zhang (fusulinids) and Lin Mu (ammonoids). Shilong Mei, who is the pioneering researcher working on the Penglaitan GSSP section, has guided the search and joined in field work a few times (Fig. 2). In the future, international colleagues will be invited to join in a formal international research group to complete the replacement section to meet the requirements as a GSSP.

The Guadalupian/Lopingian boundary is marked by one of the greatest regressions of the Phanerozic (Haq and Schutter, 2008). The conodont lineage defining the base-Lopingian GSSP (Mei et al., 1998) is very rarely found in other regions. Although the index species was reported from the Guadalupe Mountains National Park (Lambert et al., 2010), Japan (Nishikane et al., 2011), a few sections in South China (Xia et al., 2006; Zhang et al., 2007), only the occurrence at the Douling Formation in Chenzhou, Hunan Province in addition to the GSSP section has been confirmed (Mei et al., 1998; Jin et al., 2006; Shen and Zhang, 2008) and all other reports are more or less questionable. Thus, it is very difficult to find a replacement section with the same conodont succession in other localities. Even in south China, the Lopingian Longtan and Wuchiaping for-

Fig. 1. A cubic lithologic column (upper two photos) and two cores (lower two photos) were collected at the Penglaitan GSSP section in 2019.

Fig. 2. The Chinese team worked on the Baixiangdong section near Liuzhou, Guangxi Province, South China. A, from left to right, Zhang Hua, Mei Shilong, Shen Shuzhong, Zhang Yichun; B, Shen Shuzhong, Zhang Xiyang and Mei Shilong; C, Zhang Xiyang sitting on the Laibin Limestone Unit and Wang Wenqian and a student stayed on the first bed of the Wuchiaping Formation; D, a cliff in the Wuchiaping Formation.

mations usually overlie the Maokou Formation with a distinct unconformity which is marked by the Wangpo Shale and coal and bauxite deposits (Shen et al., 2019; Yu et al., 2019).

After several years' efforts made by the Chinese team, a section at Baixiangdong near Fengshan Town of Liuzhou City, which is ~90 km north to the Penglaitan GSSP section, has been found. The section is composed of the Maokou Formation in the lower part and thin- to medium-bedded limestone with cherty nodules of the Wuchiaping Formation in the upper part (Fig. 2B). The contact between the Maokou and Wuchiaping formations is quite conformable and no distinct erosional surface has been found (Fig. 2C). The thick-bedded Laibin Limestone unit at the Penglaitan section is also present at the top of the Maokou Formation at Baixiangdong (Fig. 2C). Various samples have been collected at the section during fieldwork in the last five years, studying conodonts, fusulinids, sedimentology and geochemistry. Abundant conodonts, fusulinids and brachiopods have been found in the section. Five conodont zones are recognized. They are the *Jinogondolella xuanhanensis*, *J. granti*, *Clarkina postbitteri, C. dukouensis*, *C. asymmetrica* zones in ascending order. Thus it has been confirmed that the Baixiangdong section in Liuzhou contains a comparable conodont succession to the Penglaitan GSSP section in Laibin. In addition, the section contains rich fusulinids and forams including *Metadoliolina*, *Chenella*, *Chusenella*, *Nankinella*, *Codonofusiella*, *Kahlerina*, *Lantschichites*, *Reichelina*, *Ammodiscus*, *Agathammina*, *Climacammina*, *Geinitzina*, *Globivalvulina*, *Hemigordius*, *Itchyfrondina*, *Langella* etc. (Figs 3, 4).

Carbon isotope chemostratigraphy and magnetostratigraphy has been carried out too. All the conodont, fusulinid, forams, geochemical and magnetostratigraphical data will be presented in the near future. We herein propose the Baixiangdong sec-

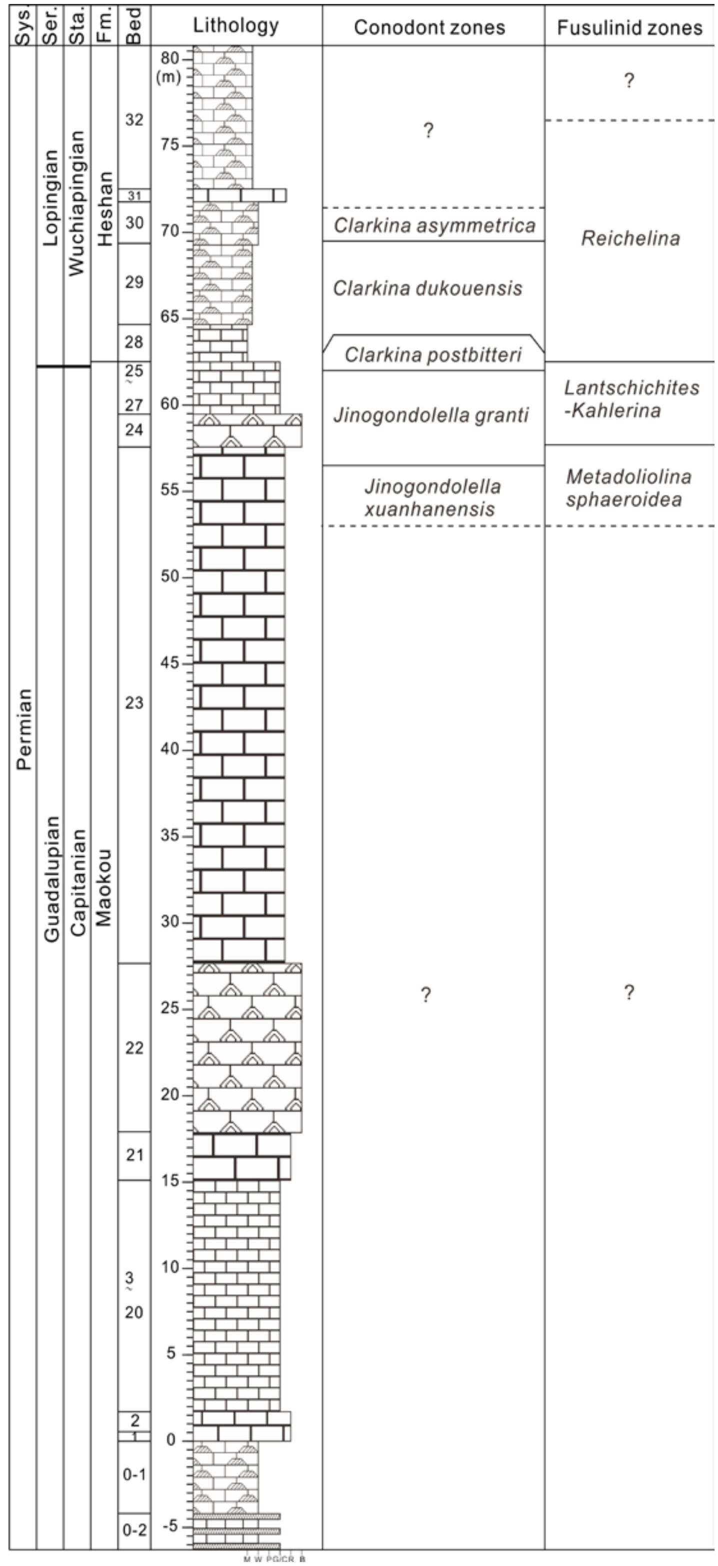

Fig. 3. Preliminary results showing the conodont and fusulinid zones at the Baixiangdong section, a potential GSSP replacement section for the base of the Wuchiapingian Stage.

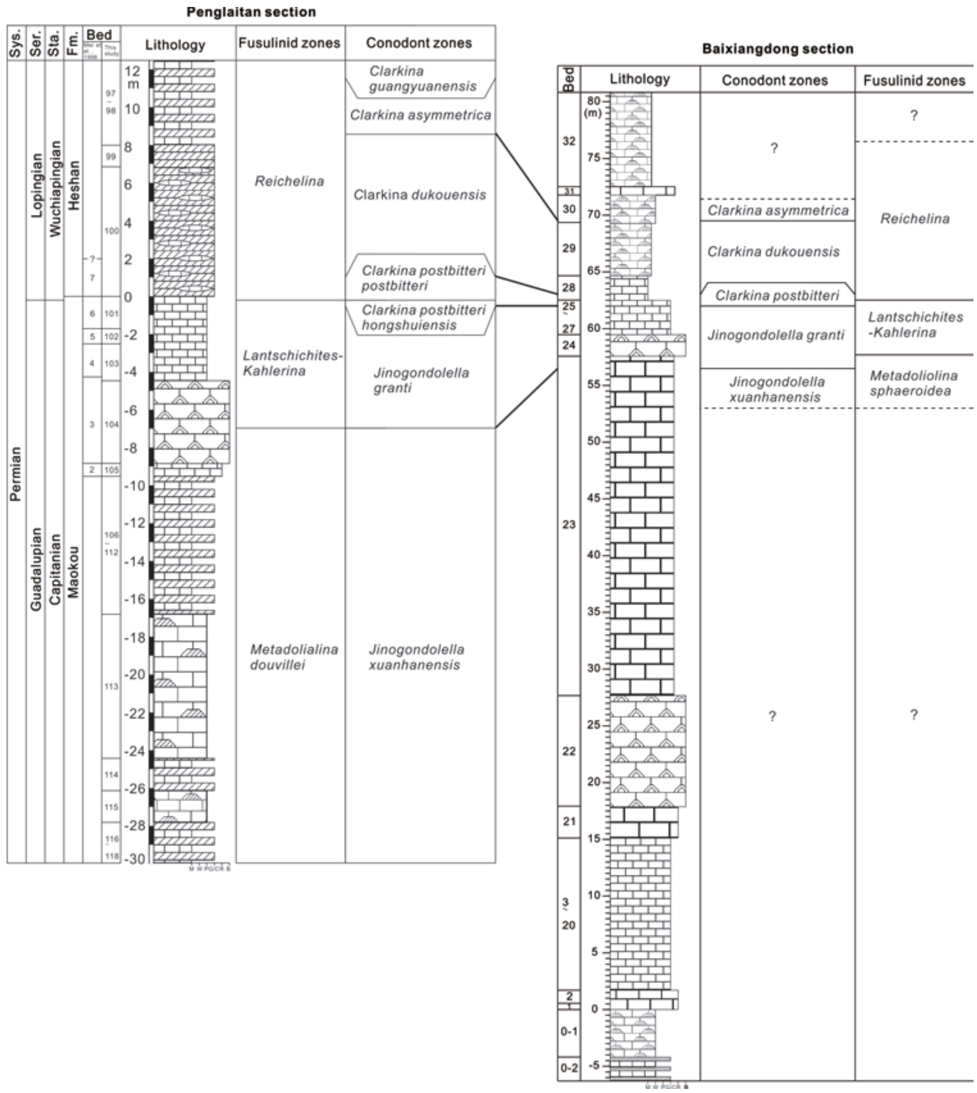

Fig. 4. A correlation between Penglaitan GSSP section and the Baixiangdong section in Liuzhou, Guangxi Province.

tion as the Lopingian-base GSSP replacement section in future after all the work are done.

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Application of Arabian palynological zones in the Negev of Israel: preliminary findings

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Abstract

Palynological study of the Arqov and Saad formations of the Negev, Israel, in Avdat-1 borehole has allowed the utility of the OSPZ Arabian palynological zones to be tested and comparison to be carried out with the assemblages of the Umm Irna Formation of the Dead Sea, Jordan. Core 7 of Avdat-1 (Saad Formation) contains common *Hamiapollenites dettmannae* and *Distriatites insolitus* indicating that it correlates with the OSPZ5 Biozone and therefore has a likely Roadian-Wordian age, rather than a Westphalian age as previously suggested. Core 6 contains *Indotriradites mundus*, whose first appearance indicates the base of OSPZ6 (Wordian, extending into the Capitanian), but also contains common *Protohaploxypinus uttingii*, *Pretricolpipollenites bharadwajii* and *Thymospora* spp. As such, the assemblages of Core 6 are most similar to those of the Umm Irna Formation, while those of Core 7 are older, as implied by the correlation of Core 7 with OSPZ5.

Background

The Permian in Israel is known only from the subsurface in boreholes in the southern and central Coastal Plain, the Judean Desert and the northern Negev. The succession consists of a basal sandstone overlain by alternating sandstones, shales, and carbonates, and in the Negev ranges between 300 and 500 m thick. The lower Saad Formation is mainly sandstone, while the upper Arqov Formation consists of sandstone, shale and limestone.

The ages of the two formations based on palynology are mainly from Eshet and Cousminer (1986) and Eshet (1990) who studied assemblages from eleven boreholes across Israel. Importantly the only core palynology samples came from Makhtesh Qatan-2 (Eshet and Cousminer, 1986) and thus the data from cuttings samples on which the majority of work was done could be regarded as being vulnerable to caving, causing difficulties for precise palynological dating and biozonation.

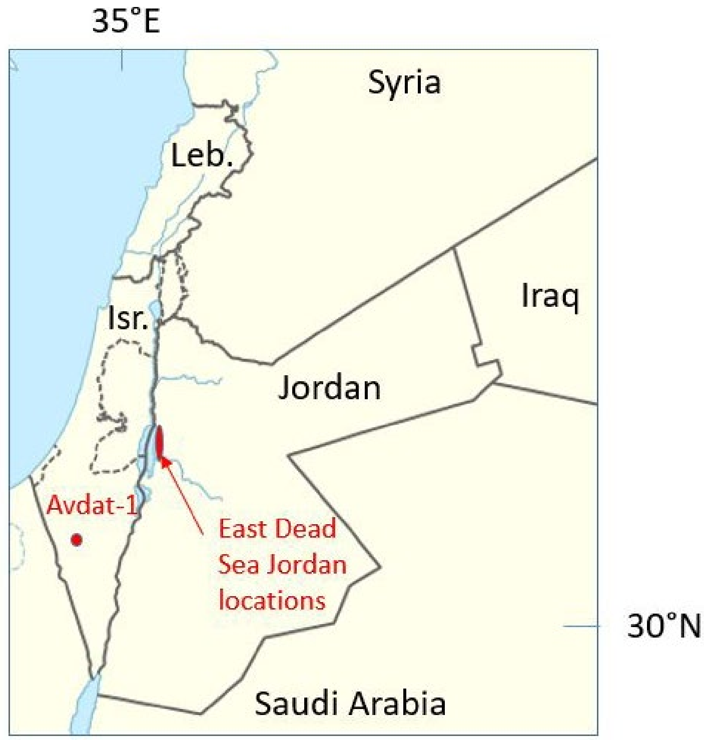

Fig.1

It was considered that a priority for Permian Israel palynological studies was detailed studies based on core samples. Extensive work done on the Carboniferous and Permian of the Arabian Peninsula, Pakistan, Iraq, Iran, Jordan and Yemen (see Stephenson 2016 for refs) has revealed the utility of the OSPZ biozonation scheme for the Carboniferous and Permian throughout the Middle East. Thus samples from the Avdat-1 well (Fig. 1) were made available for palynological study to assess the value of the OSPZ scheme in the Israel subsurface.

Palynology

Samples from two cores were analysed: Core 6 (2987.6 - 2993.7 m; Arqov Formation) and Core 7 (3122.0 - 3138.8 m; Saad Formation; Fig. 2). The assemblages of Core 6 are closely similar, in relation to stratigraphically significant taxa (see Stephenson and Powell 2013, Stephenson and Powell 2014), to the Umm Irna Formation of Jordan in that the following are common to both: *Falcisporites stablilis*, *Thymospora opaqua*, *Cedripites priscus*, *Reduviasporonites chalastus*, *Pretricolpipollenites bharadwajii*, *Playfordiaspora cancellosa*, *Distriatites insolitus* and *Protohaploxypinus uttingii*. This suggest that at least part of the Arqov Formation of Israel correlates with the Umm Irna Formation of Jordan. Core 6 assemblages are assigned to OSPZ6 (Wordian, extending into the Capitanian; Stephenson 2008, Spina et al 2018).

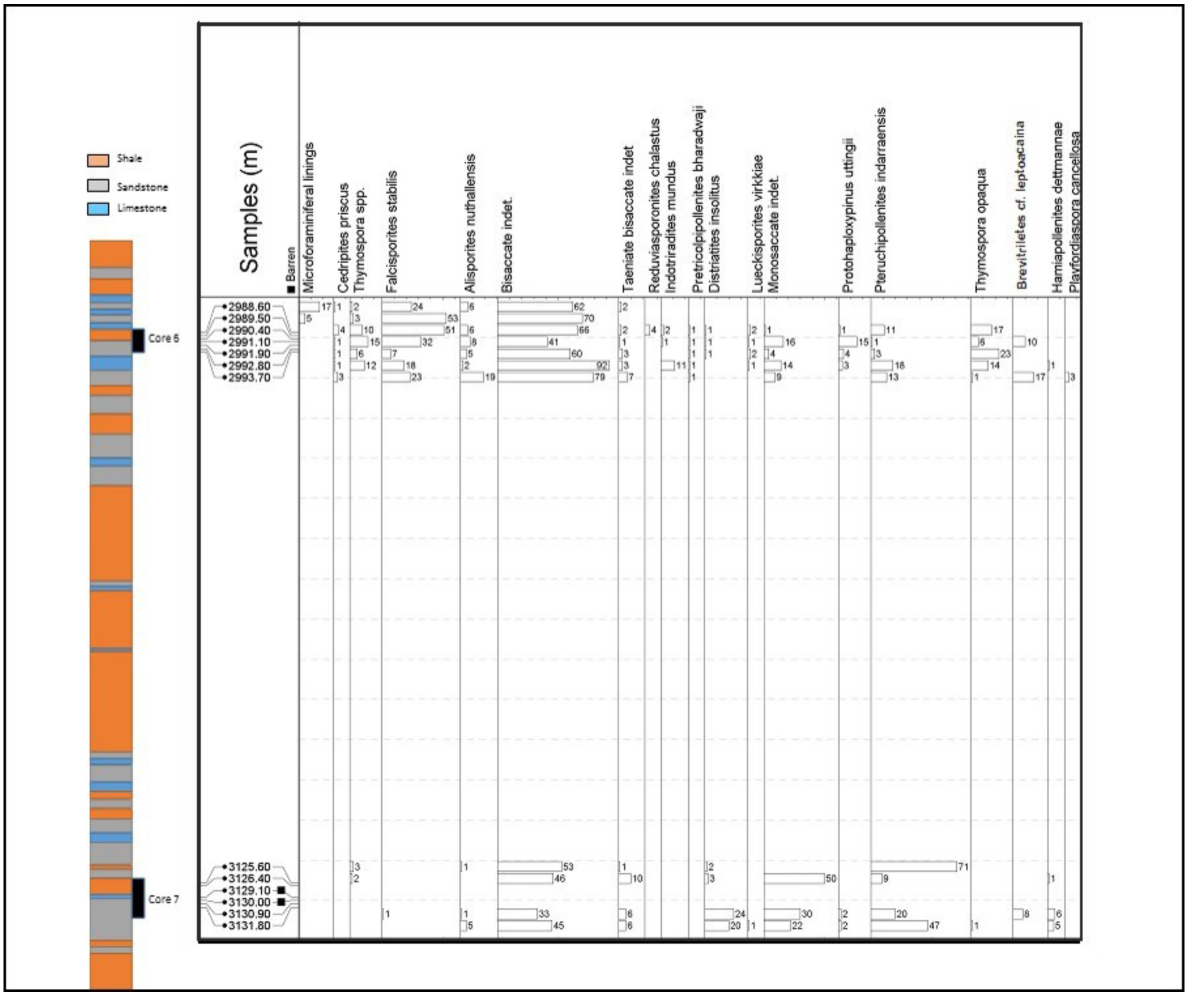

Fig.2

Core 7 assemblages lack significant Umm Irna Formation taxa and are likely significantly older than the Jordanian Permian successions. These correlate with OSPZ5 Biozone and therefore have a likely Roadian-Wordian age (Stephenson 2006, Spina et al 2018). Interestingly this age for this part of the Saad Formation in Avdat-1 conflicts with an age suggested by Horowitz (1974) who regarded the depth between 3025m and total depth (TD) in Avdat-1 to be Westphalian (Pennsylvanian).

Conclusions

This is a preliminary study mainly to assess the utility of the OSPZ biozonation scheme for the Carboniferous and Permian of Israel. Further work is planned in 2020 on a larger number of core samples from several boreholes.

Further details of the present study will be published in the *Review of Palaeobotany and Palynology* (Elsevier) in 2020.

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Reconciling the ramp versus the platform interpretation of the Tesero Oolite, Permian-Triassic boundary in the Alps: a Bahama Bank model

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Abstract

The Tesero Oolite is a thin, shallow marine oolitic unit spanning the Permian-Triassic boundary in the Southern Alps and rests on the more diverse Upper Permian shallow marine to lagoonal Bulla unit. Divergent ramp and platfom interpretations for the Tesero Oolite lead to very different palaeoenvironmental and palaeogeographic interpretations of the important Alpine Adria tectonic unit. The ramp interpretation is based on tilting the top surface of the Bellerophon Formation down to the east with overlying Tesero Oolite facies passing into deeper water, and implies a maximum ramp slope of less than 0.05° from the thickness variations. The platform interpretation is based on the layer-cake facies distributions, and the lack of thickness variations over 200 kilometres. Comparisons with the Quaternary Bahama bank show that both interpretations can be reconciled in terms of subdued shallow - deeper basin variations (ramps) on a generally uniform bank itself (platform).

Introduction

The end of the Permian marks the greatest mass extinction in the geological record, and many recent studies are exponentially increasing knowledge of the Permian-Triassic interval in an attempt to determine the causes of the mass extinction (Erwin, 2006; Wignall, 2015). This concentration of effort lets us use the Permian-Triassic boundary as a time line, along which we can relate both vertical and lateral facies changes to possible causes. The Permian-Triassic sections of the western Palaeotethys lie on the Adria block, now significantly internally deformed during Mesozoic-Cenozoic orogenies, which forms parts of the Apennines, Dinarides and eastern Alps (Fig. 1a). Furthermore, enormous lateral displacements occurred between structural units during the closing of the Palaeotethys and the opening and closing of the NeoTethys oceans. Many people have attempted to unravel this complex history, but none has produced a generally accepted scheme (e.g. Dercourt et al., 2000; Gaetani, 2010; Handy et al., 2010, 2015; Muttoni et al., 2013; Berra and Angiolini, 2014). Palaeomagnetic data indicates a nearly 3000 km right lateral displacement of Gondwana with respect to Laurussia in the mid-Permian from a Pangaea B to Pangaea A configuration (Fluteau et al., 2001). But, by the latest Permian, this re-organization was complete and it is possible to tentatively work out the facies distributions within individual tectonic units, though difficult to extrapolate beyond that. During the Cenozoic Alpine orogeny, parts of the Adria block rotated differently (Mauritsch and Frisch, 1980). For example, the Permian palaeomagnetism of the Dolomites shows around 50^{o} anticlockwise rotations of the southern Alps relative to central Europe during large post-Permian lateral movements and disruption of the Adria block (Muttoni et al., 2013) and can thus not be compared to units now adjacent to it, like the Lombardy Verrucano to the west across the Judicaria fault (Gaetani, 2010). Across the Periadriatic line, thin black limestones are interbedded within the evaporitic Alpine Haselgebirge Formation (Late Permian) of the central and eastern Northern Calcareous Alps. These are so different from the Southern Alpine sections that enormous displacements must have taken place along the Periadriatic line (Spőtl, 1992. The Southern Alps rotation is accompanied by dextral strike slip thrust faults along the strike of the Dinarides in former Yugoslavia (Kastelic and Cunningham, 2006) which

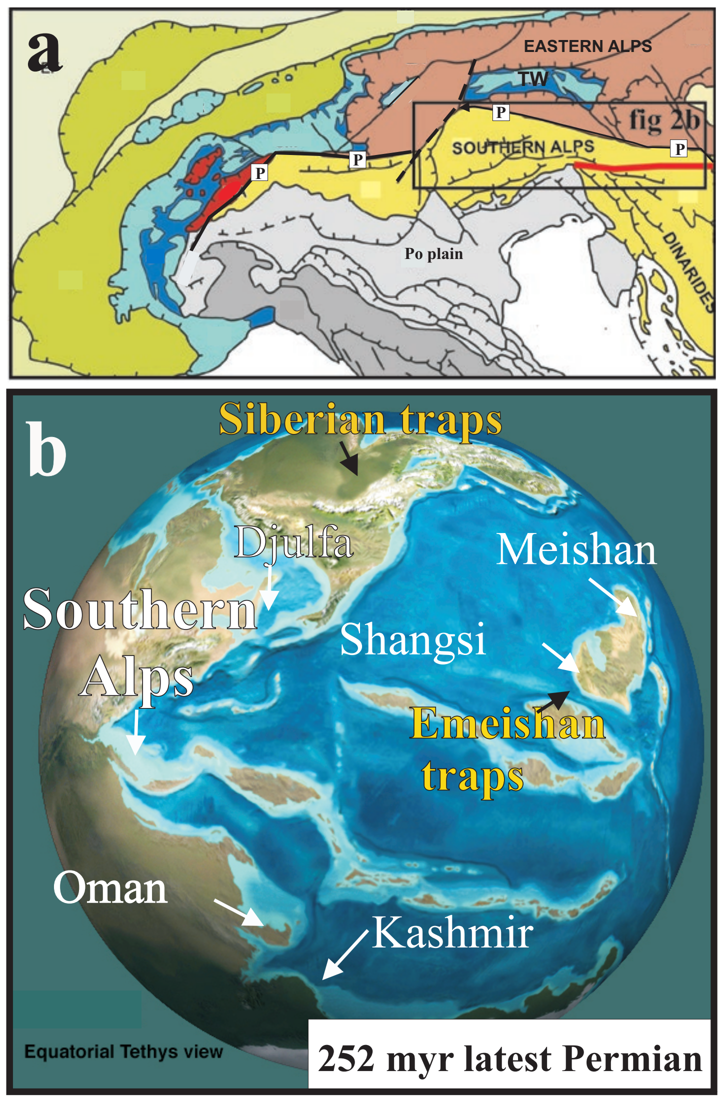

Fig. 1. a) Tectonic map of the Alpine chain and its forelands. The Alps result from the collision of two tectonic plates, Europe (blue) and Adria (brown). Red lines mark the main tectonic boundaries; P - Periadriatic Fault, a major late-orogenic fault system offset by the Giudicaria Fault (GF). TW – Tauern Window with northern calcareous alps in blue. Map compiled from Schmid et al. (2008), Ustaszewski et al. (2008), Handy et al. (2010). b) position of Adria at western end of Neotethys at PTr boundary (~252 Ma) from Berra and Angiolini (2014).

have juxtaposed sections with incompatible facies in Serbia, for example (Sudar et al., 2018)..

Over most of its outcrop, the Upper Permian Bellerophon Formation consists of thick carbonate-sulphate succession deposited in marginal (sabkha) to shallow shelf marine conditions with it top ~ 1 metre (Bulla member) consisting of more normal marine highly fossiliferous dark bioclastic wackestone, packstone and interbedded thin marly limestone with calcareous algae, foraminifera, mollusks and brachiopods (Noé, 1987; Farabegoli et al., 2007). A top erosional surface on the Bulla Member is sharply overlain by the Tesero Oolite member of the Werfen Formation, which consists of less than 5 metres of thick diverse micrite, microbialites and marls interbedded with oolitic, peloidal and bioclastic packstones (Farabegoli et al., 2007; Brandner et al., 2012). The Tesero member blankets the underlying diverse Bulla Member facies, and varies little and irregularly (between 3 and 5 metres) across the entire area, though it is absent between Bulla and Gartnerkofel (Noé, 1987). The biodiversity drops markedly at the Bulla/Tesero contact but Permian brachiopods and bivalve persist into the Tesero Member (Posenato, 2009). The First Appearance Datum (FAD) of the conodont *Hindeodus parvus* which defines the base of the Triassic is at 6 metres above the base of the Tesero Member at Gartnerkofel, but only 2 metres above the base at Bulla (Schönlaub, 1991) The main lithological change (the Late Permian Event Horizon, LPEH) from the Bulla to the Tesero Members thus does not coincide with the main extinction, nor with the base of the Triassic as defined by *H. parvus*. The strata between the LPEH and the base of the Triassic are thus of great interest for interpreting environmental changes associated with the extinction.

This paper evaluates the facies distribution in the Tesero Oolite in the southern Alps in terms of two current models; a ramp model and a platform model. I here concentrate on the well-studied east-west sections along the southern Alps, forming a relatively coherent whole, but with significant displacements along Cenozoic faults (Fig. 2a). The other sections stretching north-south along the Dinaric Alps and their relationships to the Alpine sections are much more complicated and will be summarized elsewhere. The Tesero Oolite unit is one of many thin oolitic horizons which straddle the Permian-Triassic boundary in many shallow marine areas of the world and whose significance has yet to be worked out (Li et al., 2015).

Ramp versus platform interpretation

The carbonate ramp interpretation of the Tesero Oolite section (Brandner et al., 2009) is problematic considering the limited thickness and facies variations shown in the sections and the juxtaposition of different sections within the Dolomites across Alpine thrust with displacements of tens of kilometers (Doglioni, 1987). Thus, the Tesero Oolite is missing in the San Antonio section though present in the thrust sheets on either side (Fig. 2a). Furthermore, the ramp interpretation (as shown in Fig. 2b) is based on arranging Tesero Oolite sections, and the burrowed datum on which they rest, in a line downstepping to the east. The thinning of the lowermost oolite from Tramin to Gartnerkofel (interrupted by the fault-enclosed San Antonio section) is typical of carbonate platforms like the Bahama Bank, where oolite shoals thin and pass into pelletoidal finer sediments towards the interior of the platform (Harris et al., 2015). The Tesero Oolite in the Brsnina section, 70 km east of Gartnerkofel, but in the same southern Alps structural block, is dominated by red calcareous shales with minor dolostones and two thin oolite horizons (Dolenec, 2005) (Fig. 2b), and is most like carbonate tidal flats (Rankey and Berkeley, 2012). In contrast, the Masore section is more like the western Tesero Oolite sections, but is in the Dinarides across the major fault separating them from the Alps (Dolenec et al., 2004) (Fig. 2a). A flat carbonate platform environment fits the lack of horizontal, but marked vertical facies change (during sea level variations), and was the interpretation shown by Noé (1987) in the first comprehensive study of the PTr boundary sections in the area (Fig. 3a). Quartz sand and silt are very rare in the Tesero Oolite (Boeckelmann, 1991) and the depositional environment was somehow isolated from land input and not part of a coastal to offshore ramp such as the Recent Persian Gulf. Of course, the low imperceptible slope (0.0012^o) of the west-east cross section in Figure 2b may be because it is a very oblique section across a southeast facing ramp. But, the Tesero Oolite in the Val Brutta section (#2 on Fig. 2a), which is 30 km southeast of the Tramin section, is almost entirely oolitic and of identical facies to the Tramin section (Brand et al., 2012). This implies that the facies belts ran north-south or northwest-southeast with a maximum slope of 0.05^o. This is not what most people would call a ramp. The carbonate platform interpretation is thus more appropriate, especially when compared with the best example of a Recent carbonate platform – the Bahama Bank.

Comparison with the Bahama Bank

The Bahama Bank is an isolated carbonate platform surrounded by deep ocean environments. Like the Adria unit, it lies on the western sided of an ocean in a tectonically complicated area partly enclosed by nearby land. To the northwest of Andros Island (Fig. 3b inset left), the Lucayan Formation (Pleistocene to Recent) is dominated by nonskeletal packstones and grainstones, formed in a shallow water (less than 10 metres deep) in a semirestricted environment (Beach and Ginsburg, 1980), but it does contain ooidal and skeletal bodies (Fig. 3b). The ooid sands form on shallow platform margin shoals that are parallel to the slope break (Ball, 1967; Harris, 1979) and are transported into the interior of the bank to interfinger with peloidal sediments. The section across the NW Bahama Bank has been reversed in Figure 3b to better compare with the sections of Figures 2b and 3a. The Tesero Oolite is about 10 meters thick, has two oolite-peloidal units and is very comparable to the upper unit 1 of the Lucayun Formation on the Bahama Bank (Fig. 3b). Not only is the scale the same, but the ooidal units of the NW Bahama Bank show the same thinning into deeper (but still shallow) water towards the centre of the Bank – in this case rimmed by coral reefs and islands with eolian sands (Fig. 3b). The formation of ooids and coated-grains is common during transgressive marine phases, while the peloidal muds and skeletal sands are more typical of regressive phases (Carew and Mylroie, 1995). On this analogy there are two main transgressive- regressive units within the Tesero Oolite.

Such changes in shallow waters on basically a carbonate platform are not normally considered ramp facies, especially as there is no change within the unit from shallow to deeper facies (Burchette and Wright, 1992). In fact, since ooidal bodies tend to be thicker towards Andros Island (Newell et al., 1960), the thickening of the Tesero Oolite bodies to the west may signify an approach to shoals or an island (present co-ordinates) which is possible as the tidal flat Brsnina section lies to the east (Fig. 3a). Unit 1 is the topmost unit 1 (sequence a of Wunsch et al., 2018): its base is dated to ~10.000 to 2.500 B.P (Roth and Reijmer, 2004; Wunsch et al., 2018). In which case the Tesoro Oolite with its two comparable, but thinner than Bahama unit 1, may have taken between about to 2.500-10.000 years to accumulate. This is at the lower end of the duration of the interval between the Late Permian Extinction Horizon and the *Hindeodus parvus* defined base of the Triassic, calculated as less than 60.000 years (possibly less than 8.000 years) from cyclostratigraphy (Rampino et al., 2000), 0 to 300.000 years calculated from ranges of precise U/Pb dating of volcanic ashes in the Shangsi section in China

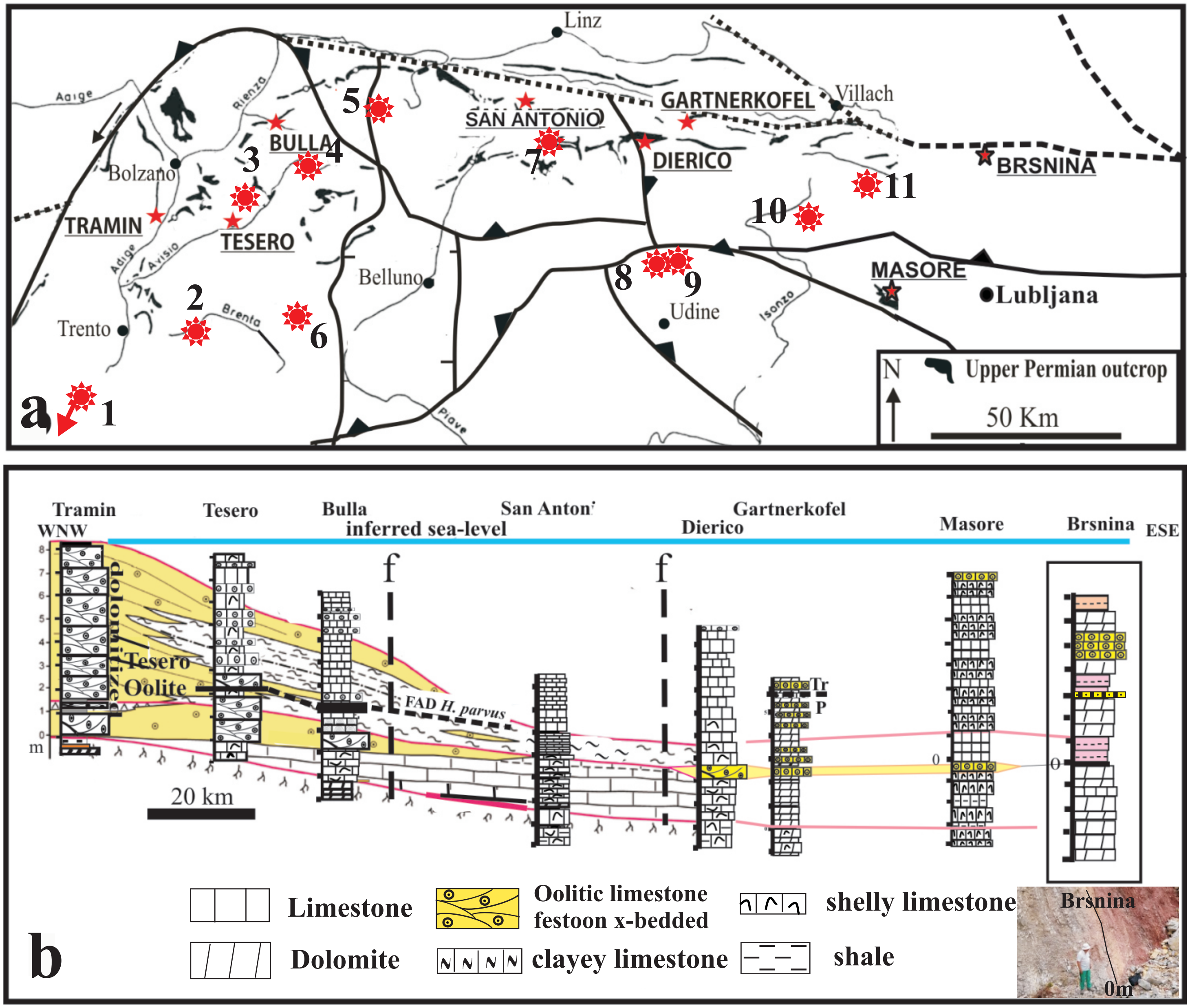

Fig. 2. a) location of Gartnerkofel and other PTr sections in the Dolomites, southern Alps. Small red stars – sections used on the ramp interpretation: larger red asterisks – sections used in platform interpretation. b) Reconstructed cross-section of the Lower Triassic carbonate ramp at the end of Tesero Oolite deposition (after Brandner et al., 2009, fig. 8), with representative sections: Tramin: Brandner et al. (2012); Tesero: Posenato (2009); Bulla: Farabegoli and Tonidandel (2012), Posenato (2009); San Antonio; Brandner (1988); Kraus et al. (2013); Dierico: Buggisch & Noé (1986); Gartnerkofel: Holser et al. (1991). Note that only the Tramin, Tesero and Bulla sections are in the same tectonic unit, the other sections are across thrust faults, and actual thickness variation is nowhere greater than 5 metres across a horizontal distance of over 130 kilometres

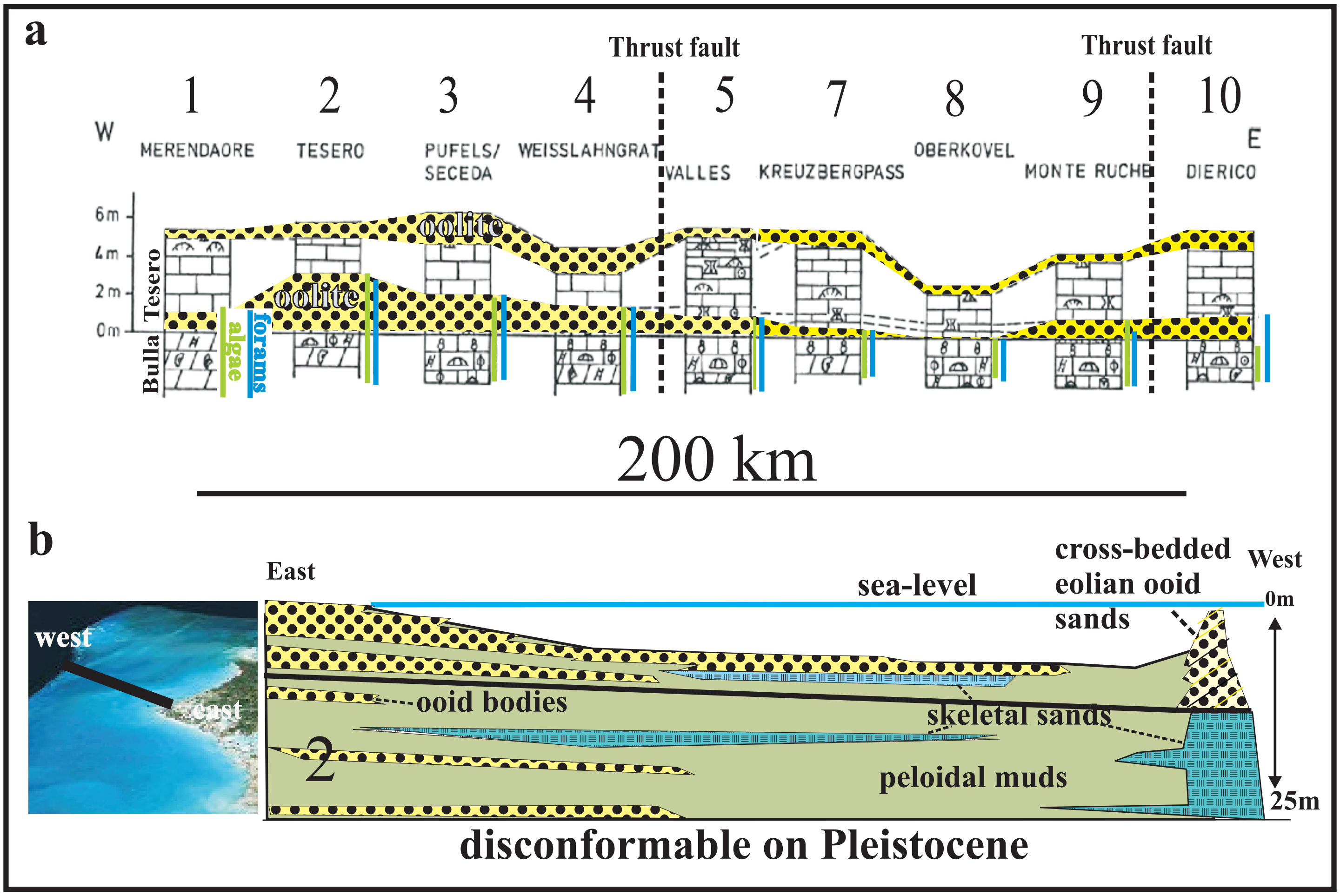

Fig. 3. a) Thickness variation and persistence of Bulla and Tesero Oolite facies from west to east (from Noé, 1987). b) Cross-section of NW Bahama Bank showing distribution of ooidal sediments, skeletal sands and peloidal muds in Pleistocene Lucayan Unit (Beach and Ginsburg,1980). Horizontal scale same as (a). Inset left is oblique view to northeast of NW part of Bahama Bank with location of cross-section of 3b.

(Mundil et al., 2004) and less than 20.000 year estimate from U/Pb dating by Shen et al. (2011).

Conclusion

The Tesero Oolite formed in a ramp-like setting on a carbonate platform like the present Bahama Bank, isolated from land in the westernmost indent of the Tethys ocean. The extent, facies and thickness of the Tesero Oolite are comparable with those of the northwestern Bahama Bank. Thus, both the ramp and platform interpretations are acceptable, though the ramp was a very shallow and gentle one. The Tesero Oolite sediments between the LPEH and the palaeontologically defined base of the Triassic may have taken less than 10000 years to accumulate.

Acknowledgements

I thank Aymon Baud, Rainer Brandner, and Paul Wignall for very helpful comments and suggestions on an earlier version of this paper.

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Report on the activities of the Late Carboniferous – Permian – Early Triassic Nonmarine-Marine Correlation Working Group for 2018 and 2019

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From the beginning of 2018 to the autumn of 2019, a team of 18 authors worked very hard to publish Schneider et al. (2019) "Late Paleozoic–early Mesozoic continental biostratigraphy — Links to the Standard Global Chronostratigraphic Scale". This follows some important publications on nonmarine Permian biostratigraphy and biochronology in the volume on the Permian timescale edited by Lucas and Shen (2018). The co-authors of the Schneider et al. (2019) article are experienced in different methods of non-marine and marine biostratigraphy and have summarized the knowledge from 24 regions on Pangea completed with new data from their own research (Fig. 1). The motivation for this cooperative publication was to calibrate all of the non-marine methods suitable for interregional long-range correlations and to integrate other data with numerical ages and the marine Standard Global Chronostratigraphic Scale (SGCS). We have selected conchostracan, insect, tetrapod body fossil and tetrapod footprint biostratigraphy as well as the traditional macroplant biostratigraphy for our compilation (Fig. 2). Palynostratigraphy was not included, as it has so far only produced correlations within floral provinces, not readily related to the SGCS. However, recent articles by Götz and Wheeler (2018) and Nowak et al. (2018) suggest that palynomorphs may be used in the future to generate some robust, inter-provincial correlations during the Carboniferous–Triassic.

As shown in Figure 2, all of these methods have different precision and provide different temporal resolution from the Late Carboniferous through the Middle Triassic. But, no one method is dispensable. For the correlation of these methods to each other we have selected the most thoroughly investigated depositional basins (Fig. 3). A further criterion was that in a chosen section, at a minimum, two regional to interregional time markers should exist, preferably biostratigraphic data combined with radioisotopic ages. With our analysis we tried to cover the entire Variscan area of northern Pangea from North America via North Africa to Europe. As a reference for the Angara biota province, and, as a reference section of the potential position of the PTB in continental deposits, the Moscow syneclise of the Russian platform with its exceptional fossil record is included; the Karoo basin of South

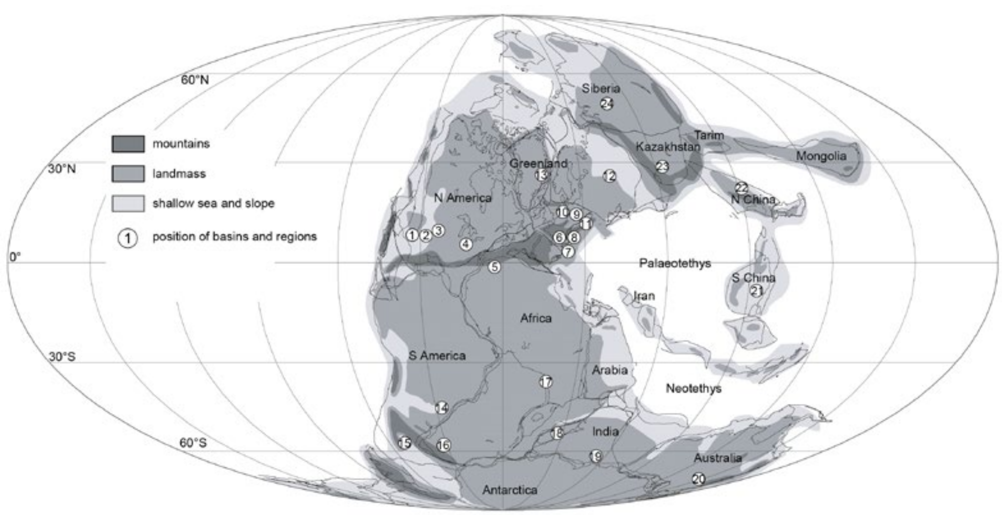

Fig. 1. Map of Permian Pangea at ca. 270 Ma showing the regions and basins correlated in Fig. 3. 1, New Mexico; 2, Texas; 3, Kansas (Midcontinent basin); 4, Ohio (Dunkard basin); 5, Morocco (Souss basin, Aragana basin, Tiddas basin, Khenifra basin, Sidi Kassem basin); 6, France (Lodève basin, Autun basin); 7, Sardinian basins; 8, Italy (Carnic Alps, Southern Alps); 9, Germany (Saar-Nahe basin, Thuringian Forest basin, Saale basin, Erzgebirge basin); 10, Southern Permian basin; 11, Czech Republic, Poland (Central and Western Bohemian basins, Krkonoše-Piedmont basin, Boskovice basin, Innersudetic basin); 12, East European platform; 13, Greenland; 14, Brazil (Parana basin); 15, Argentinia; 16, Southern Africa (Karoo basin); 17, Tanzania (Ruhuhu basin); 18, Madagascar; 19, India (Satpura basin, Pranhita-Godavary Valley, Damodar Valley); 20, Australia (Sydney basin); 21, South China; 22, North China; 23, Kazakhstan (Mangyshlak); 24, Siberia. (From Schneider et al., 2019.)

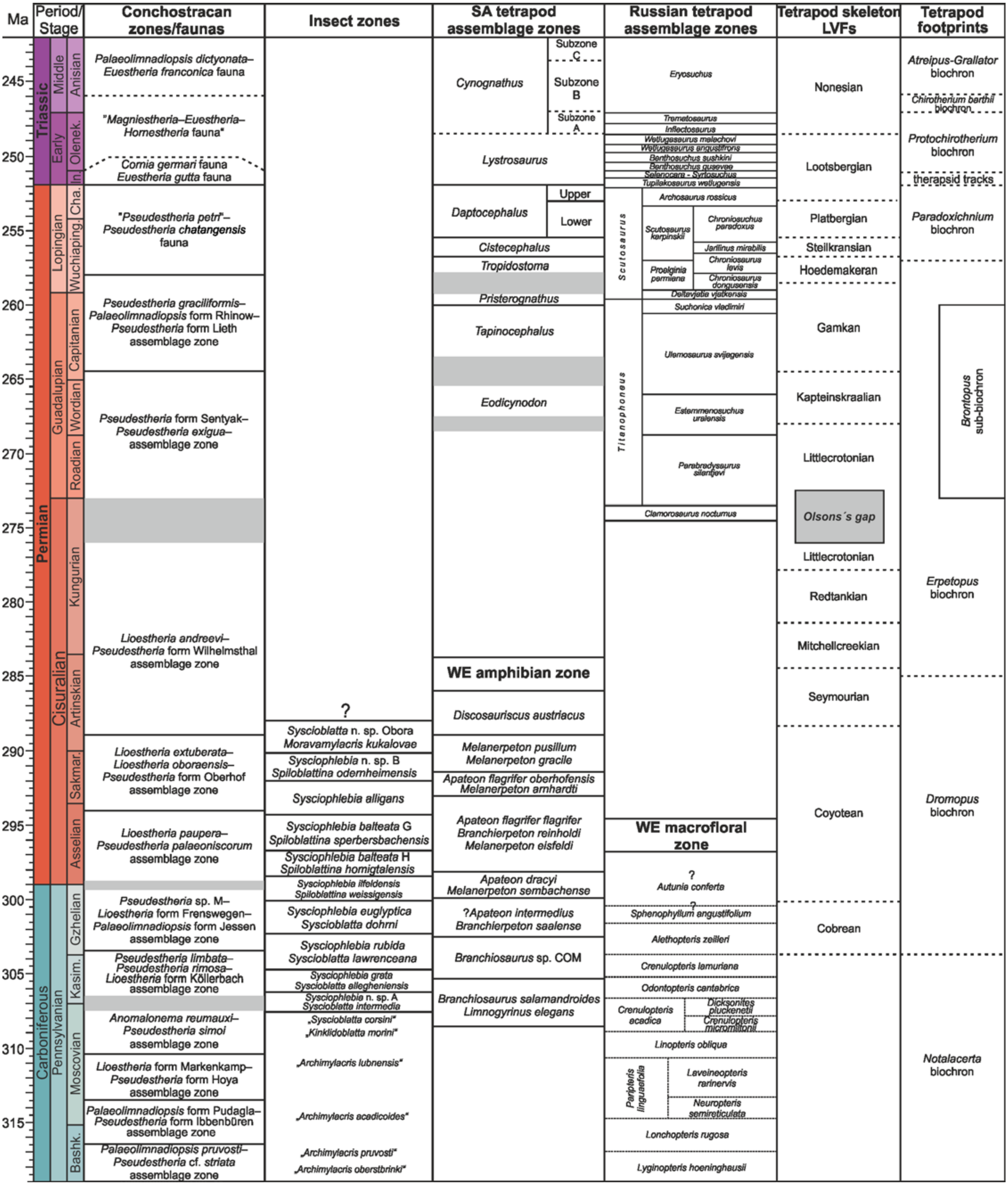

Fig. 2. Synthesis of nonmarine biostratigraphic methods. Most of the zones are calibrated to each other by co-occurrences of zone species in the same horizon or stratigraphic level; the calibration with the SGCS is based on isotopic ages and co-occurrences of non-marine and marine zone fossils. Levels of uncertainty are marked in gray. Abbreviations: SA – South African; WE – West Euopean. (From Schneider et al., 2019.)

Africa is presented as a reference for Gondwana. The lithostratigraphic subdivisions and the isotopic ages of the individual basins in Figure 3 are based on the most recent publications; for more information and full references see the papers cited in Schneider et al. (2019).

Cross correlation of the nonmarine biochronologies to the SGCS has been achieved in some parts of the Late Carboniferous-Middle Triassic in locations where nonmarine and marine strata are intercalated; the nonmarine strata produce biochronologically significant fossils and the marine strata yield fusulinids, conodonts and/or ammonoids. Other cross correlations has been aided by magnetostratigraphy, chemostratigraphy and a growing database of radioisotopic ages. In this way, a synthetic nonmarine biochronology for the Late Carboniferous-Middle Triassic based on all available nonmarine index fossils, integrated with the SGCS, could be presented (Fig. 2). It focuses on the nonmarine biostratigraphy/biochronology of blattoid insects, conchostracans, branchiosaurid amphibians, tetrapod footprints and tetrapod body fossils within the biochronological framework of land-vertebrate faunachrons. The insects, conchostracans and branchiosaurs provide robust nonmarine correlations in the Pennsylvanian-Cisuralian, and the footprints and tetrapod body fossils provide robust correlations of varied precision within the entire Pennsylvanian-Middle Triassic. Radioisotopic ages are currently the strongest basis for cross correlation of the nonmarine biostratigraphy/biochronology to the SGCS, particularly for the Pennsylvanian-Cisuralian. But some caution is required, even for the high-precision U-Pb single crystal zircon CA-ID-TIMS ages (Tichomirowa et al., 2019), which are not, in all cases, in full agreement with biostratigraphic data. Chemostratigraphy and magnetostratigraphy thus far provide only limited links of nonmarine and marine chronologies. Improvements in the nonmarine-marine correlations of late Paleozoic-Triassic Pangea require better alpha taxonomy and stratigraphic precision for the nonmarine fossil record integrated with more reliable radioisotopic ages and more extensive chemostratigraphic and magnetostratigraphic datasets.

A principal task of the Nonmarine-Marine Correlation Working Group is the presentation and discussion of recent research developments of the regional teams at international stratigraphic meetings. A highlight in this regard has been the 19th International Congress on the Carboniferous and Permian (XIX ICCP 2019), July 29th – August 2nd, 2019, in Cologne, Germany, with 200 attendants. Several sessions were dedicated to late Palaeozoic continental deposits, their biota, stratigraphy and correlation:

A2. Carboniferous and Permian multistratigraphy and correlations. Chairpersons: E. Poty, S. Shen.

A3. Late Carboniferous to Early Triassic continental successions of Western Europe and Northern Africa. Chairpersons: A. Ronchi, J. López-Gómez, S. Bourquin.

A4. Late Carboniferous to Triassic non-marine stratigraphy and biota. Chairpersons: S. Lucas, J.W. Schneider, F. Scholze.

B2. Carboniferous and Permian plants: taxonomy, palaeoecology, palaeogeography. Chairpersons: A.-L. Decombeix, H. Kerp.

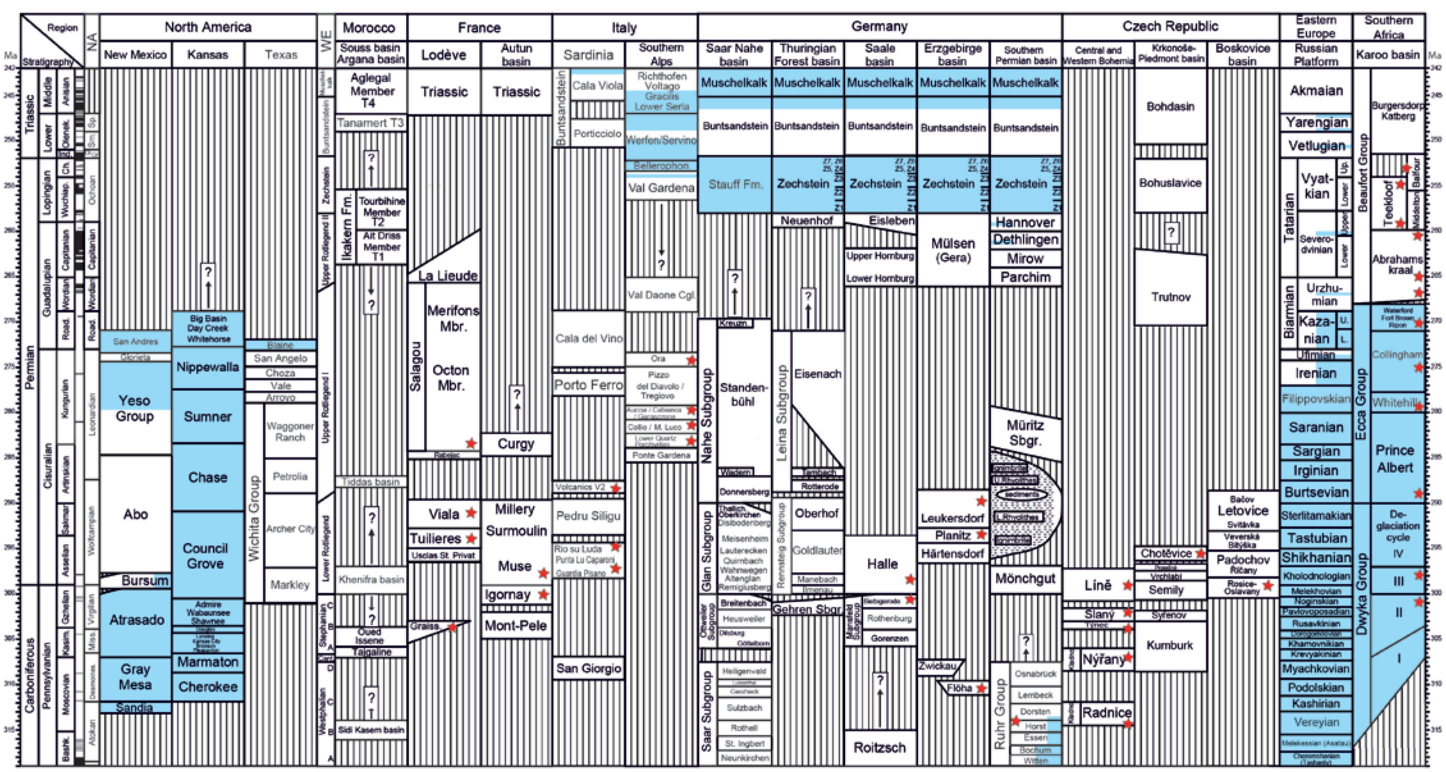

Fig. 3. Multistratigraphic correlations of basins based on the synthesis of biostratigraphic methods shown in Fig. 2. Positions of the radioisotopic ages are indicated by stars. For the data used for the correlations, the dating methods, error ranges of the radioisotopic ages and for discussion, see Schneider et al. (2019). Marine deposits are marked in blue. Abbreviations: NA – North American regional scale; WE – West European regional scale; Miss. – Missourian; Road. – Roadian; Gr. – Griesbachian; Di. – Dienerian; Sm. – Smithian; Sp. – Spathian; Cant. – Cantabrian; Graiss. – Graissesac; Cgl. – conglomerate; Kreuzn. – Kreuznach. (From Schneider et al., 2019.)

C2. Pennsylvanian and Permian paralic and non-marine environments of Central Europe. Chairpersons: C. Hartkopf-Fröder, S. Opluštil.

C3. The Permian basins of Central Europe – the state of the art. Chairpersons: T.M. Peryt, J.W. Schneider.

C4. Permo-Carboniferous basins and environments from Gondwana and peri-Gondwana. Chairpersons: A. Götz, A. Mory.

Two congress excursions were organized by members of the working group. They were dedicated to

"The classical Central European Permian: continental 'Rotliegend', marine 'Zechstein', and the Permian-Triassic transition in Germany," guided by Joerg W. Schneider, Thomas Wotte, Silvio Zeibig, and Birgit Gaitzsch; and

"The Pennsylvanian–Permian of the Saar–Nahe Basin, southwestern Germany – an intramontane continental molasse basin of the Variscides," guided by Sebastian Voigt and Thomas Schindler. And, as usual, business meetings of the International Subcommissions on Carboniferous Stratigraphy and on Permian Stratigraphy were held.

Co-organized by several members of the Nonmarine-Marine Correlation Working Group, the Third Kazan Golovkinsky Stratigraphic Meeting "Sedimentary Earth Systems: Stratigraphy, Geochronology, Petroleum Resources" and the Fifth All-Russian Conference "Upper Palaeozoic of Russia" was held from September 24 to 28, 2019, at the Kazan Federal University, Tatarstan, Russia (for abstracts and proceedings see websites below). It was attended by more than 70 scientists, mainly from Russia, but also from Germany, Poland, Ukraine, Kazakhstan, the United States, Morocco, and Malaysia. Among other presentations at the meeting, several contributions focused on the progress in studying the Upper Carboniferous and Permian marine and nonmarine deposits as well as the Permian-Triassic boundary by multistratigraphic methods. A joint meeting of members of the Permian and Carboniferous stratigraphic commissions focused on "Results and challenges of the Congress in Cologne-2019" and the tasks of Russian scientist to promote the future ratification of Carboniferous and Permian GSSP´s in Russia.

Nearly at the same time, from the 23rd to the 29th of September 2019, the 3rd International Conference of Continental Ichnology took place at Martin Luther University in Halle (Saale), Germany. Several contributions in two sessions on "Late Paleozoic and Early Mesozoic Tetrapod Ichnofaunas", chaired by L. Marchetti and C.A.Meyer, have demonstrated the progress in taxonomy and palaeobiogegraphy as well as the biostratigraphic importance of tetrapod tracks. During the congress excursion, M. Buchwitz demonstrated the new Mammendorf tracksite in the Middle to Late Permian of Germany, which will become of interregional importance because of the rarity of tetrapod tracks and skeletons in this time interval, not only in Europe. For the abstract volume see the web-link below.

Besides the improvement of nonmarine biostratigraphical methods future tasks of the working group will focus mainly on two problems. First on the solution of the Middle Permian problem. Guadalupian nonmarine deposits are very limited and scattered in Euramerica and provide so far some biostratigraphic correlations based on conchostracans and tetrapod footprints only. Additionally, volcanites suited for radioisotopic age determinations are nearly missing in this interval (Fig. 3), even in marine deposits (e.g. Davydov et al., 2016). Only the South African Karoo basin provides good nonmarine biostratigraphic records for the Guadalupian, particularly for tetrapod body fossils, and can be correlated with the SGCS using radioisotopic ages (e.g. Rubidge et al., 2013; Day et al., 2015). The correlation of the Karoo tetrapod zones with them of the East European platform in Russia, as proposed in Schneider et al. (2019), will possibly be improved by first isotopic ages from the latter basin (personal communication V. Davydov). The second and most challenging future task for nonmarine-marine correlations in the Late Carboniferous–Middle Triassic is the currently unsatisfactory biostratigraphic correlation amongst the biotic provinces of Euramerica, Angara, Cathaysia, and Gondwana. To increase the progress in nonmarine-marine correlations a call for cooperation in the correlation of single continental and mixed marine-continental basins will be published in the next issue of *Permophiles*. The aim will be to extend the correlation chart of Figure 3 to a nearly global scale. We have provided the tools to do it, let as use and improve this tools.

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The Abstract volume and the excursion guide of the 3rd International Conference of Continental Ichnology (ICCI 2019) are available at the following link: https://sites.google.com/view/3rd-icci-2019/home/abstract-volume-field-trip-guide

Report on the 19th International Congress on the Carboniferous and Permian, Cologne, July, 29th–August, 2nd, 2019

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The 19th International Congress on the Carboniferous and Permian (XIX ICCP 2019) (Fig. 1) was held from July, 29th to August, 2nd, 2019 at the University of Cologne, Germany. Organized by Hans-Georg Herbig, Michael Amler, Sven Hartenfels (all University of Cologne), and Markus Aretz (Université Paul Sabatier Toulouse, France), it came back to central Europe, after the successful meetings in Nanjing (2007), Perth (2011), and Kazan (2015), sixteen years after the 15th ICCP in the Netherlands (Utrecht, 2003), and forty-eight years after the "7ème Congres International de Stratigraphie et de Géologie du Carbonifère" in Krefeld, 1971, hitherto the only congress of the series in Germany. The congress was financially strongly supported by the German Research Foundation (DFG), the German Academic Exchange Service (DAAD), and the International Commission on Stratigraphy (ICS). Additional funds could be raised from the International Association of Sedimentologists (IAS), the German Geoscientific Network Aachen-Bonn-Köln-Jülich (ABC-J), and the Geological Survey of the German Federal State Northrhine-Westfalia (Geologischer Dienst Nordrhein-Westfalen).

Exactly 200 participants from 27 countries (Tab. 1) gathered during hot summer days in the central lecture hall of the university, which enabled compact presentation of lectures and posters. This not only facilitated rapid and easy change between the two parallel sessions, but also vivid discussions among all participants and relax with coffee, drinks and snacks. Fourteen sessions were grouped into five major themes: (1) the World of Stratigraphy, (2) the World of Palaeontology, (3) the World of Facies, Environments, and Basin Analysis, (4) the World of Oceans and Mountains, (5) the World of Economic Geology. Morning and afternoon sessions were opened by splendid keynotes (Tab. 2), each 40 minutes long (Fig. 2). Of course, the keynotes introduced into the major topics, but also were a quite successful tool to sweep people back to the lecture hall!

Inauguration speeches in the opening ceremony highlighted the traditional and future economic importance of Carboniferous rocks in western Germany (Dr. Ulrich Pahlke, Director of the Geological Survey of Northrhine-Westfalia, Krefeld), explained the rooting of the university within the city of Cologne (Mrs. Helga Blömer-Frerker, Mayor of the Cologne University district Lindenthal), introduced the wide spectrum of the Cologne geosciences (Prof. Dr. Karl Schneider, former Dean of the Faculty of Science, University of Cologne), and ended with a welcome address by Hans-Georg Herbig (Chair of the XIX ICCP).

Besides the keynotes, 104 talks and 62 posters compiled by 425 authors were presented during four days. The possibility to publish extended abstracts (maximum two pages) that included key references and partly coloured figures resulted in an abstract volume of 345 pages (ed. Hartenfels et al., 2019). Winners of the student and young scientist poster awards were elected by the participants (Tab. 3). The fifth day of the congress (Wednesday) traditionally was devoted to mid-congress field trips, which in a geotouristic manner introduced the geological highlights in the surroundings of Cologne, while other participants decided to have a private or guided stroll through historical downtown Cologne. Destinations of the field trips were (1) 12.900 year old Laacher See volcanism and medieval to industrial cultural history of the East Eifel region, guided by C. Münker, (2) the largest contiguous brown coal mining area in Europe west of Cologne (Miocene Rhenish Brown Coal) and Chateau Paffendorf, guided by S. Hartenfels, (3) Neanderthal Museum at the type locality of Neanderthal man and medieval town of Zons at the banks of the river Rhine, guided by H.-G. Herbig.

The social highlight of the congress surely was the congress dinner. It was served during a cruise on the river Rhine in front of the historical waterfront of Cologne glowing up in the falling night.

Besides the scientific sessions, the congress also was the place for the regular business meetings of the International Subcommission on Carboniferous, respectively on Permian Stratigraphy, of the SCCS working group on redefinition of the Devonian-Carboniferous boundary, and of the German Subcommission on Carboniferous Stratigraphy.

During the closing ceremony Markus Aretz presented the next venue of the congress that will take part in 2023 in Toulouse, south-western France.

The congress was flanked by three pre-congress and three post-congress field trips, except for the two day trip to the Ruhr area all with a duration of three days (Tab. 4). The field trips attracted 77 participants that from dedicated leaders got of the newest insights into the varied Carboniferous and Permian geology of central Europe, including the Southern Alps (Fig. 3). A fully coloured, 302 pages thick field guide (ed. Herbig et al. 2019) was distributed to all participants.

Changes, chances and challenges

The scientific spectrum of the congress series widened through time, not at last expressed by the inclusion of the Permian at the Congress in Buenos Aires, Argentina, in 1993. The early "Heerlen congresses" were strongly devoted to stratigraphy and inherited palaeontology. They laid the basis for biostratigraphy and correlation within the Carboniferous System, in a need to get to a common language. Still, these are major topics of the congress, as seen in the struggle for redefinition of the Devonian-Carboniferous boundary, and the quest for the GSSPs at the base of the Serpukhovian, Moscovian, Kasimovian, and Gzhelian stages. Of course, the early efforts from the Heerlen congresses were strongly related to coal mining. It was amazing to see that topics concerning coals, already declining in the last congresses, were not any more addressed at the congress except in the keynote of Annette Götz. She stated the continuing economic importance of coal for certain countries in the southern hemisphere for coming decades. Also, geological aspects of the huge salt deposits from the Upper Permian Zechstein Basin in north-central Europe, well-illustrated in the keynote of Tadeusz Peryt, or from salt deposits elsewhere were almost missing. Same holds true for the geological and economic aspects of black shales, respectively of shale gas from Carboniferous strata. However, the strong session "Mississippian carbonate rocks in North-West Europe – reservoir for deep geothermal energy" chaired by Martin Salamon and Anna Thiel (both from Krefeld) has to be highlighted.

The numerous contributions within the session "Carboniferous and Permian plants: taxonomy, palaeoecology, palaeogeography", chaired by Anne-Laure Decombeix and Hans Kerp, were impressive, and the high quality is reflected by the corresponding poster awards (Tab. 3).

Topics concerning palaeoclimate, palaeoecology and facies, and topics related to extinction and recovery of organisms were important in Cologne. On the other hand, in spite of the challenging keynote of Ulf Linnemann and coauthors on the central European Variscides, the number of contributions in the session "Carboniferous and Permian palaeoceanography, plate tectonics and the evolution of relief", including presentations on geochemistry, remained low, and it seems important to bring these topics to future congresses,

Figure 1. Participants of the 19th ICCP 2019, Cologne.

Germany (73)	Italy (6)	Spain (3)	Hungary (1)
China (24)	United Kingdom (6)	Czech Republic (2)	Kazakhstan (1)
Russia (17)	Australia (4)	Mexico (2)	Morocco (1)
Belgium (11)	India (4)	The Netherlands (2)	Portugal (1)
Poland (10)	Austria (3)	Ukraine (2)	Slovenia (1)
France (9)	Ireland (3)	Canada (1)	Turkey (1)
USA (8)	Japan (3)	Egypt (1)	

Table 1. Distribution of participants

Figure 2. Clockwise from upper left: 1) Ready to start – some of our students at the registration desk. 2) The venue in the central lecture hall of the university. 3) During coffee break. (4) Isabel Montañez presenting her keynote lecture.

GÖTZ, A.E. (University of Portsmouth) – Late Palaeozoic energy resources of Gondwana - archives of climate change that power the world.
LINNEMANN, U. (Senckenberg Natural History Collections Dresden) and coauthors – The Central European Variscides – the heart of Pangea.
MCGHEE, G.R. (Rutgers University, Piscataway/New Jersey) – Carboniferous giants and mass extinction: The legacy of the Late Palaeozoic Ice Age.
MONTAÑEZ, I.P. (University of California, Davis) – Understanding feedbacks between climate, pCO2, and ecosystems in the late Palaeozoic Earth system.
NIKOLAEVA, S. (The Natural History Museum London, Borissiak Paleontological Institute Moscow and Kazan University) – Boundaries in sections, not in research: new and old Carboniferous stratotypes of Russia.
PERYT, T. (Polish Geological Institute - National Research Institute, Warsaw) – The origin and evolution of the North-European Zechstein Basin: A Polish perspective.
SHEN, S.-Z. (Nanjing University) – The Permian timescale: Progress, problems and perspectives.

Table 2. Keynote lectures

enabling more and more a holistic view of the Carboniferous and Permian time slices.

This cannot be underestimated, as the Carboniferous and Permian is so similar to our world: young mountain ranges, glaciated poles, extinction and recovery. Thus, the time slices are a deep-time equivalent of our world. We can study and try to explain processes in a geological time frame, which today, in our tiny life span, we experience. Therefore, the study of the Carboniferous and Permian is of prime interest and it is our noble task to continue this research, and especially, to inspire and encourage students to follow.

This brings me to the second major issue – the dwindling number of Carboniferous and Permian researchers. It was very problematic to find a person or group to organize the next Carboniferous-Permian Congress and I am indebted to Markus Aretz to shoulder this task in Toulouse – in the meanwhile many working groups are too small for that, or will shrink, as colleagues are about to retire during the next years. Thus, the community must take care to keep its possibilities for sufficient impact in geoscience. Actually, organization of a succeeding congress in North America is overdue (lastly and only Champaign-Urbana, Illinois/USA 1979, and Calgary, Canada, 1999). Even more, a congress in western or central Gondwana, viz. in South America or Africa would be desirable. Actually, the only congress hosted there was in Buenos Aires, 1993. The understanding of the Carboniferous and Permian world, and the sought globally applicable chronostratigraphic subdivision cannot be achieved without understanding the development from Gondwana, respectively from the Southern Continents. In this context, it has to be noted that not a single researcher from South America or sub-Saharan Africa was present at the 19th ICCP, probably mostly due to high costs, and we have to avoid decoupling of colleagues from these important regions.

Finally, however, I would like to report that we had a fine number of young, promising scientists in Cologne, and, as already mentioned above, we have to encourage them to continue with Carboniferous and Permian topics: 27,5 % of our participants were master and PhD students, among those almost half female (47,3 %), and this is a good prospect for future!

Final additions and next steps

Due to certain delay we postponed the deadline for contributions to the congress proceedings to March, 31, 2020, even if we appreciate earlier submissions. Also, participants that did not yet indicate their interest are invited to contribute. All contributions should be send to iccp-2019@uni-koeln.de. Further informations can be found on the website of the congress http://iccp2019-Cologne.uni-koeln.de/. There, you also will find a photo gallery from the congress and from some field trips, and the possibility to download the abstract and field guide volume. Printed volumes can be acquired for 25.00 Euro each via geobibliothek@uni-koeln.de.

Finally, this is the place to say thank you: first, to all the participants for excellent presentations, vivid discussions and the inspiring atmosphere which lasted throughout the congress and on the field trips. And, second, to all people behind the stage for organization of and care-taking during the congress, especially our students who made an excellent job!

Congress publications

Hartenfels, S., Herbig, H.-G., Amler, M.R.W. and Aretz, M. eds, 2019. 19th International Congress on the Carboniferous and Permian, Cologne, July 29–August 2, 2019, Abstracts. Kölner Forum für Geologie und Paläontologie, v. 23, 345 pp.

Herbig, H.-G., Aretz, M.; Amler, M.R.W. and Hartenfels, S. eds, 2019. 19th International Congress on the Carboniferous and Permian, Cologne, July 29–August 2, 2019, Field Guides. Kölner Forum für Geologie und Paläontologie, v. 24, 302 pp.

Student Poster Award

1. **SCHULZE HOBELING, REBEKKA**, Institute of Geology and Palaeontology, University Münster, Germany.
SCHULZE HOBELING, R., BLOMENKEMPER, P., KERP, H. & BOMFLEUR, B.: Arthropod-plant interactions from the late Permian Umm Irna Formation, Dead Sea region, Jordan.

2. **FORAPONOVA, TATIANA**, Borissiak Paleontological Institute, Moscow, Russia.
FORAPONOVA, T.: First data on in-situ pollen from synangia of Permotheca type-species from the Middle Permian of the Russian Platform.

3. **SAILLOL, MATTHIEU,** Université de Toulouse (UPS), GET (OMP), Toulouse, France.
SAILLOL, M., GOUYGOU, T., ARETZ, M. & CHRISTOPHOUL, F.: The Ségure Basin (Corbières, southern France): evolution of a Stephanian basin in the southern external zones of the Variscan Orogen.

Young Scientist Poster Award

1. **EL DESOUKY, HEBA**, Mansoura University, Department of Geology, Faculty of Science, Mansoura, Egypt.
EL DESOUKY, H., KORA, M. & HERBIG, H.-G.: Reconsideration of a neglected fossil group – the tabulate coral fauna from the Viséan (Mississippian) of the Sinai Peninsula (Egypt)

2. **FORTE, GIUSEPPA**, Naturmuseum Südtirol/Museo di Scienze Naturali dell'Alto Adige. Bozen/Bolzano, Italy.
FORTE, G., BRANZ, R., NOWAK, H., PRETO, N. & KUSTATSCHER, E.: Morphometric range and δ13C signature of the Lopingian (late Permian) conifers from the Bletterbach flora (Dolomites, NE Italy)

3. **NOWAK, HENDRIK**, Naturmuseum Südtirol/Museo di Scienze Naturali dell'Alto Adige. Bozen/Bolzano, Italy.
NOWAK, H., KUSTATSCHER, E., FORTE, G. & ROGHI, G.: Permian macro- and microfloras of the Southern Alps.

Table 3. Poster awards

Pre-congress field trips

DENAYER, J. C. PRESTIANNI, C., MOTTEQUIN, B. & POTY, E. – The Uppermost Devonian and Lower Carboniferous in the type area of Southern Belgium.

WREDE, V., DROZDZEWSKI, G., JUCH, D., LEIPNER, A. & SOWIAK, M. – The Pennsylvanian of the Ruhr Basin and Osnabrück region, western Germany – facies, stratigraphy, and tectonics of a paralic foreland basin of the Variscides.

SCHNEIDER, J., WOTTE, T., GAITZSCH, B., WERNEBURG, R., ZEIBIG S. & SCHOLZE, F. – The classical Central European Permian: Continental "Rotliegend", marine "Zechstein", and the Permian-Triassic Transition in Germany.

Post-congress field trips

H.-G. HERBIG, H.-G., KORN, D., AMLER, M.R.W., HARTENFELS, S. & JÄGER, H. – The Mississippian Kulm Basin of the Rhenish Mountains, western Germany – fauna, facies, and stratigraphy of a mixed carbonate-siliciclastic foreland basin.

VOIGT, S., SCHINDLER, T., THUM, H. & FISCHER, J. – Pennsylvanian–Permian of the Saar-Nahe Basin, SW Germany.

NOVAK, M., FORKE, H.C. & SCHÖNLAUB, H.P. – The Pennsylvanian–Permian of the Southern Alps (Carnic Alps/Karavanke Mts.), Austria/ Italy/Slovenia – fauna, facies and stratigraphy of a mixed carbonate-siliciclastic shallow marine platform along the northwestern Palaeotethys margin.

Table 4. Field trips

Figure 3. Clockwise from upper left: 1) Winners of the poster awards; from left: Matthieu Saillol (Toulouse), Tatiana Foraponova ((Moscow), Rebekka Schulze Hobeling (Münster), Hendrik Nowak (Bozen), Heba El Desouky (Mansoura); presenting: Hans-Georg Herbig. 2) Mid-congress field trip to the Rhenish Brown Coal mining area. 3) Field trip to the Southern Alps guided by Holger C. Forke (standing in front), Hans Peter Schönlaub (in yellow shirt) and Matevž Novak (in front of H.P. Schönlaub). 4) Field trip to the Rhenish Mountains; Dieter Korn in front of lowermost Carboniferous Hangenberg Limestone, eastern provincial quarry Drewer.

15th International Permian-Triassic Field Workshop in Sardinia/Italy

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The 15th International Permian-Triassic Workshop took place on May 13–18, 2019 in Sardinia. It was organized and guided by Professor Luca G. Costamagna, University of Cagliari, supported by Dr. Dirk Knaust, Equinor/Norway. Their invitation was followed by 17 participants from Germany, France, Norway, Israel, England, Jordan and Poland.

The basement of Sardinia consists of differently deformed and metamorphosed Variscan units (Lower Cambrian to Lower Carboniferous) including the well-known intra-Ordovician „Sardian unconformity“ (Stille, 1939). As elsewhere in many parts of Europe, the basement is unconformably overlain by continental clastics and volcanics deposited in local troughs (Upper Carboniferous to Permian). The Triassic succession is only up to 200–250 m thick and unconformably overlies the Variscan basement or Permian strata. The Triassic facies resembles the Germanic Triassic, but it is attributed to the Sephardic bioprovince, and it exhibits rapid lateral variations. The Triassic strata form, as in Central Europe, a transgressive-regressive cycle consisting of the Buntsandstein (red beds), Muschelkalk (carbonates) and Keuper groups (carbonates, evaporites). Thus, the German names of the groups are also used in Sardinia. The groups are subdivided into numerous formations. The maximum transgression (mfs) of the transgressive-regressive cycle took place in the Ladinian. The Sardinian Triassic was probably deposited on a structural high that was paleogeographically situated between Western Europe, Central Europe and the Tethys Ocean. In the northwest of the island, the Triassic is unconformably overlain by Jurassic strata.

Fig. 1. Keuper Group (Carnian), Cala Viola north of Alghero, NW-Sardinia (Photo: M. Franz)

The starting point of the workshop was Cagliari in the south of Sardinia. Two rented minibuses were used for transport. To get a representative overview, the island tour was almost 1000 km long from Cagliari in the south, Carbonia in the southwest, Jerzu in the east and Alghero in the north. Permian and Triassic outcrops occur mainly in the western part of the island, mainly roadcuts, quarries and coastal cliffs. The outcrops are usually relatively small and tectonically isolated.

The group also visited one of the World Heritage Site “nuraghes”, impressive large fortifications made of huge stone blocks of local origin, that only exist in Sardinia and date back up to 3800 years.

In 2020 the coordination of the International Permian-Triassic Workshops will pass to Dr. Sylvie Bourquin, University of Rennes / France, who plans to organise the 16th workshop in the Ardèche area of Southern France

Fig. 2. Muschelkalk Group (Punta del Lavatoio Fm., Ladinian) with synsedimentary tectonics, south of Alghero, NW-Sardinia (Photo: O. Kleditzsch).

Report on the 3th International Congress on Stratigraphy, Milano, 2-5 July 2019

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From 2 to 5 July 2019 stratigraphers from all over the world met in Milan (Italy) at the prestigious venue of the Università degli Studi di Milano for the third edition of the International Congress on Stratigraphy, STRATI 2019.

Following STRATI 2013 (Lisbon, Portugal) and STRATI 2015 (Graz, Austria), the congress was organized on behalf of the International Commission on Stratigraphy (ICS) by the Commissione Italiana di Stratigrafia (CIS)-Società Geologica Italiana (SGI) and Dipartimento di Scienze della Terra "Ardito Desio" of the University of Milan, with the patronage of IUGS (International Union of Geological Sciences), ICS (International Commission on Stratigraphy), INQUA (International Union for Quaternary Research), ISPRA (Dipartimento per il Servizio Geologico d'Italia), AIQUA (Associazione Italiana per lo Studio del Quaternario) and SPI (Società Paleontologica Italiana).

Strati 2019 welcomed more than 380 participants (including the student helpers) from universities, research institutes and industries of almost 40 nationalities (Australia, Austria, Belgium, Brazil, Canada, Chile, China, Czech Republic, Denmark, United Arab Emirates, Finland, France, Germany, Hungary, India, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg,

Fig. 1. Group photo of the participants to the 3rd International Congress on Stratigraphy, STRATI 2019

Netherlands, Norway, Peru, Poland, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan, Tunisia, Turkey, UK, USA) (Fig. 1). In order to promote cultural exchanges and the scientific growth of young people, European and non-European graduate students were able to participate at particularly favourable terms.

The congress provided the opportunity to present and discuss the up-to-date results in all the fields of Stratigraphy. The topics of the congress ranged from the Precambrian to the Holocene and included all the stratigraphic techniques. They were organized in a rich scientific program with 8 themes and 28 sessions, which received about 400 contributions, both oral and poster. Moreover, the scientific program also included three prestigious plenary lectures. As in previous editions, the congress hosted meetings of the ICS and of its Subcommissions to debate topics and problems in updating and improving the geological time scale.

A scientific session focused on Permian and titled ST3.5 “Carboniferous-Permian GSSPs and correlations: state of the art” (*Conveners and Chairpersons: Lucia Angiolini, Xiangdong Wang, Shuzhong Shen)* was held on 2 July 2019. It was followed by the Business Meeting of ICS Subcommission on Permian Stratigraphy on the same day and by fruitful discussions over the congress (Fig. 2).

Important events took place during the congress. On 2 July Lucia Angiolini and Fabrizio Berra (Università degli Studi di Milano; Chief Editors of RIPS - Rivista Italiana di Paleontologia e Stratigrafia) presented the special volume of the RIPS dedicated to Maurizio Gaetani, the world-renowned Professor of Geology and Stratigraphy at the University of Milan, passed away prematurely on 19 December 2017. On 4 July David Harper (ICS Chair) awarded with the ICS Medals Shuzhong Shen (Nanjing University, China) and Philip Gibbard (University of Cambridge, UK) (Fig. 3).

STRATI 2019 was also a great occasion to see excellent outcrops with the guide of the most experienced stratigraphers. Six pre- and post-congress field trips, ranging from one day up to 3 days, were organized in some of the most important and classic localities of Italy, from Sicily and Sardinia to Vesuvio volcano.

The post congress excursion “FT11. Permian and Triassic sedimentary basins from Sicily” (6-9 July, *Field Trip leaders/ co-leaders: P. Di Stefano, S. Todaro*) aimed to show the Late Paleozoic and Early Mesozoic fills of the sedimentary basins originally located along the western margin of the Ionian Tethys and now tectonically imbricated in the Maghrebian fold and thrust belt. In particular, the excursion focused on the Permian and Triassic sediments from the Sosio and Roccapalumba areas, the Upper Triassic *Halobia* limestone of the Sicanian Basin and the facies distribution in the external zones of a rimmed carbonate platform of Late Triassic age.

STRATI 2019 was also designed to promote relationships and exchanges between academia and the industrial world at internationalization. As part of STRATI 2019, six national and international exhibitors (ENI S.p.A., 36TH INTERNATIONAL GEOLOGICAL CONGRESS MARCH 2-8 2020 DELHI INDIA, RIPS - Rivista Italiana di Paleontologia e Stratigrafia, SGI - Società Geologica Italiana, SPI – Società Paleontologica Italiana, ISPRA-Dipartimento per il Servizio Geologico d’Italia) had the opportunity to rent exhibition spaces retained on site for the entire time of the congress, as well as to present issues in scientific sessions of the most significant advances of their productions.

Overall, this third edition of the congress has witnessed an increase in interest and participation from stratigraphers around the world and confirmed the importance and appreciation of this appointment.

General Chairs: Marco Balini, University of Milan, Italy and Elisabetta Erba, University of Milan, Italy

Scientific Committee: Adele Bertini, Peter Brack, William Cavazza, Mauro Coltorti, Piero Di Stefano, Annalisa Ferretti, Stanley C. Finney, Fabio Florindo, Fabrizio Galluzzo, Piero Gianolla, David A.T. Harper, Martin J. Head, Thijs van Kolfschoten, Maria Marino, Simonetta Monechi, Giovanni Monegato, Maria Rose Petrizzo, Claudia Principe, Isabella Raffi, Lorenzo Rook.

Fig. 2 – From left to right: Shuzhong Shen (Nanjing University, China), Lucia Angiolini (University of Milan, Italy) and Charles Henderson (University of Calgary, Canada).

Fig. 3 - From left to right: Shuzhong Shen, David Harper (ICS Chair), Stan Finney (IUGS secretary-general) and Philip Gibbard at the ICS Prize Ceremony.

Fig. 4. The team of the STRATI 2019 student helpers.

Organizing Committee: Lucia Angiolini, Cinzia Bottini, Bernardo Carmina, Domenico Cosentino, Fabrizio Felletti, Daniela Germani, Fabio M. Petti, Alessandro Zuccari.

Field Trip Committee: Fabrizio Berra, Mattia Marini, Maria Letizia Pampaloni, Marcello Tropeano

Special thanks are due to the student helpers of Dipartimento di Scienze della Terra "Ardito Desio", who contributed with seriousness and great willingness to the success of the congress (Fig. 4).

Global Stratotype Section and Point (GSSP) for the base-Sakmarian Stage

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A new Global Stratotype Section and Point (GSSP) for the base-Sakmarian (Permian, Cisuralian) has been formally ratified at the Usolka section in the South Urals, Russia by ICS with unanimous approval. It was also agreed by the IUGS Executive Committee on 30 June 2018. This is the first GSSP established in Russia.

Initially, the Kondurovka section, located on the right bank of the Sakmara River of the Orenburg region of the Southern Urals was selected as the candidate of the GSSP for the base-Sakmarian by SPS (Chair Glenister). The section, represented by a thick series of shallow deposits very rich in fossil content (conodonts, ammonoids, fusulinids), has been studied by many specialists for a long time [Chernykh, 2005, 2006; Chuvasov et al., 2002, 1993; Davydov, 1998, 1999; Schmitz and Davydov, 2012; Zeng et al., 2012]. The conodont *Sweetognathus* aff. *merrilli* was initially chosen as a diagnostic marker for the lower Sakmarian boundary. Subsequently, the level, diagnostic marker and criteria for GSSP of the base-Sakmarian were repeatedly discussed by the SPS, headed by Chair Shuzhong Shen. After extensive discussions, it was shown that there was significant reworking of conodonts in the Kondurovka section. Also, the initial boundary marker *Sweetognathus* aff. *merrilli* was unsuccessfully selected, the required additional geochronological and geochemical data were not available; as a result, the Kondurovka section was rejected as a GSSP.

The well-exposed condensed and continuous section of Usolka with abundant conodonts gives a complete picture of the continuous record of conodonts in the interval from the Gzhelian to the middle part of the Artinskian Stage. So it was proposed as a candidate for the Global Stratotype Section and Point (GSSP) for the base of the Sakmarian Stage of the International Time Scale. Considering that the Kondurovka section is a historical Russian stratotype of the Sakmarian stage also with a complete succession of conodonts, fusulinids and ammonoids, [Chuvashov et al, 1993, 2002a, b], the Kondurovka section was recommended as an auxiliary section.

As a result of the study of two sections - Usolka, deposited in deep sea conditions and Kondurovka, an auxiliary shallow-water section - and after further extensive discussion, consensus was reached on the final choice of the section, boundary level

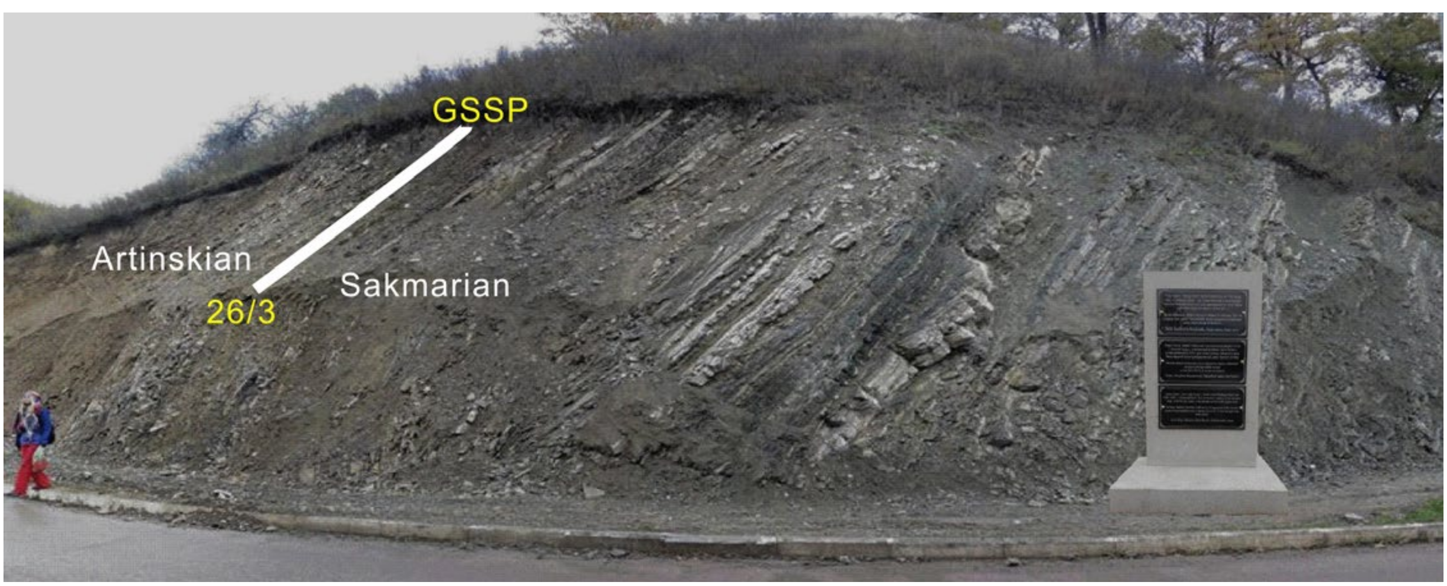

Fig. 1

and marker. The conodont *Mesogondolella monstra* was finally selected as the new marker of the lower boundary of the Sakmarian Stage, coinciding with the appearance of *Sweetognathus binodosus* in the shallow facies of the Kondurovka section. Established by V. Chernykh, the evolutionary lineages of *Mesogondolella uralensis-M. monstra – M. manifesta* and *Sweetognathus* aff. *merrilli-S. binodosus* are a reliable justification for establishing GSSP of the base-Sakmarian.

The biostratigraphic data of the accepted boundary are also confirmed by the chemostratigraphic curves of $\delta^{13}C$ and $\delta^{18}O$ obtained in the Usolka section (Zeng et al., 2012), as well as in the Kondurovka section. Strontium isotopes were obtained in the Asselian-Sakmarian transition of the Usolka section. The calculated strontium isotopic composition at the base of the Sakmarian stage is $^{87}Sr/^{86}Sr = 0.70787$. Radiometric data of the base-Sakmarian is obtained by extrapolated between dating of the Asselian and Sakmarian Stages at 293.52. ±0.17Ma [Schmitz and Davydov, 2012].

The authors of the base-Sakmarian GSSP are: V.V. Chernykh, B.I. Chuvashov, Shuzhong Shen/ Ch/M/ Henderson, Dong-Xun Yuan, M.H. Stephenson.

Both the Usolka and Dalny Tulkas sections have been included in the "Turatau National Park". Now the Monument at the Sakmarian Lower Boundary has been established, and the Bashkirian Government and Working Group with pleasure invite the International Subcommission on Permian Stratigraphy to the opening of the Monument at the end of May or the beginning of June 2020.

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Permian and other Paleozoic Trace Fossils

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A review article recently published in the *Bolletino della Società Paleontologica Italiana* (2019, volume 58, number 3, pages 223-266) titled "An ichnological perspective on some major events of Paleozoic tetrapod evolution" by Spencer G. Lucas will be of interest to students of the Permian. This article provides a comprehensive review of the Paleozoic tetrapod trace-fossil record and its implications for understanding the timing and nature of key events in Paleozoic tetrapod evolution.

http://paleoitalia.org/media/u/archives/01_Lucas_2019_BSPI_583.pdf

Abstract: Tetrapod trace fossils (primarily footprints) provide significant insight into some major events of the Paleozoic evolution of tetrapods. The oldest fossils of tetrapods are Middle Devonian footprints from Ireland. Bona fide Devonian tetrapod footprints indicate lateral sequence walking by quadrupedal tetrapods with a smaller manus than pes. These trackways indicate that tetrapods other than "ichthyostegalians" remain to be discovered in the Devonian body-fossil record. Devonian tetrapod footprints are from nonmarine paleoenvironments, so they do not support a marginal marine/marine origin of tetrapods. Nevertheless, the Devonian tetrapod footprint record is too sparse to be of paleobiogeographic significance and to evaluate unsubstantiated claims of Late Devonian tetrapod mass extinctions. "Romer's gap", a supposed paucity of Lower Mississippian terrestrial fossils, has largely been filled by sampling and description of already known fossils. It includes the first substantial assemblage of tetrapod footprints, from Blue Beach, Nova Scotia, Canada. This assemblage consists of footprints of small and large temnospondyls and reptiliomorphs, which supports the concept that the Carboniferous diversification of terrestrial tetrapods had begun during (or before) Tournaisian time. No definite pre-Pennsylvanian amniote footprints are known, so the Early Pennsylvanian age of the oldest amniote footprints and body fossils is the same. The Kasimovian revolution was a prolonged and complex change

across the middle-late Pennsylvanian boundary from the "coal forests" to a more xerophytic vegetation accompanied by changes and "sluggish evolution" in the marine biota and the appearance of new tetrapod taxa in the body-fossil record, notably the oldest high fiber herbivores, the diadectomorphs and the edaphosaurid eupelycosaurs. However, the tetrapod footprint record changes little during the Kasimovian and documents much older records of diadectomorph and eupelycosaur (possible edaphosaurs) footprints in the Bashkirian, thus diminishing the extent of tetrapod originations during the Kasimovian revolution. The Permian tetrapod footprint record is much more extensive and better understood than the Carboniferous footprint record. Tetrapod footprints confirm the body-fossil record in demonstrating no significant changes in tetrapod evolution took place across the Carboniferous-Permian boundary. The late Early Permian sauropsid radiation is best documented by a change in the tetrapod footprints from synapsid- and non-amniote-dominated assemblages to those dominated by the footprints of captorhinomorphs and parareptiles. Lower Permian tetrapod footprints from eolian sediments demonstrate the colonisation of deserts by tetrapods. Olson's gap is a global hiatus in the tetrapod body-fossil record during which eupelycosaur-dominated assemblages of the Early Permian were replaced by therapsid-dominated assemblages of the Middle-Late Permian. The gap in the body fossil record corresponds to most of Kungurian time, and the tetrapod footprint record indicates an abundance of captorhinomorph footprints and very few eupelycosaur footprints just before and during Olson's gap, suggesting that the extinction of the eupelycosaurs had already begun well before the first appearance of therapsids. The substantial extinction of dinocephalian therapsids and other tetrapods at approximately the end of the Middle Permian, the dinocephalian extinction event, is well documented by the tetrapod footprint record in paleoequatorial Pangea, where there is a paucity of tetrapod body fossils during this interval. The lack of an end-Permian tetrapod mass extinction finds support in the tetrapod footprint record because most Upper Permian tetrapod footprint ichnogenera continue into the Triassic. Upper Permian archosauriform footprints add evidence that their diversification, and the upright gait, began during the Permian. Most Paleozoic tetrapod trackways indicate quadrupedal lateral sequence walking with a sprawling gait, but relatively narrow gauge tetrapod trackways as old as Carboniferous may indicate some semi-upright to upright walking. Definite upright walking is demonstrated by Upper Permian therapsid and archosauriform footprints, and no know footprints of bipedal tetrapods are known from Paleozoic strata, although a few Permian tetrapod taxa known from skeletons may have been bipeds. Besides footprints, other Paleozoic tetrapod trace fossils (bromalites, burrows and dentalites) are too poorly known and too little studied to provide much insight into Paleozoic tetrapod evolution. Nevertheless, the tetrapod footprint record documents key events in Devonian-Permian tetrapod evolution and needs to be part of a complete understanding of Paleozoic tetrapod evolutionary history

Fig. 1 Some Permian track makers and their tracks

SUBMISSION GUIDELINES FOR ISSUE 69

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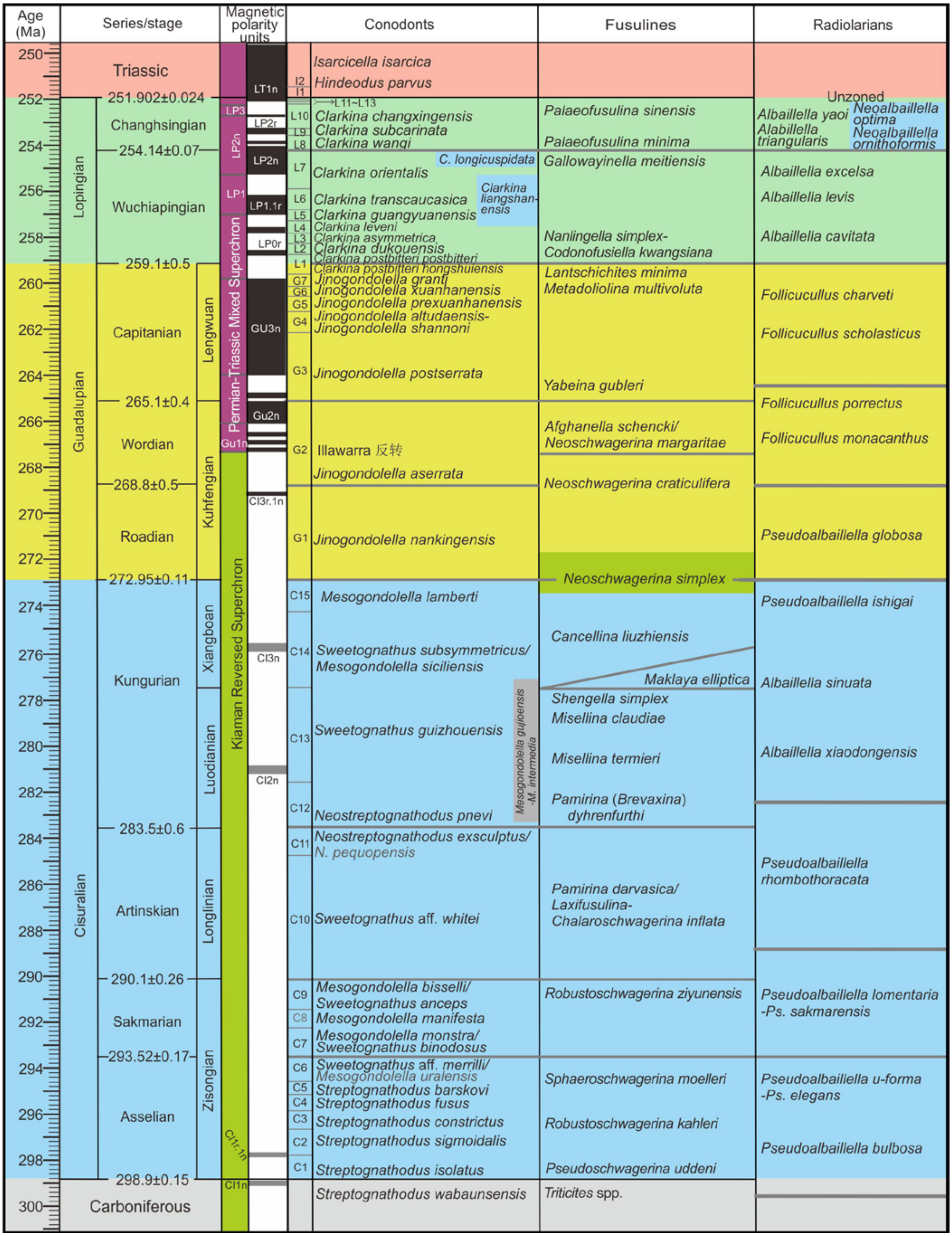
The deadline for submission to Issue 69 is July, 31th, 2020.



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).