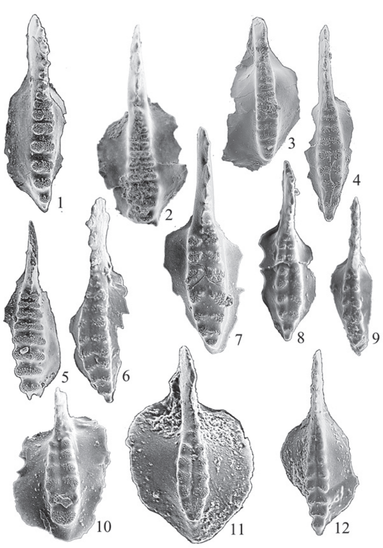
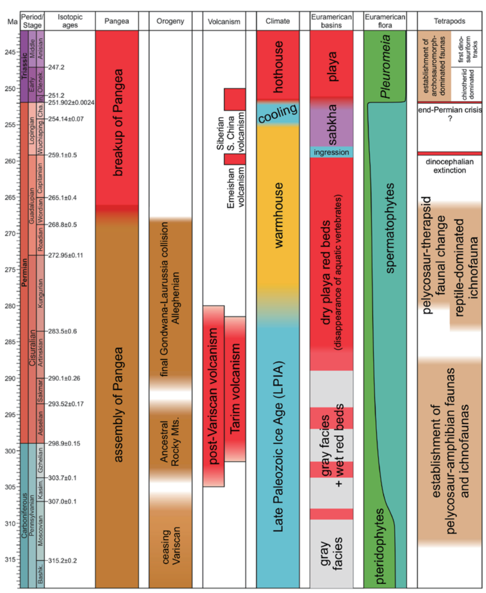
Permophiles

International Commission on Stratigraphy





Newsletter of the Subcommission on Permian Stratigraphy

Number 69

ISSN 1684-5927

November 2020

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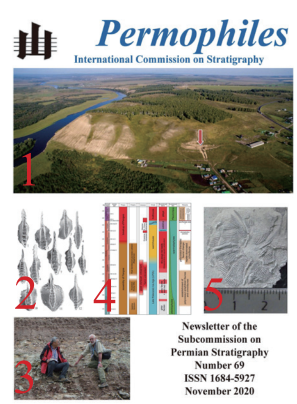

Fig. 1. The Mechetlino Section (candidate base-Kungurian GSSP section), Chernykh, this issue.
Fig. 2. Upper Sakmarian-Lower Artinskian conodonts from the Dal'ny Tulkas Section (candidate base-Artinskian GSSP section), Chernykh, this issue.
Fig. 3. Shuzhong Shen and Joerg Schneider at the continental PTB section at the Caaschwitz quarry, Central Europe, Schneider, this issue.
Fig. 4. Significant global and regional processes of tectonics, paleoclimate, depositional environments and biota during the Late Carboniferous to Middle Triassic, Schneider, this issue.
Fig. 5. *Cyclolobus* sp. from Crni Potok, Montenegro, Horacek et al., this issue.

Notes from the SPS secretary

Yichun Zhang

Introduction and thanks

This note represents my first communication as the new SPS secretary and an editor of Permophiles. Because of the influence of COVID-19, I had no opportunity to edit this issue of Permophiles with SPS Chair Lucia Angiolini face to face. But, I would like to acknowledge her guidance via emails. As the secretary of SPS, I will try to do my best to promote the scientific exchange among our Permian community.

Minutes of SPS meeting on Zoom webinar, 22 October 2020

On 22 October, 2020, the SPS Chair Lucia Angiolini and Vice-Chair Mike Stephenson organized a zoom webinar for the voting members. In total, twelve voting members attended the webinar including Lucia Angiolini, Alexander Biakov, Valery Chernykh, Charles Henderson, Spencer Lucas, Ausonio Ronchi, Tamra Schiappa, Joerg Schneider, Shuzhong Shen, Mike Stephenson, Yue Wang, and Yichun Zhang.

The agenda of the meeting comprised the following topics, after an introduction:

•Terms of Reference of the voting members;

•towards the completion the Permian System: the base-Artinskian GSSP at Dal'ny Tulkas section, Russia and the base-Kungurian GSSP at Mechetlino, Russia;

•SPS Working groups;

•the Permian community webinar on 13 November 2020.

During the introduction all the attendants introduced themselves, then Mike Stephenson presented to the officers suggestions for the voting members' Terms of Reference, that is the rules of engagement, how voting members should work together, what their purpose is, and what is expected of them as voting members. In the discussion that followed, several main themes emerged:

•contributing and finding contributions to Permophiles, "a great place for ideas";

•trying to increase the numbers of the Permian community especially reaching out to students and early-career researchers - maybe by preparing a short and effective video on the Permian;

•facilitating the development of the Permian timescale in order to finish it and then starting to fit the events of the Permian world into that framework;

•also, participation in webinars by the voting members was considered a very important commitment to undertake.

Later, on behalf of Valery Chernykh, Lucia Angiolini presented the Dal'ny Tulkas Section (a potential candidate section for the base of the Artinskian Stage) and the Mechetlino Section (a potential candidate section for the base of the Kungurian Stage). The contents of these presentations, prepared by Valery Chernykh, are published in the current issue of *Permophiles* at p.9 and p.14 were sent in advance to all voting members, with the request to prepare and pose questions on the candidate sections. So, after the presentation, Lucia Angiolini showed the questions raised by the voting members and Valery's answers. The questions included the topics (1) radiometric dating of ash beds in Dal'ny Tulkas and Mechetlino; (2) correlations of the Ural sections beyond Russia; (3) whether the fossils in the Mechetlino section are enough for defining a GSSP section. The answers were as follows: there are U-Pb zircon ages for the ash beds in Dalny Tulkas, but not yet for Mechetlino; correlation is possible with North and South America and China; the distribution of conodonts, ammonoids and foraminifers suggests that the Mechetlino section is continuous enough and and has sufficient fossils to define a GSSP. However, it appeared that the correlations need to be worked out more. In fact, the question about the correlations was followed by a deep discussion which mainly concerned the concept of the conodont species *Sweetognathus whitei*, the marker to define the base of the Artinskian Stage. Charles Henderson presented the work of his team, emphasizing that the type *S. whitei* from Wyoming is late Asselian rather than Artinskian and that the species of *Sweetognathus* from Dalny Tulkas is not *S. whitei*, but nevertheless is correlatable worldwide (see the contribution of Charles Henderson in this issue at p.23)

Spencer Lucas, Shuzhong Shen and Lucia Angiolini pointed out that this debate about "two *S. whitei* species" has been going on a long time, and an agreement among conodont specialists should be reached before defining the base of the Artinskian GSSP section. Consequently, Lucia Angiolini suggests another more restricted webinar to be held in November between Valery and Charles to move forward and solve this conodont conundrum.

Then, Lucia Angiolini discussed the working groups of SPS with the voting members. Charles Henderson and Joerg Schneider reported the progress of the working groups they are chairing on behalf of their group. They all agreed to reconvene the working groups with the suggestion to convert the working group on the 'Guadalupian Series and Global Correlation' into a working group on 'Correlation Marine and continental Guadalupian'.

Finally, Mike Stephenson presented plans for an SPS corresponding members' webinar to be held on 13 November 2020 with the main aim of engaging corresponding members in an inclusive way and to make the SPS mission and activities clear to all the Permian community. But this is another story and we will report about it in the next Permophiles issue.

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The present issue contains diverse contributions including the review of the base-Artinskian and base-Kungurian sections in southern Urals, Russia as well as the comments on the conodont taxonomy related to the definition of these GSSP candidate sections. Also, this issue includes some interesting topic such as the distribution of tetrapods around the Permian-Triassic boundary and the description of the Permian succession in Montenegro, western Tethys. These contributions will improve our knowledge on the Permian overall. Permophiles has a very important role as it serves not only as a place for publishing interesting scientific topics, but also as a forum for some significant Permian discussions.

This issue starts with two contributions by Valery Chernykh. In the first one, he introduces all the paleontological and geochemistry work that has been undertaken at the Dal'ny Tulkas Section in southern Urals, and its merits to meet the requirements of ICS to define a GSSP. Similarly, in another contribution, Valery reports the research progress on the Mechetlino Section and also shows the advantages of the section as a potential base-Kungurian GSSP section.

Valery Chernykh's reports are followed by two contributions by Charles Henderson. Charles agrees that the propositions of both the base-Artinskian and the base-Kungurian GSSP are almost ready. But, for the base-Artinskian, the most significant question is the Sweetognathus whitei species concept, which has been proposed as the biomarker to define the base of the Artinskian Stage. However, the type of this species is from Wyoming, with its age to be late Asselian. So, Sweetognathus asymmetricus is suggested to represent the conodont species to define the base-Artinskian GSSP. As for the base-Kungurian GSSP, Charles points that the FAD of Neostreptognathodus pnevi is an ideal index to establish the correlations between South Urals and North America. But, this is absent in South China. The sea-sevel lowstand and marked provincialism are probably a challenge for global correlations, writes Charles.

Spencer Lucas gives a detailed review on the tetrapod biostratigraphy around the Permian-Triassic boundary. He summarizes the history of more than 150 years of research on the tetrapods from the Permian-Triassic strata in the Karoo Basin, South Africa. Based on the high-resolution CA-ID-TIMS U/Pb dating, the PTB in the Karoo Basin is suggested to lies in the Lootsbergian, well above the lowest occurrence of Lystrosaurus.

Micha Horacek and co-authors present the Permian succession of the Budva Zone of Montenegro. The five sections described from this region are of Middle-Late Permian age. Overall, most studied strata represent a basinal marine environments with some paleogeographic links with the Palaeotethys Ocean.

Charles Henderson reports about the recent works of the Guadalupian Working Group. A paper has been accepted by the journal Earth Science Reviews. He also present suggestions with respect to future works on the Guadalupian.

Finally, Joerg Schneider summarizes the works of the Nonmarine-Marine Correlation Working Group. Multistratigraphic methods have been applied by the group to promote the challenging nonmarine-marine correlations. He also suggests a wider global view on abiotic and biotic processes in the study of nonmarine-marine correlations.

Future issues of Permophiles

The next issue of Permophiles will be the 70th issue.

We welcome contributions related to Permian studies around the world. So, I kindly invite our colleagues in the Permian community to contribute harangues, papers, reports, comments and communications.

The deadline for submission to Issue 70 is 31 December 2020. Manuscripts and figures can be submitted via email address (yczhang@nigpas.ac.cn) as attachment.

To format the manuscript, please follow the TEMPLATE.

Chair and Vice-chair note

Lucia Angiolini and Michael Stephenson

Due to the Covid-19 pandemia, the appointments of officers in ICS Subcommissions could not be conducted at the International Geological Congress, postponed until August 2021. So the changeover of ICS officers and voting members was fixed for 1 August 2020 in order to retain the normal four-year length of service.

After the eight years of very productive work of the past executive lead by Shuzhong Shen, the new officers have just started to promote Permian studies and to improve correlation and the resolution of the Permian Timescale.

The new executive is composed by Lucia Angiolini of the University of Milano, Michael Stephenson of the British Geological Survey and Yichun Zhang of the Nanjing Institute of Geology and Palaeontology, to cover different expertise from brachiopods to palynomorphs and fusulinds in different part of world. But, most important, the new executive is focused to stimulate Permian studies and research, to promote collaboration among Permian workers, to solve issues and controversies and to widen the Permian community in size, diversity and international coverage, involving in particular young scientists.

Several meetings have been held by the new officers in order to fix the SPS mission and main goals which can summed up in the following bullet points:

-Establish the terms of reference of voting members

-Turbocharging the Artinskian-base and Kungurian-base GSSP

-Organising webinars to discuss and develop themes of research for the Permian

-Promoting the publication of Permophiles and its distribution to a wide audience

-Renew the working groups and suggest new ones

Of all these, certainly, promoting a completion of the Permian System is the most urgent task, in agreement to the common thread that guided the actions of the previous executive. But we would like also to develop a different strategy which involves a stimulating circulation of ideas and thoughts, more discussion and more contributions from a larger number of researchers.

This was achieved during the Zoom webinar of the voting members organized on the 22 October 2020, where there was a very lively and productive discussion, as you can read in the report below. The next step will be to hold a corresponding members webinar organized for the 13 November 2020, which we hope will be attended by a large number of people interested in the multidisciplinary and interdisciplinary scientific themes of the Permian. However, to reach the goal of having more discussion and development of themes of research for the Permian, we need the contribution of all corresponding members and of most of the people working on Permian science in the world.

Even if these are difficult times for everybody, we hope that this easier way of web-communication to continue our teaching and research, will promote more studies to develop the Permian timescale and more fruitful discussion. But we will never forget the importance of going back to the field to make our results stronger. So among the goals we want to reach, there is also the organization of field excursions on the last Permian GSSPs we have to establish.

When times are better.

Prof. Lucia Angiolini

Prof. Michael Stephenson

Prof. Yichun Zhang

Notes from the SPS Past Chair

Shuzhong Shen

This note represents my last communication as the SPS Chair. I have been really enjoyed working with the past vice-chair Joerg Schneider and the past secretary Lucia Angiolini. I would express my sincere gratitude to Joerg and Lucia for their easy communication and strong support during the last eight years. All of us have become very good friends. I would also thank the former SPS Chair Charles Henderson and all SPS voting members for their active involvements in the Permian activities. It was with great pleasure that I turned over the SPS chair position to Lucia Angiolini from August 1, 2020 and I am sure SPS will be well served by her leadership in collaboration with Mike Stephenson (new vice-chair) and Yichun Zhang (new secretary). I am very glad to see they have already started the SPS work actively. A zoom webinar on the Permian remaining GSSPs will be organized in two weeks. This is a very good sign to show the Permian spirit for future.

As I look back the last eight years, considerable progress has been made for the Permian. First, the base-Sakmarian GSSP has been finally published on Episodes (https://doi.org/10.18814/epiiugs/2020/020058) (Chernykh et al., 2020a). This is the first GSSP established in Russia. Thanks to the Russian colleagues for their great efforts to move the GSSP work forward. In addition, the proposals for the base-Artinskian and base-Kungurian GSSPs have been published on Permophiles as well (Chuvashov et al., 2002). I think these proposals provided the bases for further discussion among the SPS. Second, the resolution of the Permian timescale has been greatly enhanced. The end-Permian mass extinction has been precisely confined within a very narrow interval 61±48ka (Burgess et al., 2014) and it is probably much shorter (Shen et al., 2019) and a series of high-precision dates have been provided by a few papers (Baresel et al., 2017a; Baresel et al., 2017b; Burgess et al., 2014; Shen et al., 2019). Recently, a couple of high-precision dates for the Guadalupian Series were also published (Davydov et al., 2018; Davydov and Schmitz, 2019; Ramezani and Bowring, 2018; Wu et al., 2017; Wu et al., 2020; Yang et al., 2018). Third, a team consisting of the Nanjing group and North American colleagues including Charles Henderson, Lance Lambert, Jahan Ramezani, Douglas Erwin and Jonena Heast worked on the Guadalupian Series in the Guadalupe Mountains National Park intensively during the last five years and great progress has been made on the three GSSPs in the Guadalupian Series (Shen et al., ESR in review). Fourth, the Permian biostratigraphical framework has been greatly improved too. Two special publications on the Permian timescale have been published (Lucas and Shen, 2018; Shen and Rong, 2019), two chapters in the GTS led by Charles Henderson (Henderson et al., 2012) and 15 issues of Permophiles have been published too. Lucia and I did the editing work mainly for those Permophiles issues. Fifth, two Carboniferous-Permian congresses were held during the last eight years, one is in Kazan and another is in Cologne. I would express my thanks to the organizers for their excellent organizations of these two congresses. The Permian correlation on the continental sequences has been summarized too (Schneider et al., 2020). So much progress has been made in the past and there is no enough space to list all of them.

On the other hand, some challenges for the Permian Subcommission still remain. First, the priority for SPS is to define the last two GSSPs (base-Artinskian and base-Kungurian). New great progress for the Kungurian Stage has been made recently (Chernykh et al., 2020b). The base-Artinskian GSSP is still difficult because of the unpublished conodont taxonomic issues. Davydov (Davydov, 2020) proposed to use a date from an ash bed to define this GSSP, but problems are also present if this proposal is considered. I hope SPS can have a great discussion on this issue. Second, although the Guadalupian Series has been investigated extensively by the Chinese-American group. The final papers on the GSSPs have not been published yet. We found the base-Wordian GSSP probably needs further studies. Third, the previously-defined base-Lopingian GSSP at the Penglaitan section in Guangxi, South China has been flooded due to a dam established at 100 km downstream of the Hongshui River. The current water-level of the Hongshui River is usually about 20 m higher than before. Thus, it is hard to see the GSSP section now. A replacement section near the Penglaitan section has been found and we are working on this section intensively. We hope we can publish the study and use this section to replace the Penglaitan section as the base-Lopingian GSSP section in future. It is within a mountain area, so no worry about the flooding risk. The section is purely composed of carbonates across the Guadalupian/Lopingian boundary and continuous conodont succession has been found.

Time is flying. I wish the new SPS executive under the leadership of Lucia Angiolini will make greater progress on the Permian issues in future. I am very happy to assist their work if I have anything to contribute.

References

Baresel, B., Bucher, H., Brosse, M., Cordey, F., Kuang, G. D., and Schaltegger, U., 2017a, Precise age for the Permian–Triassic boundary in South China from high-precision U-Pb geochronology and Bayesian age–depth modeling: Solid Earth, v. 8, no. 2, p. 361–378.

Baresel, B., d'Abzac, F.-X., Bucher, H., and Schaltegger, U., 2017b, High-precision time-space correlation through coupled apatite and zircon tephrochronology: An example from the Permian-Triassic boundary in South China: Geology, v. 45, no. 1, p. 83–86.

Burgess, S. D., Bowring, S. A., and Shen, S. Z., 2014, High-precision timeline for Earth's most severe extinction: Proceedings of the National Academy of Sciences, v. 111, no. 9, p. 3316–3321.

Chernykh, V. V., Chuvashov, B. I., Shen, S. Z., Henderson, C. M., Yuan, D. X., and Stephenson, M. H., 2020a, The Global Stratotype Section and Point (GSSP) for the base-Sakmarian Stage (Cisuralian, Lower Permian): Episodes, p. 1–19.

Chernykh, V. V., Kotlyar, G. V., Chuvashov, B. I., Kutygin, R. V., Filimonova, T. V., Sungatullina, G. M., Mizens, G. A., Sungatullin, R. K., Isakova, T. N., Boiko, M. S., Ivanov, A. O., Nurgalieva, N. G., Balabanov, Y. P., Mychko, E. V., Gareev, B. I., and Batalin, G. A., 2020b, Multidisciplinary study of the Mechetlino Quarry section (Southern Urals, Russia) — the GSSP candidate for the base of the Kungurian Stage (Lower Permian): Palaeoworld, v. 29, p. 325–352.

Chuvashov, B. I., Chernykh, V. V., Leven, E. J., Davydov, V. I., Bowring, S. A., Ramezani, J., Glenister, B. F., Henderson, C. M., Schiappa, T. A., Northrup, C. J., Snyder, W. S., Spinosa, C., and Wardlaw, B. R., 2002, Progress report of the base of the Artinskian and base of the Kungurian by the Cisuralian Working Group: Permophiles, no. 41, p. 13–16.

Davydov, V. I., 2020, Shift in the paradigm for GSSP boundary definition: Gondwana Research, v. 86, p. 266–286.

Davydov, V. I., Biakov, A. S., Schmitz, M. D., and Silantiev, V. V., 2018, Radioisotopic calibration of the Guadalupian (middle Permian) series: Review and updates: Earth-Science Reviews, v. 176, no. Supplement C, p. 222–240.

Davydov, V. I., and Schmitz, M. D., 2019, High-precision radioisotopic ages for the lower Midian (upper Wordian) Stage of the Tethyan time scale, Shigeyasu Quarry, Yamaguchi Prefecture, Japan: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 527, p. 133–145.

Henderson, C. M., Davydov, V. I., and Wardlaw, B. R., 2012, The Permian Period, in Gradstein, F. M., Ogg, J., Schmitz, M., and Ogg, G., eds., The Geologic Time Scale 2012: Amsterdanm, Elsevier, p. 653–679.

Lucas, S. G., and Shen, S. Z., 2018, The Permian timescale: an introduction: Geological Society, London, Special Publications, v. 450, no. 1, p. 1–19.

Ramezani, J., and Bowring, S. A., 2018, Advances in numerical calibration of the Permian timescale based on radioisotopic geochronology: Geological Society, London, Special Publications, v. 450, no. 1, p. 51–60.

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

Shen, S. Z., Ramezani, J., Chen, J., Cao, C. Q., Erwin, D. H., Zhang, H., Xiang, L., Schoepfer, S. D., Henderson, C. M., Zheng, Q. F., Bowring, S. A., Wang, Y., Li, X. H., Wang, X. D., Yuan, D. X., Zhang, Y. C., Mu, L., Wang, J., and Wu, Y. S., 2019, A sudden end-Permian mass extinction in South China: GSA Bulletin, v. 131, no. 1–2, p. 205–223.

Shen, S. Z., and Rong, J. Y., 2019, Integrative Stratigraphy and Timescale of China: Science in China Series D: Earth Sciences, v. 62, no. 1, p. 1–348.

Wu, Q., Ramezani, J., Zhang, H., Wang, T. T., Yuan, D. X., Mu, L., Zhang, Y. C., Li, X. H., and Shen, S. Z., 2017, Calibrating the Guadalupian Series (Middle Permian) of South China: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 466, p. 361–372.

Wu, Q., Ramezani, J., Zhang, H., Yuan, D. X., Erwin, D. H., Henderson, C. M., Lambert, L. L., Zhang, Y. C., and Shen, S. Z., 2020, High-precision U-Pb zircon age constraints on the Guadalupian in West Texas, USA: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 548, p. 109668.

Yang, J. H., Cawood, P. A., Du, Y. S., Condon, D. J., Yan, J. X., Liu, J. Z., Huang, Y., and Yuan, D. X., 2018, Early Wuchiapingian cooling linked to Emeishan basaltic weathering?: Earth and Planetary Science Letters, v. 492, p. 102–111.

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2) Guadalupian Series and global correlation; Chair-Charles Henderson
3) Correlation between marine and continental Carboniferous-Permian Transition; Chair-Joerg Schneider

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A brief review of the Dal'ny Tulkas Section (Southern Urals, Russia) - potential candidate for a GSSP to define the base of the Artinskian stage in the global chronostratigraphic scale

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The Dal'ny Tulkas section was proposed as the GSSP for the lower boundary of the Artinskian Stage in 2005 on the basis of conodonts, fusulinaceans, ammonoids and radiolarians (Chuvashov et al., 2002a, b, 2004; Amon and Chernykh, 2004; Chuvashov, 2005). Comprehensive paleontological research, which included the study of conodonts, ammonoids, foraminifera, radiolarians, trilobites (Chernykh et al., 2005, 2019, 2020; Chernykh, 2006; Valery et al., 2014; Chuvashov et al., 2013, 2015; Valery et al., 2015; Filimonova et al., 2019), was carried out at the Sakmarian-Artinskian interval of the section in subsequent years. Lithological and radiometric studies (Schmitz et al., 2009; Schmitz and Davydov, 2012), strontium isotopes (Schmitz et al., 2009), stable isotopes C and O (Zeng et al., 2012; Nurgalieva et al., 2018), geochemical (Sungatullin et al., 2018) and magnetometric (Balabanov et al., 2018) work were also carried out. Work was supervised by the chairman of the Permian commission of the interdepartmental stratigraphic committee of Russia, Galina Vasilyevna Kotlyar.

The boundary deposits of the Sakmarian and Artinskian are represented most fully in the section at the Dal'ny Tulkas stream, located on the southern end of the Usolka anticline near the eastern outskirts of the Krasnousol'sky settlement, Bashkortostan (Fig. 1). In the Dal'ny Tulkas section, the boundary interval consists of the deposits of the Kurort suite of the predominantly Sterlitamak horizon of the Sakmarian Stage and the Tulkas suite of the Artinskian Stage.

The Kurort suite includes silty carbonate mudstones, shales, sandstones, marly, sometimes detrital, limestones, with conodonts, fusulinids, radiolarians, rare ammonoids and bivalves. The Tulkas suite consists of shales and mudstones, carbonate concretions, detrital limestones (bioclastic grainstone and rudstone) with interbeds of ash tuffs, siltstones. The section contains conodonts, fusulinids, ammonoids and rare radiolarians (Fig. 2).

In relation to the requirements of the International Commission on Stratigraphy:

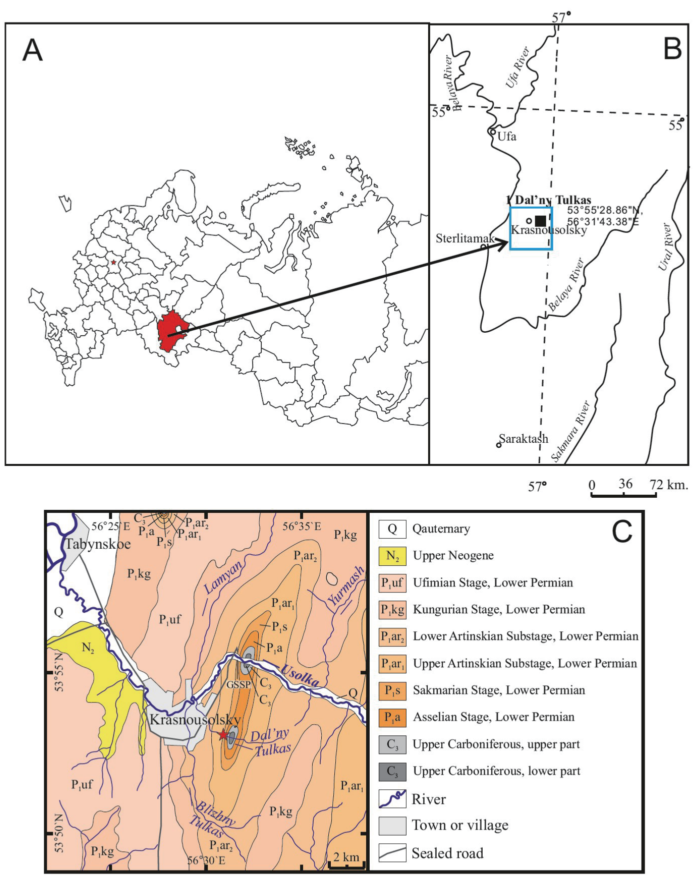

Fig. 1. (A) Location of the Dal'ny Tulkas section in the Republic of Bashkortostan, Russia (Bashkortostan is marked in red); (B) Location of Dal'ny Tulkas (1); (C) Geological map, showing the studied area and the location of the GSSP section for the base of the Artinskian Stage (indicated by red star).

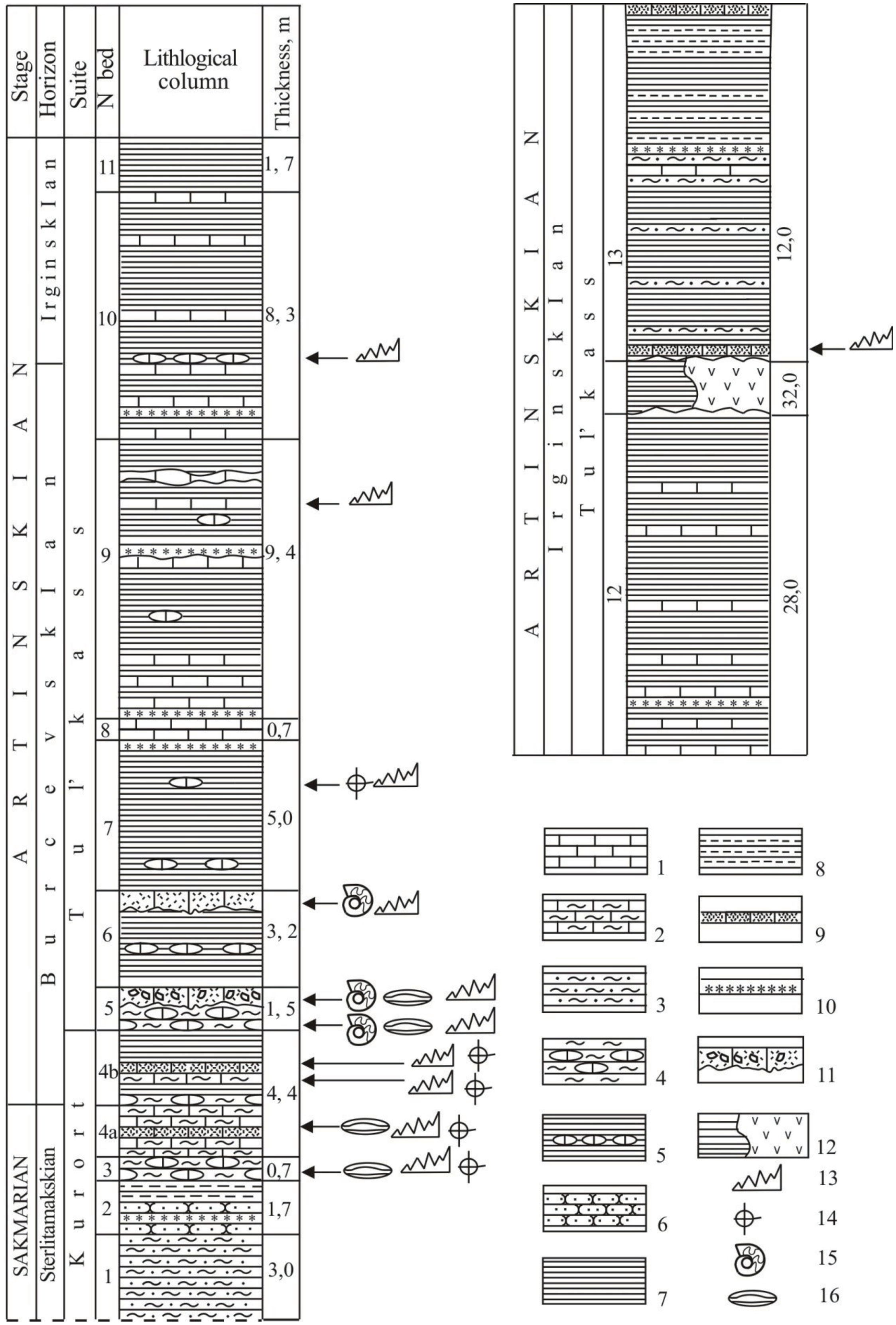

Fig. 2. Stratigraphic column with distribution of samples with conodonts, fusulinaceans, radiolarians and ammonoids: 1 – limestone; 2 – carbonate mudstone; 3 – silty mudstone; 4 – mudstone with carbonate concretions; 5 – shale with carbonate concretions; 6 – sandstone; 7 – shale; 8 – siltstone; 9 – bioclastic limestone (grainstone and rudstone); 10 – ash tuffs; 11 – limestone with limestone intraclasts; 12 – not-exposed parts of section; pointers indicate horizons with the most important species: 13 – conodonts, 14 – radiolarians, 15 – ammonoids, 16 – fusulinaceans.

a) the section represents continuous sedimentation of marine sediments (limestones, detrital limestones, marlstones, mudstones with carbonate nodules, sandstones, calcareous siltstones) without significant facies changes;

b) the section is exposed as part of a quarry representing the Sterlitamak horizon of the Sakmarian stage to the Irginsky horizon of the Artinskian stage with a total thickness of more than 90 m;

c) various remains of well-preserved organisms are found in the section: conodonts, fusulinids, ammonoids, radiolarians, brachiopods, fish, plant remains (algae, calamites), palynomorphs. The lower boundary of the Artinskian Stage is proposed to be marked by the first appearance of the cosmopolitan conodont *Sweetognathus whitei*, a member of the restored phyloline *Sweetognathus merrilli – Sw. binodosus – Sw. anceps – Sw. whitei – Sw. clarki*;

d) interbeds of ash tuffs are present in the section in the Sakmarian-Artinskian interval at three levels - in the upper part of bed 2 (4 m below the base of the Artinskian Stage), in the upper part of bed 7 (10.5 m above the base of the Artinskian Stage) and at the base of bed 9 (2 m higher than the previous sample). These interbeds make it possible to perform radiometric dating. The ash beds are continuous over a considerable distance;

e) The section has been studied by magnetostratigraphic, geochemical and radiometric methods;

f) The section is one of the parts of the Toratau Geological Park within the Republic of Bashkortostan, is easily accessible to visitors and is under state protection.

An analysis of the studies allows us to state that the Dal'ny Tulkas section meets all the requirements of the International Stratigraphic Scale and can be proposed as a candidate for the GSSP of the base of the Artinskian Stage.

References

Amon E.O. and Chernykh V.V., 2004. Stage boundaries and radiolarian zonal scale for Lower Permian deposits in region of Cis-Uralian Stratotype. Permophiles, v. 44, p.10.

Balabanov Y., Sungatullin R., Sungatullina G. and Kosareva L., 2018. A Paleomagnetic Study of the Section of Dal'ny Tulkas, Lower Permian. Proceedings Kazan Golovkinsky Stratigraphic Meeting «Advances in Devonian, Carboniferous and Permian Research: Stratigraphy, Environments, Climate and Resources». Kazan, Russian Federation, 19-23 September 2017. Filodiritto Publisher, Bologna, p. 44–50.

Chernykh V.V., 2005. Zonal Methods in Biostratigraphy. Zonal Scale for the Lower Permian of the Urals accjrding to conodonts. Institute of Geology and Geochemistry, Urals Branch of RAS. Ekaterinburg, 217 pp. (In Russian).

Chernykh V.V., 2006. Lower Permian conodonts of Urals. Institute of Geology and Geochemistry, Urals Branch of RAS. Ekaterinburg, 130 pp. (In Russian).

Chernykh V.V., Chuvashov B.I. and Davydov V.I., 2005. Stratotype of Lower boundary of Artinskian Stage. Annual-2004. Institute of Geology and Geochemistry, Urals Branch of RAS, Ekaterinburg, p. 45–49 (In Russian).

Chernykh V., Kotlyar G., Kutygin R., Sungatullina G., Sungatullin R., Mizens G., Boiko M., Nurgalieva N., Balabanov Y., Oshurkova M., Zbukova D., Gareev B. and Batalin G., 2019. Dal'ny Tulkas Section (Southern Urals, Russia): a potential candidate for the GSSP to define the base of the Artinskian Stage in the Global Chronostratigraphic Scale, new data. In: Nurgaliev, D. (Ed.), Sedimentary Earth Systems: Stratigraphy, Geochronology, Petroleum Resources. Filodiritto Publisher, p. 71–76. Doi:10.26352/D924F5011.

Chernykh V.V., Kotlyar G.V., Kutygin R.V., Filimonova T.V., Sungatullina G.M., Sungatullin R.Kh., Mizens G.A. and Isakova T.N., 2020. Paleontological characteristics of the "Dal'ny Tulkas" Section (Southern Urals). Geologicheskii vestnik, no. 1., p. 13–24. DOI: http://doi.org/10.31084/2619-0087/2020-1-2. (In Russian)

Chuvashov, B.I., Chernykh, V.V. and Bogoslovskaya M.F., 2002a. Biostratigraphic characteristic of the stratotypes of the Stages of Lower Permian. Stratigraphy and Geological correlation. v. 10., no. 4, p. 3–19.

Chuvashov, B.I., Chernykh, V.V., Leven, E.Y., Davydov, V.I ., Bowring, S., Ramezani, J., Glenister, B. F., Henderson, C., Schiappa, T. A., Northrup, C.J., Snyder, W.S., Spinosa, C. and Wardlaw, B.R., 2002b. Progress report on the base of the Artinskian and base of the Kungurian by the Cisuralian Working Group. Permophiles, v. 41, p.13–16.

Chuvashov B.I., Chernykh V.V, Bogoslovskaya M.F. and Amon E.O., 2004. Artinskian stage of Cis-Uralian (Lower Permian)division: biostratigraphy and correlative potential. Permophiles, v. 44, p. 11–12.

Chuvashov B.I., Chernykh, V.V., Shen S.Z. and Henderson C.M., 2013. Proposal for the Global Stratotype Section and Point (GSSP) for the base-Artinskian Stage (Lower Permian). Permophiles, v. 58, p. 26–34.

Chuvashov B.I., Chernykh V.V., Davydov V.I., Shen, S.Z. and Henderson C.M., 2015. Dal'ny Tulkas section, Southern Urals. Deep water successions of the Carboniferous and Permian. A Field Guidebook of 18th International Congress on the Carboniferous and Permian. Pre-Congress A3 Trip, August, 6-10, 2015. Academy of Sciences of the Republic of Tatarstan Press, Kazan, p. 20–29.

Filimonova T.V., Isakova T.N., Sungatullina G.M., Sungatullin R.K., Chernykh V.V. and Mizens G.A., 2019. The assemblages of foraminifers in the Sakmarian-Artinskian Boundary of the section Dal'ny Tulkas, Southern Urals, Russia. In: Hartenfels S., Herbig, H.G., Amler, M.R.W. and Aretz M. (eds.). Kölner Forum Geol. Paläont., 23 (2019). Abstracts 19th International Congress on the Carboniferous and Permian, Cologne, p. 101–102.

Nurgalieva N., Gareev B. and Batalin G. 2018. Dal'ny Tulkas and Mechetlino Lower Permian Sections: Carbonate Carbon and Oxygen isotopes. In: Nurgaliev D., Barclay M., Nikolaeva S. and Silantiev V.(Eds.), Proceedings Kazan Golovkinsky Stratigraphic Meeting, 2017: Advances in Devonian, Carboniferous and Permian Research: Stratigraphy, Environments, Climate and Resources Kazan, Russian Federation, 19-23 September 2017, p. 202–205.

Schmitz M.D., Davydov V.I. and Snyder W.S., 2009. Permo-Carboniferous Conodonts and Tuffs: High precision marine Sr isotope geochronology. Permophiles, v. 53, Supplement

Appendix. Conodonts from the Dal'ny Tulkas Section (Chernykh, 2006)

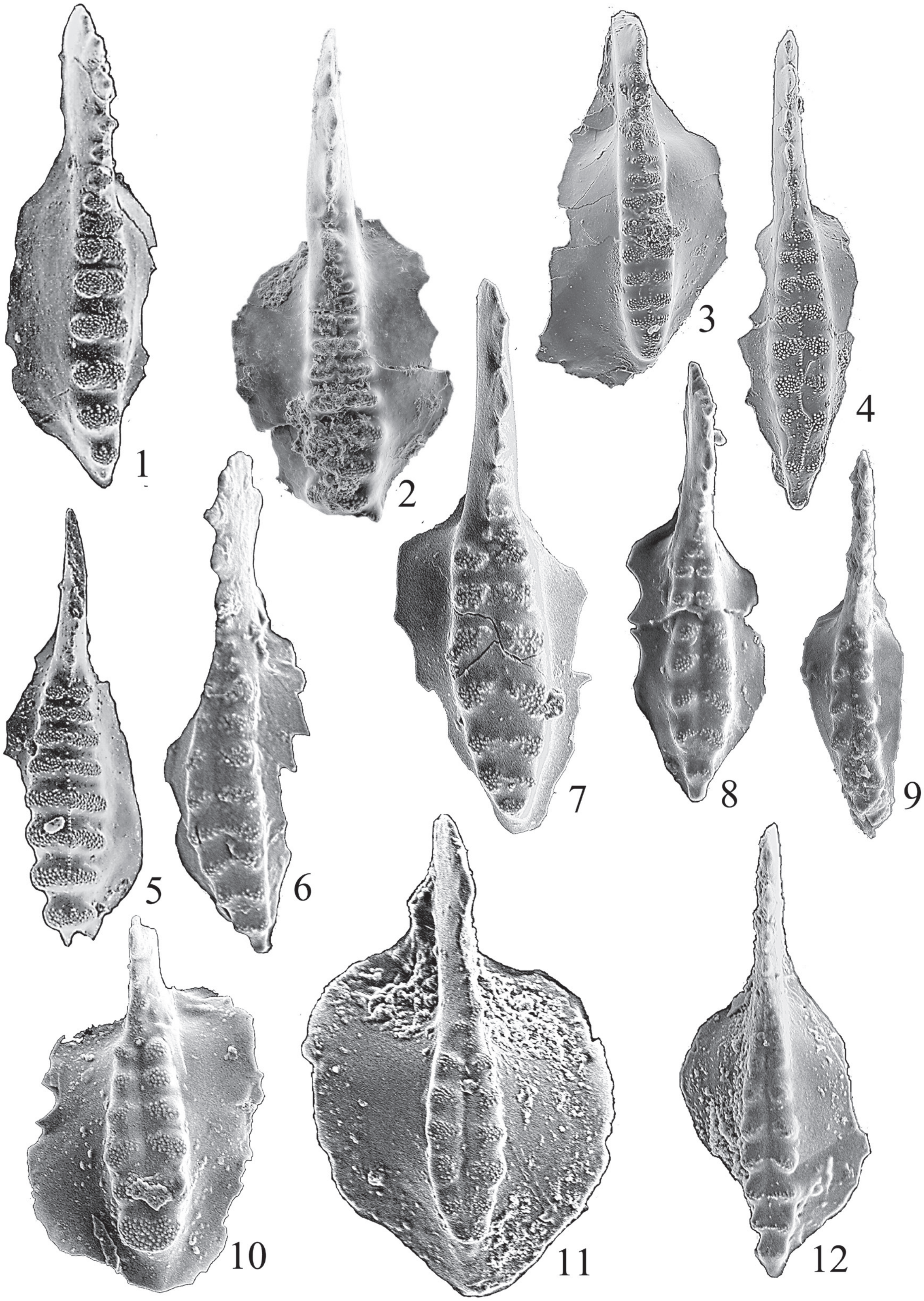

Plate I. Upper Sakmarian-lower Artinskian conodonts (x100). Fig. 1, 2. *Sweetognathus anceps* Chernykh, 2005: 1 – holotype DT-19, bed 5; lower part of Artinskian; 2 – DT-24, bed 4a; Upper Sakmarian. Fig. 3-5. *Sweetognathus whitei* (Rhodes), 1963: 3 – DT-18a, form transitional from *Sw. anceps* to *Sw. whitei*; 4 – DT-18b, typical form with the fully developed middle ridge; bed 4b; 5 – T/19-3; bed 5; lower part of Artinskian. Fig. 6-8. *Sweetognathus obliquidentatus* (Chernykh), 1990: 6 – holotype ZSP-1070/19v; 7 – DT40-3; 8 – T/19-1-5; bed 5; lower part of Artinskian. Fig. 9, 12. *Sweetognathus* aff. *ruzhencevi* (Kozur), 1976: 9 – DT40-6; 12 – DT40-13; bed 5; lower part of Artinskian,. Fig. 10, 11. *Sweetognathus graves* Chernykh, 2006: 10 – DT40-10k; 11 – holotype U40-9b; bed 5; lower part of Artinskian.

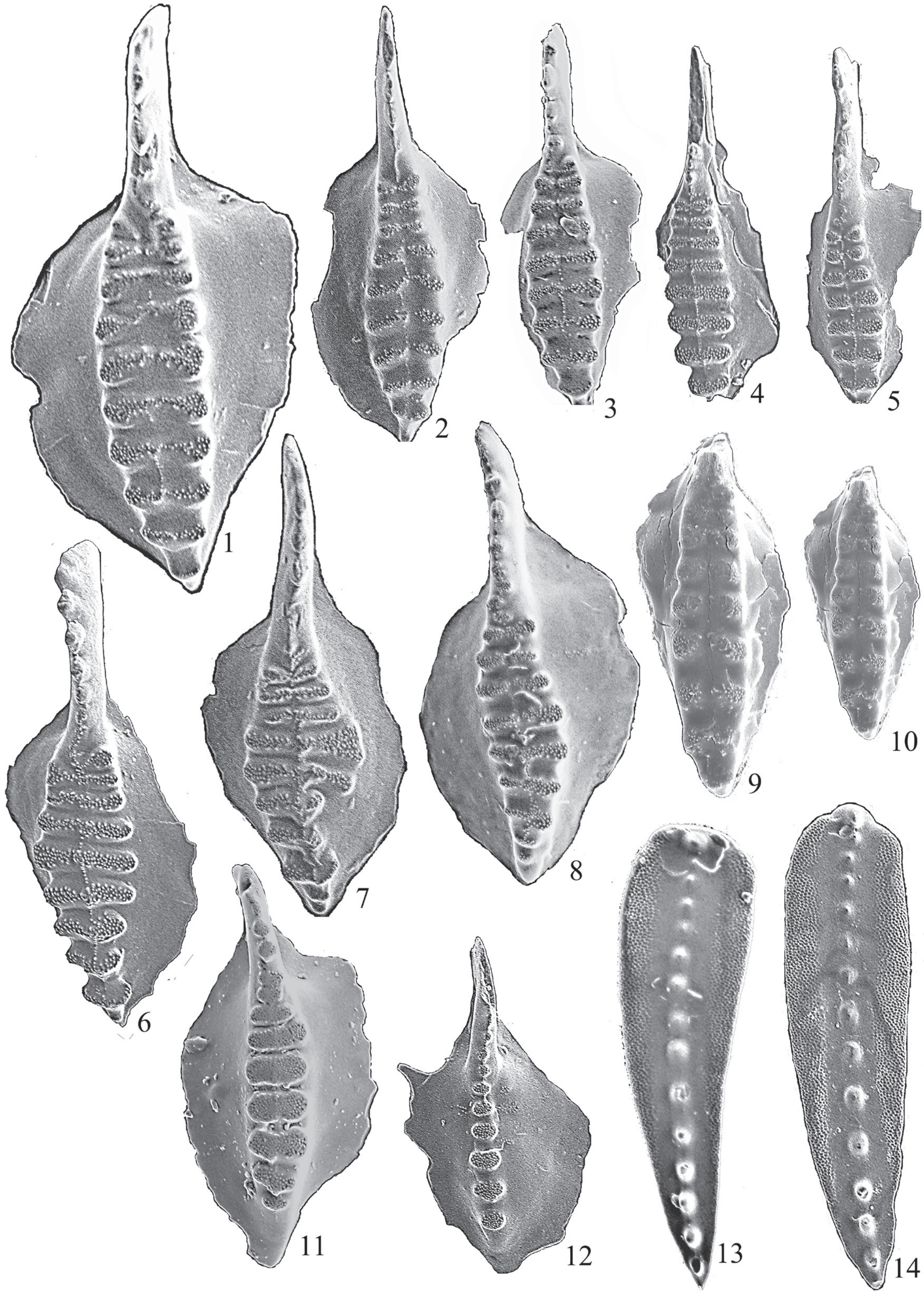

Plate II. Lower Artinskian conodonts (x 90, except specifically indicated). Fig. 1, 7, 8. *Sweetognathus* aff. *whitei* (Rhodes), 1963: 1 – DT40-27, the relicts of the longitudinal middle ridge are visible; 7 – DT40-19; 8 – DT40-21; bed 10. Fig. 2, 3. *Sweetognathus* aff. *clarki* (Kozur), 1976: 2 – DT40-18; the relicts of the longitudinal middle ridge are visible, the posterior pairs of carinal nodes are disconnected; 3 – DT40-22; bed 10. Fig. 4-6. *Sweetognathus whitei* (Rhodes), 1963: 4 – DT40-29, the partially reduced middle ridge is located above the upper surface of carinal nodes; 5 – DT40-17; the middle ridge is located lower the upper surface of carinal nodes; 6 – DT40-24; bed 10. Fig. 9, 10. *Sweetognathus clarki* (Kozur), 1976: 9 – DT40-33; 10 – DT40-32; bed 10. Fig. 11, 12. *Sweetognathus binodosus* Chernykh, 2005: 11 – DT40-23; 12 – DT40-20; bed 10. Fig. 13, 14 (x 60). *Mesogondolella laevigata* Chernykh, 2005: 13 – U40-26; 14 – holotype DT40-25; bed 10.

1 (ICOS 2009 Abstracts edited by C.M. Henderson and C. MacLean), p. 49.

Schmitz M.D. and Davydov V.I., 2012. Quantitative radiometric and biostratigraphic calibration of the Pennsylvanian–Early Permian (Cisuralian) time scale and pan-Euramerican chronostratigraphic correlation. GSA Bulletin, v. 124, p. 549–577.

Sungatullin R., Mizens G., Sungatullina G., Gareev B., and Batalin G., 2018. Geochemistry of the Lower Permian Mechetlino and Dal'ny Tulkas Sections, Southern Urals. Proceedings Kazan Golovkinsky Stratigraphic Meeting «Advances in Devonian, Carboniferous and Permian Research: Stratigraphy, Environments, Climate and Resources». Kazan, Russian Federation, 19-23 September 2017. Filodiritto Publisher, Bologna, p. 216–223.

Valery V. Chernykh, V.V. and Chuvashov B.I., 2014. Uralian stratotypes of the stage boundaries of the Lower Series of the Permian System. Permophiles, v. 59, p. 8–13.

Valery V. Chernykh, V.V. and Chuvashov B.I., 2015. Limitotypes of Lower boundary Sakmarian and Artinskian Stages on Urals. Lithosphaera, n. 1, 35–52. (In Russian)

Zeng, J., Cao, C. Q., Davydov, V. I. and Shen, S. Z., 2012. Carbon isotope chemostratigraphy and implications of paleoclimatic changes during the Cisuralian (Early Permian) in the southern Urals, Russia. Gondwana Research, v. 21, p. 601–610.

A brief account of the Mechetlino Section (Southern Urals, Russia) - potential candidate for a GSSP to define the base of the Kungurian stage in the global chronostratigraphic scale

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This information is provided to allow members of the Permian community to assess the Mechetlino section as a candidate for the GSSP of the Kungurian Stage.

The upper part of the Sarginsky horizon of the Artinskian Stage is exposed on the right bank of the Yuryuzan river, near the village of Mechetlino (South Urals, Bashkortostan) (Fig. 1). It is followed higher in the section by a thick series of carbonate-clayey deposits of the Saraninskian and Filippovskian horizons of the Kungurian Stage which contains fusulinids, ammonoids, and conodonts. The section contains numerous ash tuff layers.

This section was proposed as a stratotype for the lower boundary of the Kungurian Stage of the General Stratigraphic Scale at the beginning of this century (Chuvashov and Chernykh, 2000; Chuvashov et al., 2002).

However, much more complete material for substantiating the lower boundary of the Kungurian stage was obtained in the study of the Mechetlino quarry (Fig. 1). This quarry exposes the boundary interval of the Artinskian-Kungurian sandy-carbonate deposits in a section with total thickness of 15 meters.

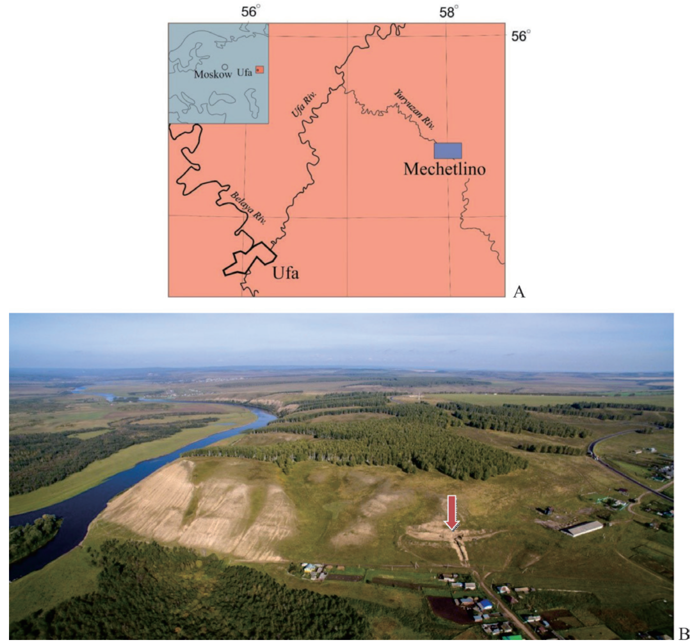

Fig. 1. Mechetlino section
A – location; B – general aerial view (the arrow shows the position of the Mechetlino quarry).

The boundary interval is represented by deposits of the Sarginskian horizon of the Artinskian Stage and the Saraninsky horizon of the Kungurian Stage. The Sarginskian horizon includes groups of argillites, organogenic detrital fine-grained limestones, marls, fine-grained calcareous sandstones, and argillites with interbeds of ash tuffs. The Saraninskian horizon is represented by a series of interbedded calcareous sandstones, argillites and marls with thin layers of detrital limestone and interbeds of ash tuffs (Fig. 2).Almost all the rocks contain a significant admixture of carbonate material and were subjected to acid disintegration for the extraction of conodonts.

Paleontological studies were carried out in the boundary Artinskian-Kungurian interval, opened in the quarry. These studies include the study of conodonts used as marker species of the boundaries of the lower Permian stages, ammonoids, foraminifera, trilobites, and fish (Chernykh, 2005, 2006, 2008, 2012a, 2018a, 2018b; Chernykh and Chuvashov, 2006; Chernykh et al., 2018a, 2018b, 2020; Chuvashov and Chernykh, 2007; Filimonova et al., 2019; Ivanov, 2016; Kotlyar et al., 2016; Isakova et al., 2018; Kutygin, 2018).

Here, detailed lithological and geochemical studies (Mizens et al., 2018; Sungatullin et al., 2018), study of strontium isotopes (Schmitz and Davydov, 2012), stable isotopes C and O (Nurgalieva et al., 2018) and magnetometric studies were also carried out (Balabanov et al., 2018, 2019).

The section was demonstrated to domestic and international specialists in 2007 (Davydov and Henderson, 2007) and in 2015 (Chernykh et al., 2015).

The Mechetlino section was further expanded by vertical walls at three levels (Fig. 6) in 2017 in connection with the creation of the Yangan-Tau Geopark. Additional samples taken for conodonts reduced the gap between conodont-bearing layers between the

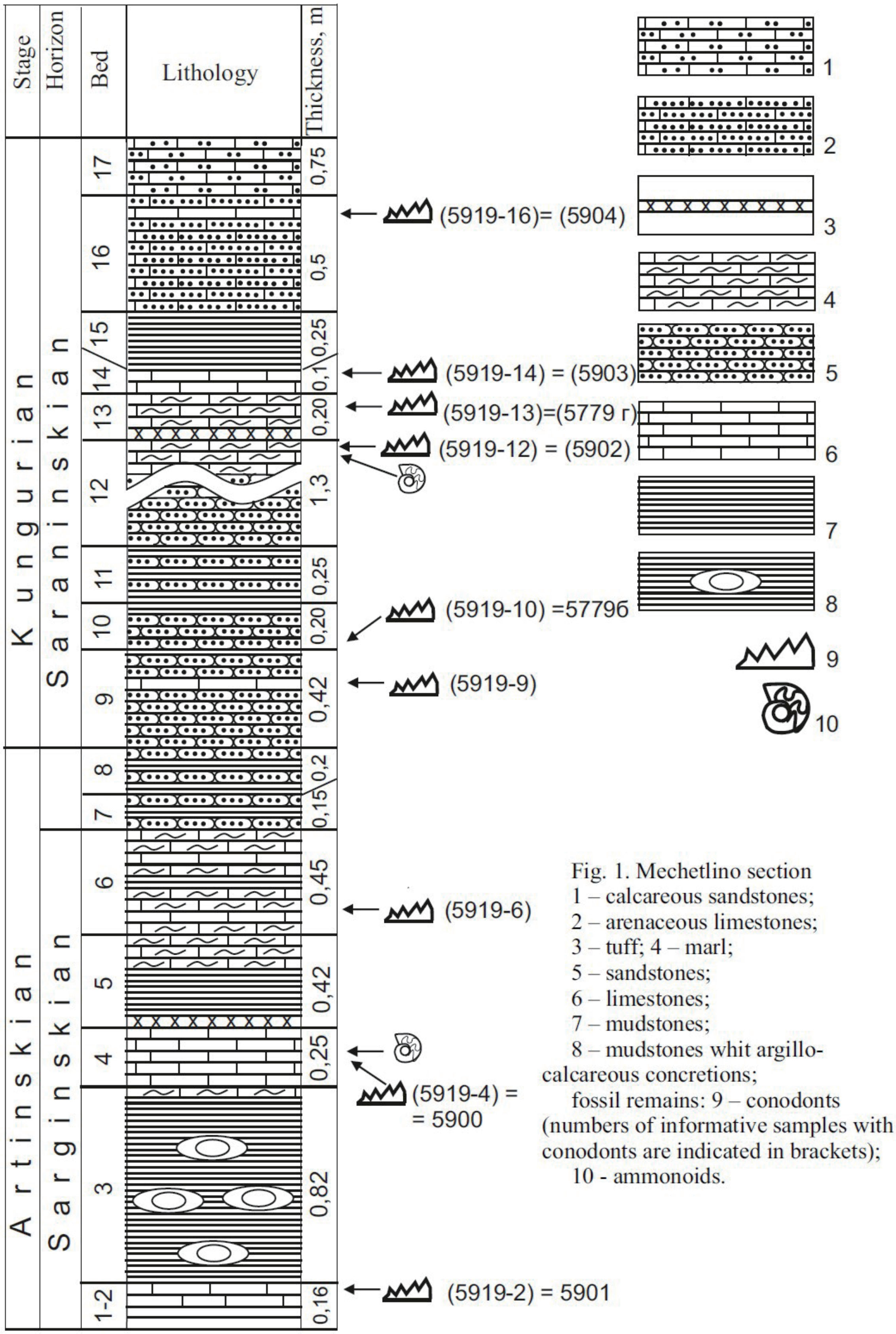

Fig. 2. Stratigraphic column with distribution of samples taken for conodonts and ammonoids.

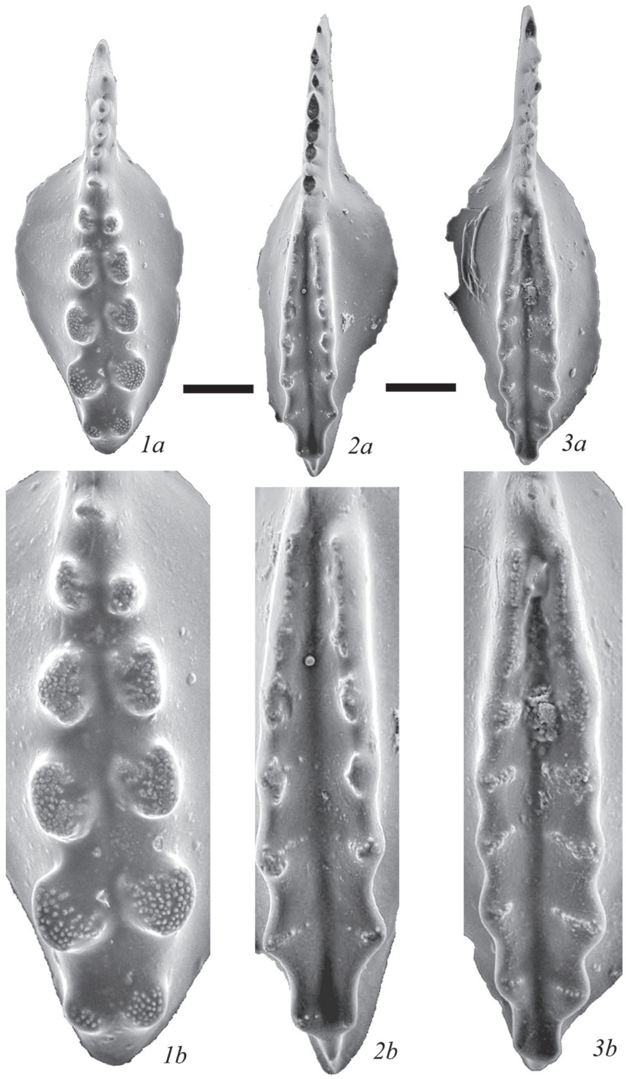

Fig. 3. The evolutionary lineage of *Neostreptognathodus pequopensis* Behnken – *N. pnevi* Kozur et Movshovitsch: 1 – *N. pequopensis,* from bed 4, Artinskian, Sarginskian horizon; 2 – transitional from *N. pequopensis* to *N. pnevi*, from bed 9; 3 - *N. pnevi*, from bed 9, Kungurian, Saraninskian horizon.

Artinskian and Kungurian to less than one meter (Fig. 2).

The Mechetlino section was proposed as a GSSP for the base of the Kungurian Stage of the International Stratigraphic Scale according to the results of the executed studies (Chuvashov and Chernykh, 2011; Chernykh et al., 2012; Chernykh et al., 2018a, 2018b, 2020).

Here are the results of the study of the Mechetlino section in light of the requirements for the section submitted to the International Commission on Stratigraphy as a GSSP for the lower boundary of the Kungurian Stage:

a) the section was formed as a result of sedimentation of marine sediments (limestones, detrital limestones, marls, mudstones with carbonate nodules, sandstones, calcareous siltstones) without significant facies change. Judging by the presence in the section of numerous transitional forms between specimens of conodonts, we can assume that there are no significant hiatuses in sedimentation;

b) the section exposes the interval from the Sarginskian horizon of the Artinskian Stage to the Saraninskian horizon of the Kungurian Stage in three vertical quarry walls (Figs. 6) with a total thickness of more than 15 m;

c) a variety of well-preserved fossils were found in the section: conodonts, foraminifera, ammonoids, brachiopods, fish, plant remains (algae, calamites). The lower boundary of the Artinskian Stage is marked by the first appearance of the cosmopolitan conodont *Neostreptognathodus pnevi* Kozur, the terminal member of the restored phyloline *Sweetognathus clarki* Kozur – *N. pequopensis* Behnken - *N. pnevi Kozur* (Fig. 3). The species *N. lectulus* Chernykh appears, similar to the species *N. pnevi*, with the reduction of the anterior parapet cusps in N. ruzhencevi Kozur (Fig. 4) at the same stratigraphic level (bed 9).

N. labialis Chernykh appears slightly higher (bed 10). Its position in the evolutionary lineage is determined (Fig. 5). A detailed description of the distribution of conodonts in the Mechetlino section and an analysis of their evolutionary transformation in the boundary Artinskian-Kungurian interval are given in publications (Chernykh, 2018a, 2018b) and are accompanied by ten tables with images of all the specimens.

d) Interbeds of ash tuffs are present in the section in the boundary Artinskian-Kungurian interval at two levels - in the lower part of bed 5 (1.5 m below the base of the Kungurian Stage), in the lower part of bed 13 (1.7 m above the base of the Kungurian Stage). These interbeds make it possible to trace the stratigraphic levels over a considerable distance.

g) The Mechetlino section has been studied by magnetostratigraphic and geochemical methods (Balabanov et al., 2018; Gunar et al., 2018; Nurgalieva et al., 2018; Sungatullin et al., 2018). The model age of the lower boundary of the Kungurian Stage was determined as 283.5 ± 0.5 million years (Schmitz and Davydov, 2012).

h) The section is one of the features of the Yangan-Tau

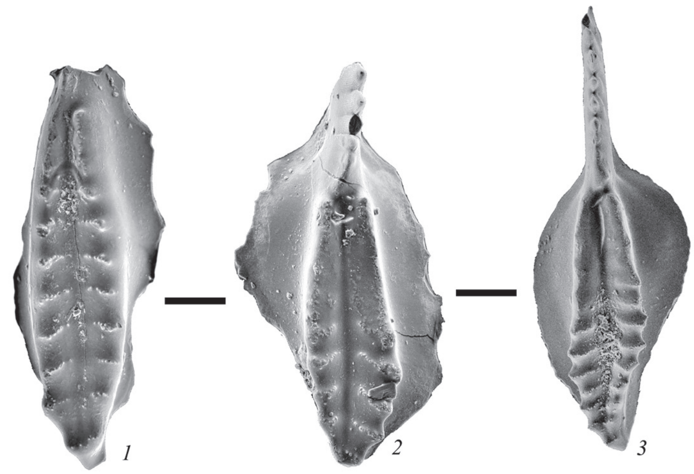

Fig. 4. The evolutionary lineage of *Neostreptognathodus ruzhencevi* Kozur – *N. lectulus* Chernykh. 1 – *N. ruzhencevi*, from bed 2, Artinskian, Sarginskian horizon; 2 – *N. lectulus*, bed 9, Kungurian, lower part of Saraninskian horizon; 3 – *N. lectulus*, bed 13, Kungurian, middle part of Saraninskian horizon.

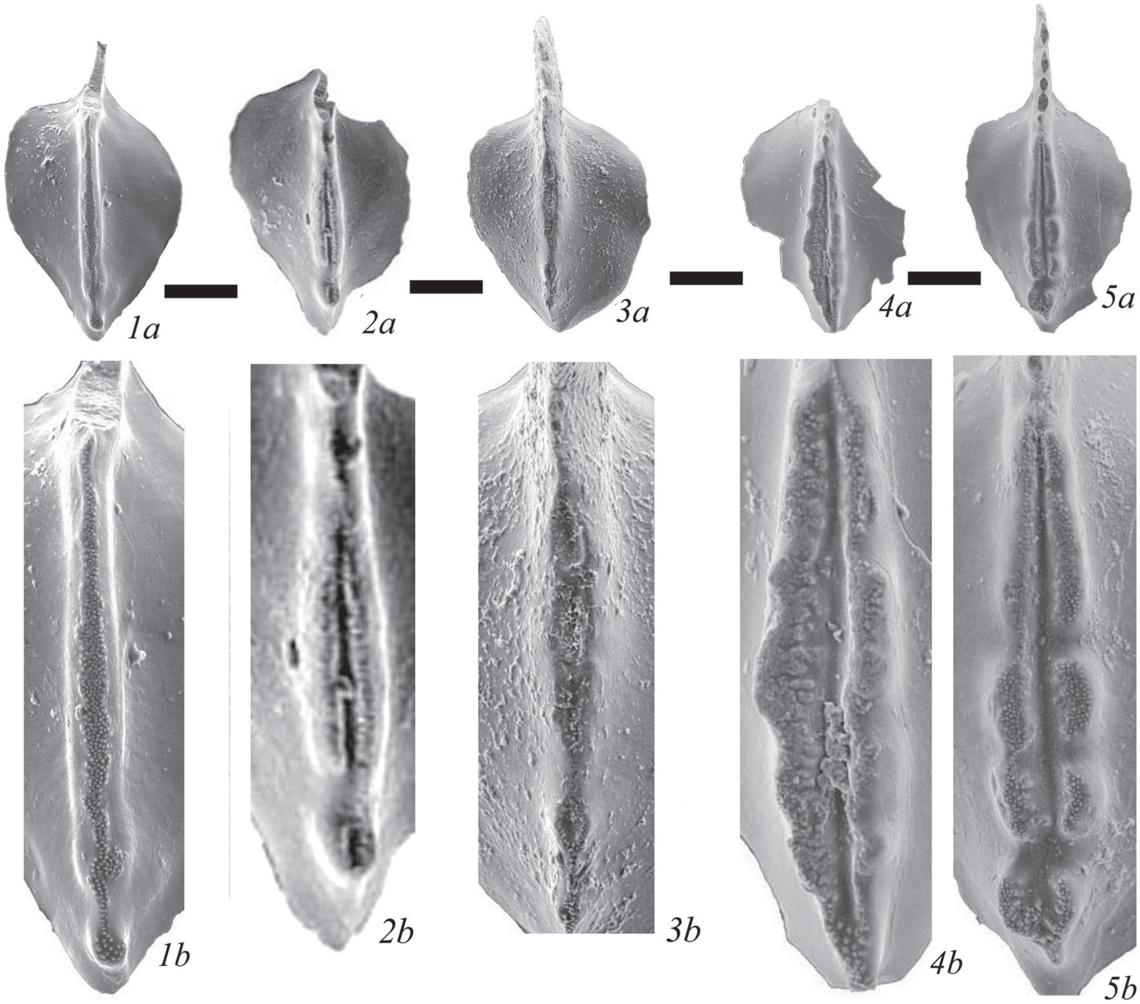

Fig. 5. The evolutionary lineage of *Sweetognqthus somniculosus* Chern. – *Neostreptognathodus pseudoclinei* Kozur et Movschovitsch – *N. labialis* Chernykh. 1 – *Sw. somniculosus*, bed 6, Artinskian, Sarginskian horizon; 2 – transitional from *Sw. somniculosus* to *N. pseudoclinei*, bed 10; 3 – *N. pseudoclinei*, bed 12; 4, 5 – *N. labialis*, bed 12, Kungurian, Saraninskian horizon.

Geological Park created in the territory of Bashkortostan. Through the efforts of the administration of the Yangan-Tau Sanatorium, the section was opened with vertical walls at three levels, the territory was cleared, and observation platforms were created (Fig. 6). It is easily accessible by bus and is under state protection.

The occurrence of conodonts (bed 9), foraminifers, and ammonoids (bed 12) in this section, makes it possible to carry out a global correlation of the base of the Kungurian Stage (Chernykh, 2003, 2012b, Chernykh et al., 2018a).

References

Balabanov, Y.P., Sungatullin, R.Kh., Sungatullina, G.M. and Kosareva, L.R., 2018. Paleomagnetic Studies of the Mechetlino Section (Southern Urals). Proceedings Kazan Golovkinsky Stratigraphic Meeting. Kazan, Russian Federation, 19-23 September 2017. Filodiritto Publisher, Bologna, p. 35–43.

Balabanov, Y.P., Sungatullin, R.Kh., Sungatullina, G.M., Kosareva, L.R., Glukhov, M.S., Yakunina, P.G., Zhernenkov, A.O., Antonenko, V.V. and Churbanov, A.A., 2019. Magnetostratigraphy of the Reference Sections of the Cisuralian Series (Permian System). Recent Advances in Rock Magnetism, Environmental Magnetism and Paleomagnetism. International Conference on Geomagnetism, Paleomagnetism and Rock Magnetism (Kazan, Russia). Cham, Springer Geophysics, Switzerland, p. 317–342.

Chernykh, V.V., 2003. Global correlation of the Artinskian and Kungurian stages by conodonts. Litosfera, v. 1, p. 64–71. (In Russian)

Chernykh, V.V., 2005. Zonal Methods in Biostratigraphy. Zonal Scale for the Lower Permian of the Urals according to conodonts. Institute of Geology and Geochemistry, Urals Branch of RAS. Ekaterinburg, 217 pp. (In Russian)

Chernykh, V.V., 2006. Lower Permian conodonts of Urals. Institute of Geology and Geochemistry, Urals Branch of RAS. Ekaterinburg, 130 pp. (In Russian)

Chernykh, V.V. 2008. Determination of the stage boundaries of the International Stratigraphic Scale for conodonts. Litosfera, v. 1, p. 3–17 (In Russian)

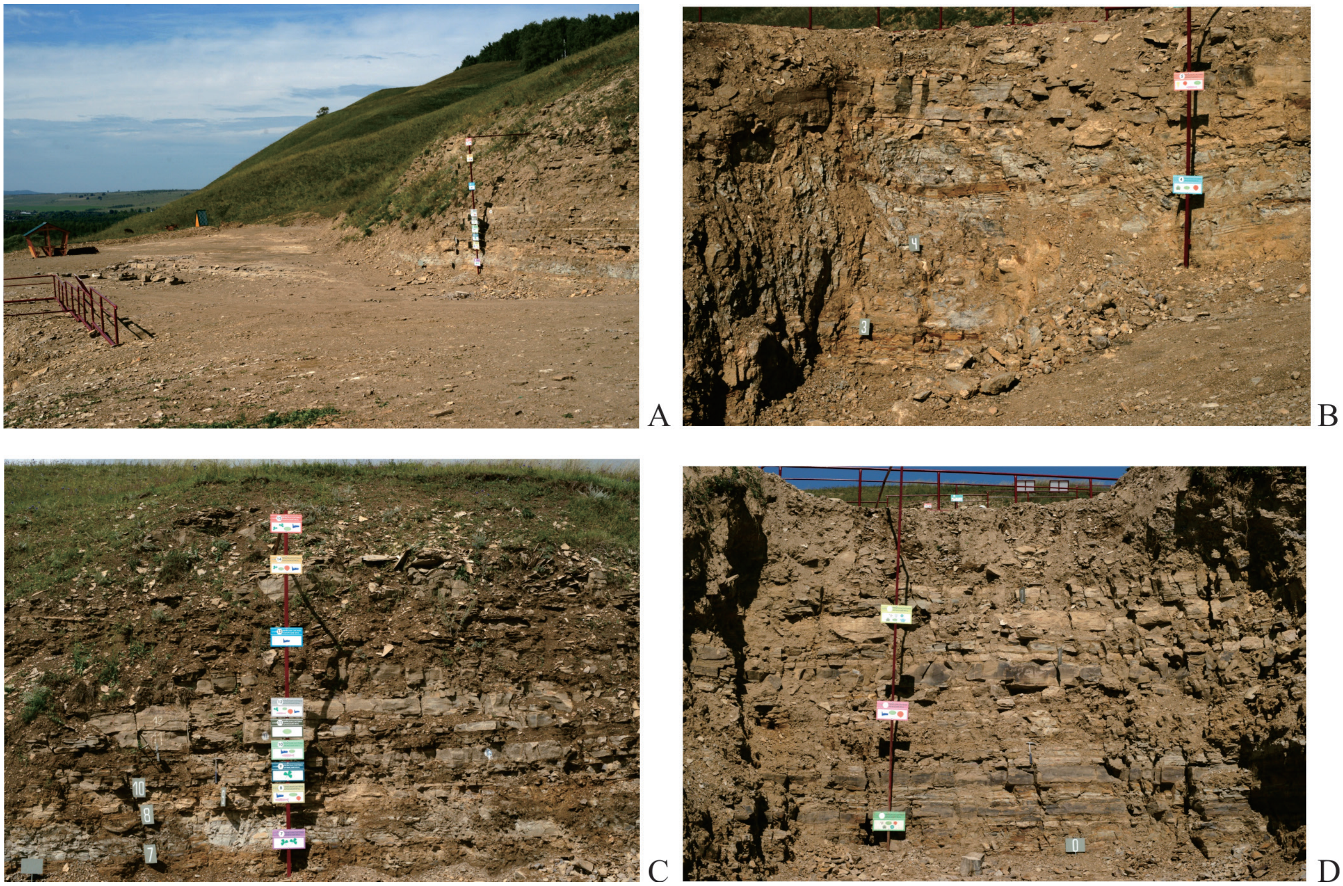

Fig. 6. Mechetlino quarry (2018): A. – upper terrace; B – vertical wall on the upper terrace (arrow indicates bed 12); C – the middle wall of quarry; D – the lower wall of quarry.

Chernykh, V.V., 2012a. Conodont biochronotypes of the lower boundary of the Kungurian Stage in the Urals. Annual -2011 (159). Institute of Geology and Geochemistry, Urals Branch of RAS, Ekaterinburg, p. 27–32 (In Russian)

Chernykh, V.V., 2012b. Correlation of the Gzhelian and Lower Permian deposits of the Urals. Litosfera, v. 4, p. 30–52. (In Russian)

Chernykh V.V., 2018a. Conodonts from the boundary Artinsko-Kungurian deposits of the Mechetlino section (Bashkortostan, South Ural). Article I. Characteristic of the conodont associations. Litosfera, v. 18, n.2, 235–245. (In Russian)

Chernykh, V.V., 2018b. Conodonts from the boundary Artinsko-Kungurian deposits of the Mechetlino section (Bashkortostan, South Ural). Article II. Stratigrafic distribution of conodonts. Litosfera, v. 18, n. 3, 363–381. (In Russian)

Chernykh, V.V. and Chuvashov, B.I., 2006. On the lower boundary of the Kungurian stage in the Mechetlino section. Yearbook-2005 of the Institute of Geology and Geochemistry, Ural Branch of the Russian Academy of Sciences. Ural Branch of the Russian Academy of Sciences, Yekaterinburg, p. 36–38. (In Russian)

Chernykh, V.V., Chuvashov, B.I., Davydov, V.I. and Schmitz, M.D., 2012. Mechetlino Section: A candidate for the Global Stratotype and Point (GSSP) of the Kungurian Stage (Cisuralian, Lower Permian). Permophiles, v. 56, p. 21–34.

Chernykh, V.V., Chuvashov, B.I., Davydov, V.I., Henderson, C.M. and Shen, S.Z., 2015. Southern Urals. Deep water successions of the Carboniferous and Permian. A Field Guidebook of XVIII International Congress on Carboniferous and Permian. Academy of Sciences of Republic of Tatarstan Press, Kazan, 88 p.

Chernykh, V.V., Kotlyar, G. V., Kutygin, R.V., Filimonova, T.V., Sungatullina, G.M., Mizens, G.A., Sungatullin, R.Kh., Isakova, T.N., Boiko, M.S., Ivanov, A.O. and Mychko, E.V., 2018a. Geological section Mechetlino (South Urals). Paleontological characteristics. Institute of Geology, UFITS RAS, Ufa. Geologicheskii Vestnik. special issue, v. 1, p. 119–137. (In Russian)

Chernykh, V.V., Kotlyar, G.V., Kutygin, R.V., Filimonova, T.V., Sungatullina, G.M., Mizens, G.A., Sungatullin, R.Kh., Isakova, T.N., Boiko, M.S., Ivanov, A.O. and Mychko, E.V., 2018b. Paleontological Characteristics of the Mechetlino Section (Southern Urals). Kazan Golovkinsky Stratigraphic Meeting, 2017: Advances in Devonian, Carboniferous and Permian Research: Stratigraphy, Environments, Climate and Resources. Filodiritto International Proceedings, p. 70–81.

Chernykh, V.V., Kotlyar, G.V., Chuvashov, B.I., Filimonova, T.V., Sungatullina, G.M., Mizens, G.A., Sungatullin, R.Kh., Isakova, T.N., Boiko, M.S., Ivanov, A.O., Nurgalieva, N.G., Balabanov, Y.P. Mychko, E.V., Gareev, B.I. and Batalin, G.A., 2020. Multidisciplinary study of the Mechetlino Quarry section (Southern Urals, Russia) — the GSSP candidate for the base of the Kungurian Stage (Lower Permian). Palaeoworld, v. 29, n. 2, p. 325–352.

Chuvashov, B.I. and Chernykh, V.V., 2000. Kungurian stage of the General Stratigraphic scale of the Permian system. Doklady Akademii Nauk, v. 375, p. 370–374.

Chuvashov, B.I. and Chernykh, V.V., 2007. Biostratigraphic and lithofacies characteristics of the boundary Artinsk-Kungurian deposits of the section Mechetlino – potential stratotype of the lower boundary Kungurian Stage of the International Stratigraphic scale. Geology of the Urals and adjacent territories. Institute of Geology and Geochemistry of the Ural Branch of the Russian Academy of Sciences, Ekaterinburg, IGG UB RAS, p. 201–218. (In Russian)

Chuvashov, B.I. and Chernykh, V.V., 2011. The Mechetlino Section (South Ural): a potential limitotype of the boundary of the Artinskian/Kungurian Stages. Doklady Akademii Nauk, v. 441, p. 657–660.

Chuvashov, B. I., Chernykh, V.V., Leven, E.Ya., Davydov, V.I., Bowring, S.A., Ramezani, J., Glenister, B. F., Henderson, Ch. M., Schiappa, T. A., Northrup, C. J., Snyder, W. S., Spinosa, C. and Wardlaw, B. R. 2002. Progress report on the base of the Artinskian and base of the Kungurian by the Cisuralian Working Group. Permophiles, 41, pp. 13–16.

Davydov, V.I. and Henderson, Ch.M. 2007. The Cisuralian Field Workshop. Permophiles, v. 49, p. 4–6.

Filimonova, T.V., Isakova, T.N., Sungatullina, G.M., Sungatullin, R.K., Chernykh, V.V. and Mizens, G.A., 2019. The assemblages of foraminifers in the Artinskian/Kungurian boundary of the Mechetlino Quarry section (geopark Yangan-Tau), Southern Urals, Russia. Abstracts 19th International Congress on the Carboniferous and Permian, Cologne, July 29 – August 2, 2019. Kölner Forum Geol. Paläont., v. 23, p. 103–104.

Isakova, T.N., Filimonova, T.V. and Kulagina, E.I., 2018. The significance of foraminifers in definition of the stage boundaries in the Permian system of the International Stratigraphic Scale at the example of the Mechetlino section. Geological bulletin, n. 1, p. 111–118. (In Russian)

Ivanov, A.O., 2016. Chondrichthyans from the Lower Permian of Mechetlino, South Urals, Russia. The Bulletin of Geosciences, v. 92, n. 4, p. 717–729.

Kotlyar, G., Sungatullina, G., Sungatullin, R., 2016. GSSPs for the Permian Cisuralian Series stages. Permophiles, v. 63, p. 32–37.

Kutygin, R. V. 2018. *Clausiuraloceras mechetlense*, new ammonoid species from Kungurian of Southern Cisuralian Region. Paleontological Journal, v. 52, n. 4, p. 365–378.

Mizens, G.A., Sungatullin, R.Kh., Sungatullina, G.M., Gareev, B.I., Batalin, G.A. and Sadriev, F.F., 2018. Reference section of Cisuralian series (Permian System): geochemical features. Litosfera, v. 18, n. 6, p. 819–838. (In Russian)

Nurgalieva, N., Gareev, B. and Batalin, G. 2018. Dal'ny Tulkas and Mechetlino Lower Permian Sections: Carbonate Carbon and Oxygen isotopes. In: Nurgaliev, D., Barclay, M., Nikolaeva, S. and Silantiev, V. (Eds.). Proceedings Kazan Golovkinsky Stratigraphic Meeting, 2017: Advances in Devonian, Carboniferous and Permian Research: Stratigraphy, Environments, Climate and Resources Kazan, Russian Federation, 19-23 September 2017, p. 202–205.

Schmitz, M.D. and Davydov, V.I., 2012. Quantitative radiometric and biostratigraphic calibration of the Pennsylvanian–Early Permian (Cisuralian) time scale and pan-Euramerican chronostratigraphic correlation. GSA Bulletin, v. 124, no. 3/4, p. 549–577.

Sungatullin, Rafael, Mizens, Gunar, Sungatullina, Guzal, Gareev and Bulat, Batalin, 2018. Georgii Geochemistry of the Lower Permian Mechetlino and Dal'ny Tulkas Sections, Southern Urals. Proceedings Kazan Golovkinsky Stratigraphic Meeting «Advances in Devonian, Carboniferous and Permian Research: Stratigraphy, Environments, Climate and Resources». Filodiritto Publisher, Bologna, p. 216–223.

Appendix. Conodonts from the Mechetlino Section

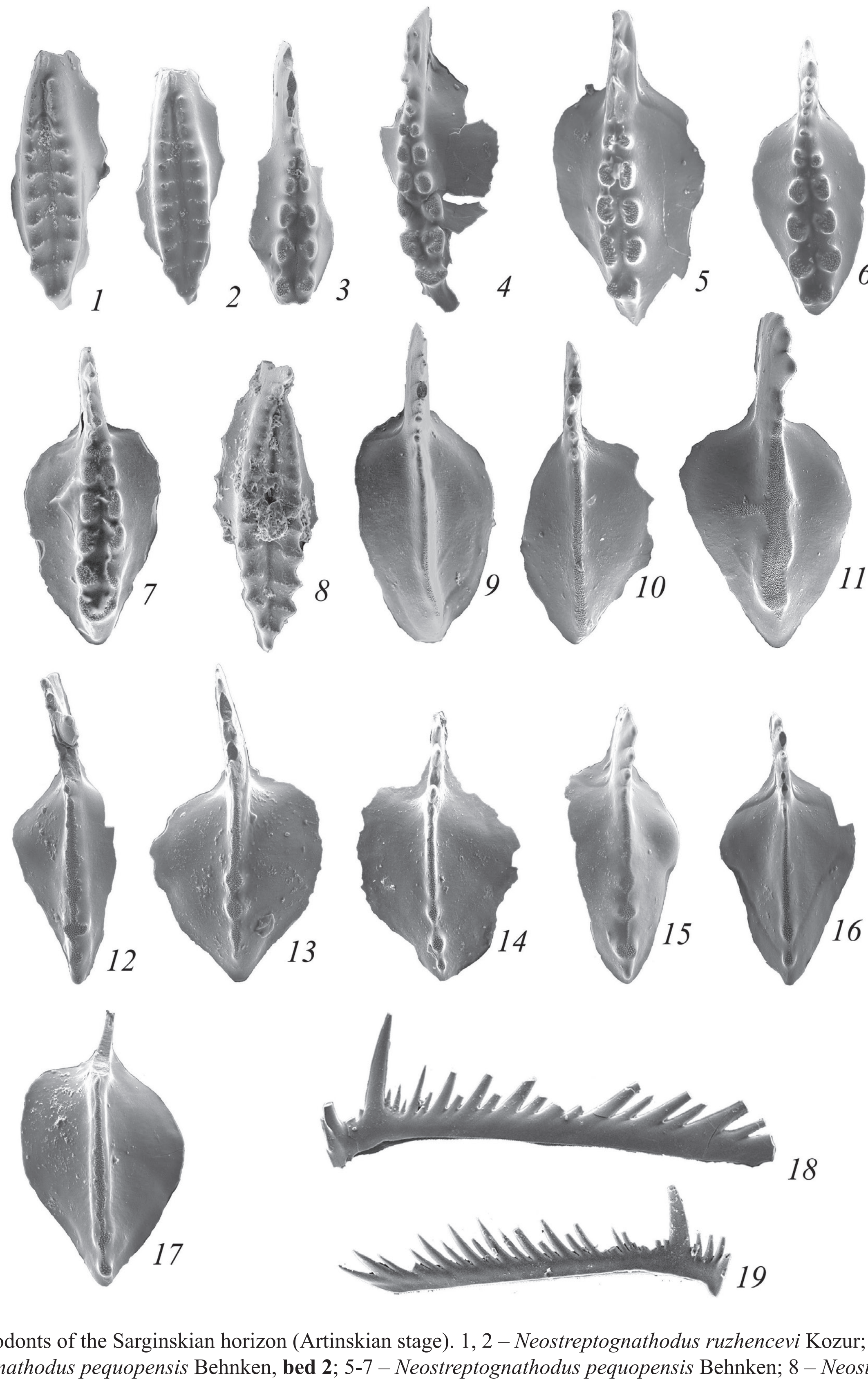

Plate I. Conodonts of the Sarginskian horizon (Artinskian stage). 1, 2 – *Neostreptognathodus ruzhencevi* Kozur; 3, 4. *Neostreptognathodus pequopensis* Behnken, **bed 2**; 5-7 – *Neostreptognathodus pequopensis* Behnken; 8 – *Neostreptognathodus ruzhencevi* Kozur; 9-16. *Sweetognathus somniculosus* Chernykh; 18, 19. Sc-элемент (Sc-element), **bed 4**;17. *Sweetognathus somniculosus* Chernykh, **bed 6**.

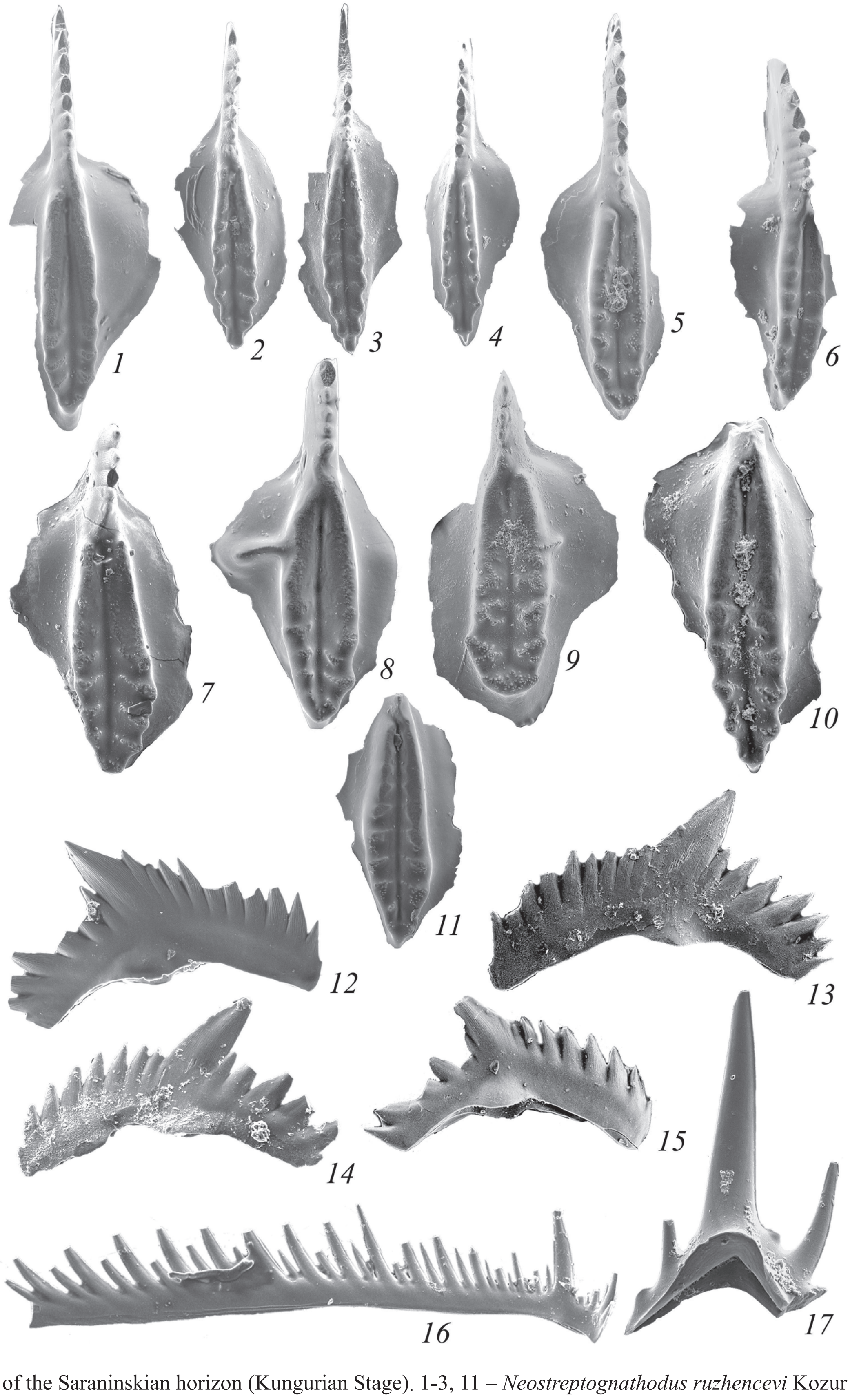

Plate II. Conodonts of the Saraninskian horizon (Kungurian Stage). 1-3, 11 – *Neostreptognathodus ruzhencevi* Kozur transitional from *N. ruzhencevi* Kozur to *N. lectulus* Chernykh; 4-6 – *N. pequopensis* Behnken transitional from *N. pequopensis* Behnken to *N. pnevi* Kozur et Movschovitsch; 7, 8 – *N. lectulus* Chernykh; 9 - *N.* aff. *lectulus* Chernykh; 10 – *N. pnevi* Kozur et Movschovitsch; 13-15 – Pb-element; 16 – Sc-element; 17 – M-element. **Bed 9**.

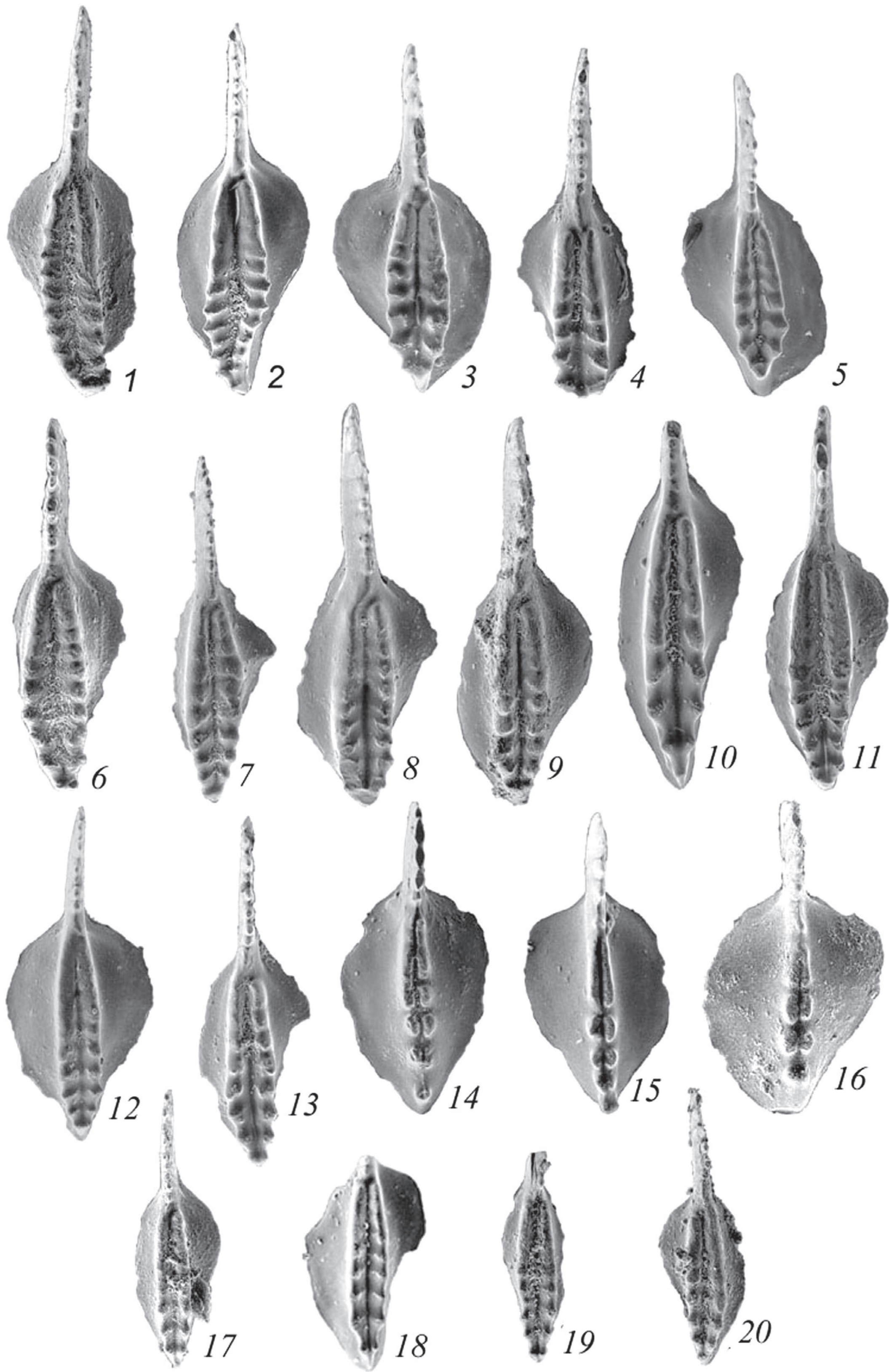

Plate III. Conodonts of the Saraninskian horizon (Kungurian Stage). 1-8 – *Neostreptognathodus lectulus* Chernykh; 9-13 – *N. pnevi* Kozur et Movschovitsch; 14-16 – *N. labialis* Chernykh; 17-20 – *N. pnevi* Kozur et Movschovitsch (juvenile forms). **Bed 13.**

Henderson's Harangue #7

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To be or not to be *Sweetognathus whitei*?

Introduction

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

"To be, or not to be, that is the question, whether 'tis nobler in the mind to suffer the slings and arrows of outrageous fortune, or to take Arms against a Sea of troubles, and by opposing them, end them..." (from William Shakespeare's Hamlet).

I will keep this harangue short. My article elsewhere in this issue (Are we ready yet to propose a GSSP for base-Artinskian and base-Kungurian?) tells the outrageous fortune of two forms of *Sweetognathus whitei*. One is from the late Asselian and it is the real one, but many claim it to be much younger. The other is from the early Artinskian and it is a noble homeomorph, but in truth it can be distinguished and now goes by the name *Sweetognathus asymmetricus*. If the latter can swim against its Sea of troubles, it will become the defining species for the base-Artinskian GSSP.

The *Sweetognathus* lineage first appears in Bolivia and the mid-continent USA near the Carboniferous-Permian boundary. Early forms, including *Sweetognathus merrilli* and *Sweetognathus whitei*, lived during the late Paleozoic Ice Age (LPIA), and as such are found in cyclothems, generated by the fate of sea level as great continental ice-sheets waxed and waned. These early species are not globally distributed, but they occur in association with a fast evolving genus called *Streptognathodus*. With the termination of the LPIA (P1 event) at the very end of the Asselian, we see a great wave of sea-level rise and the global migration of a new lineage including *Sweetognathus binodosus*, *Sw. anceps* and *Sw. asymmetricus*. These species are not associated with the high-frequency fluctuations related to glacial eustacy, but rather in longer duration 3rd order sequences after the ice age. By the time *Sweetognathus asymmetricus* evolved, the once great *Streptognathodus* had become extinct. Thus, we have two *Sweetognathus whitei.* One suffers the slings and arrows of an ice age accompanied by *Streptognathodus* and another, occurs much higher in the stratigraphy, well after the ice age, and without its former companion.

Conclusion

Allow me to conclude this harangue. "A rose by any other name would smell as sweet…" (from William Shakespeare's Romeo and Juliet). But a conodont by a different name might smell more like an aringa or herring – it certainly tells a different story. You can oppose my taxonomy: after all, the fate of many paleontologists is to disagree. But please don't ignore the rocks as I indicated in my very first Permophiles harangue (#63). Studying the sequence stratigraphy provides a test for our biostratigraphy. Sequence biostratigraphy shows us that *Sweetognathus whitei* and *Sweetognathus asymmetricus* were strangers in the Seas of climate change, with their origins separated by 4.4 million years.

Are we ready yet to propose a GSSP for base-Artinskian and base-Kungurian?

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Introduction

The short answer is "Yes, almost". There are a few things to work out and consider, but in general, the proposals for a point in Dalny Tulkas section for the base-Artinskian and for a point in Mechetlino section for base-Kungurian are ready to go. Most of my discussion below will relate to the Artinskian, but I will also remark briefly on the Kungurian. I apologize that there is a lot of discussion on conodonts below, but please read on.

Base-Artinskian GSSP

Proximity to the base of the Artinskian stage is obvious in a well exposed section because the lithofacies will display a retrogradational succession. In the Canadian Arctic, the base-Artinskian coincides with the FO (local first occurrence) of *Sweetognathus asymmetricus* (not *Sw. whitei* – more on that below) and the maximum flooding surface of an upper Sakmarian to Artinskian depositional sequence (Chernykh et al., 2020; Beauchamp et al. in press for 2020). The proposed point at the base of Bed 4b at Dalny Tulkas is in a carbonate mudstone with calcareous concretions. This "bed" occurs about 2.5 metres above a clayey siltstone and very fine-grained sandstone with non-calcareous algae and terrestrial plant detritus; the top of this sandstone would mark a sequence boundary. *Sweetognathus asymmetricus* first occurs in similar transgressive facies in the Raanes Formation of the Canadian Arctic (Beauchamp and Henderson, 1994), in the Buckskin Mountain (Fig. 1.1) and Pequop formations of Nevada, and in the Chihsia Formation of South China (Henderson, 2018).

In addition, to sequence stratigraphy there are many other correlation tools and they are discussed in several papers (see Chuvashov et al., 2013 and Chernykh in this issue). These include fusulinaceans, strontium and carbon isotopes and geochronology. Schmitz and Davydov (2012) dated an ash-bed immediately above the sequence boundary at 290.8 Ma and interpolated a 290.1 Ma age for the FAD (first appearance datum) of *Sweetognathus whitei* (later *Sw.* aff. *whitei*, and now *Sw. asymmetricus*) a few metres higher. The current Geologic Time Scale book (Henderson and Shen in Gradstein et al., 2020) interpolates an age of 290.5 Ma.

The speciation of conodonts around this level provides an excellent datum for the base of the Artinskian. The only issues are about the name and the correlation implications, if workers persist in calling it *Sw. whitei*. I have presented this problem in Permophiles previously and I have discussed this issue in a biostratigraphic synthesis on the Permian (Henderson, 2018). I

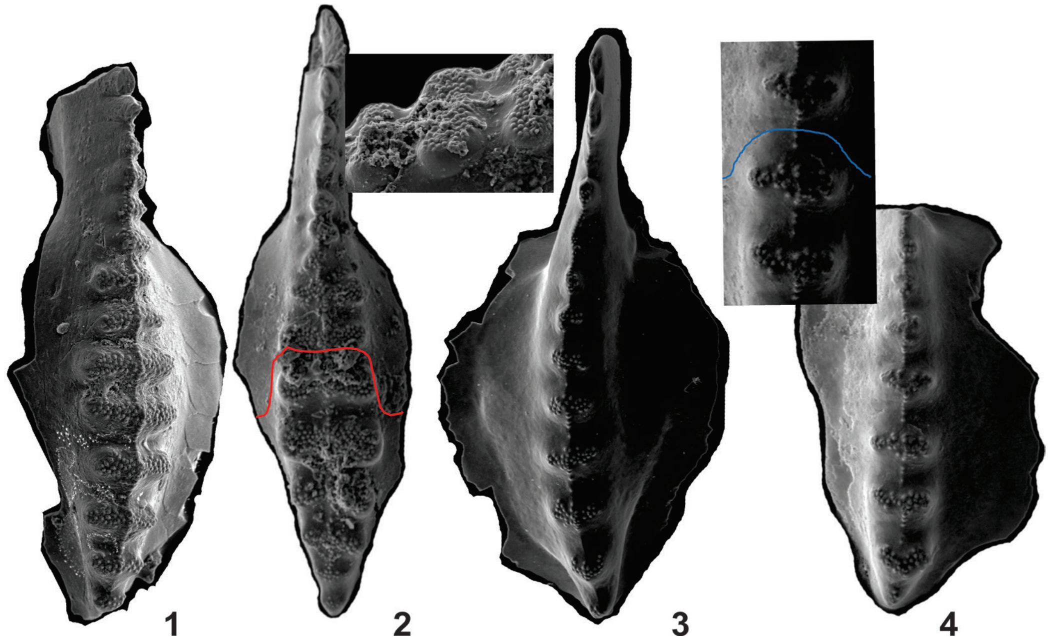

Fig. 1. Specimens of *Sweetognathus asymmetricus* (lower Artinskian) and *Sw. whitei* (upper Asselian). Specimens 2 and 3 are about 1 mm long. 1. *Sweetognathus asymmetricus* (oblique upper view), Buckskin Mountain Fm. Carlin Canyon, Nevada 1352-4 (706). 2. *Sweetognathus asymmetricus* (upper view), Bed 4b Dalny Tulkas section (GSSP level for base Artinskian. Red line shows the shape of the platform carinal area. Close-up inset shows the very regular distribution of pustulose microornament. 3. *Sweetognathus whitei* (upper view), topotype material from Rhodes 1963 locality 4. *Sweetognathus whitei* (upper view), topotype material from Rhodes 1963 locality. Close-up inset shows irregular distribution of pustulose microornament and blue line shows shape of the platform carinal area.

am presenting a talk at the GSA online meeting this year (October 26) on the topic and my student Wyatt Petryshen as well as Emilia Jarochowska and Kenneth de Baets have a paper in revision (Petryshen et al., accepted pending edits) that focusses on this topic; Wyatt is also giving a poster (October 27) at GSA online. *Sweetognathus whitei* (Rhodes, 1963) was originally recovered from a carbonate unit immediately above the Tensleep Sandstone along the Slip Road near Mayoworth, Wyoming (Fig. 1.3, 1.4). I have lots of this topotype material. It was Heinz Kozur during a meeting in Albuquerque who said I should collect this material since I lived close the locality; it is exactly 1220 km from my home actually. He said he thought that the material illustrated by Rhodes (1963) differed from the *Sweetognathus whitei* everyone was correlating with the base-Artinskian, but he didn't know how they differed. He was right!

Sweetognathus whitei has also been recovered from the Florence Limestone of the Barneston Formation (cyclothem) in Kansas; I also have material from this level courtesy of Brad Cramer. The Wyoming and Kansas material are both associated with abundant specimens of *Streptognathodus* spp. (95% of the specimens at type locality; less than 5% of specimens are of *Sweetognathus*) and are found within high-frequency cyclothem successions generated by glacial eustacy during the P1 phase of the late Paleozoic Ice Age (LPIA). The other *Sweetognathus* sp. that I now refer to as *Sw. asymmetricus* (Sun et al., 2017) occurs in many localities around the world within transgressive facies of a major 3rd order depositional sequence that occurs well above the cyclothemic succession. *Sweetognathus asymmetricus* never occurs with *Streptognathodus* because that Carboniferous holdover genus became extinct in the Sakmarian. More importantly, these two forms are actually poor homeomorphs, since the morphology is actually quite different when you look carefully. The upper platform with the dumbbell shaped transverse nodes or ridges is sloped and rounded in *Sweetognathus whitei* (Fig. 1.3, 1.4). This rounded slope means that the pustulose microornament that characterize this genus is irregular in distribution and migrates down the transverse nodes. The upper platform with the dumbbell shaped transverse nodes or ridges is steep and flat in *Sweetognathus asymmetricus* (Fig. 1.1, 1.2). The steep margins result in a regular distribution of pustules confined to the upper surface of the transverse nodes.

Some colleagues do not think that the form named *Sweetognathus asymmetricus* by Sun et al. (2017) from the lower Chihsia at the Tieqiao section is the same form found in transgressive Artinskian facies elsewhere. Wang Cheng-yuan et al. (1987) distinguished a new form that they called *Sw. subsymmetricus* (from the Kufeng near Nanjing) and restricted *Sweetognathus whitei* to specimens found in beds 18-22 of the lower Chihsia at Tieqiao. Wang et al. (1987) suggested that the anterior transverse ridges are asymmetric across a central longitudinal ridge in *Sw. subsymmetricus*. Sun et al. (2017; in a paper I reviewed) named a new species *Sw. asymmetricus* and indicated it was found in association with *Sw. whitei* in the same beds (beds 18-24) at Tieqiao as mentioned by Wang et al. (1987). They indicated that *Sw. asymmetricus* differs from the similar *Sw. subsymmetricus* by having a shorter blade, more expanded basal cavity, wider carinal nodes or transverse ridges, and increased spacing of posterior transverse ridges. The specimens they referred to *Sw. whitei* had symmetric anterior nodes, but these forms with the high steep margined platforms are not *Sw. whitei.* Therefore, *Sweetognathus asymmetricus* includes a population that includes forms with both symmetric and asymmetric anterior nodes, in which the pustulose microornament is regular and confined to the upper surface. I note in my studies that both the symmetric and asymmetric forms of *Sw. asymmetricus* are present at the FAD in Russia, and at the FO in the Canadian Arctic and in Nevada. This is not a concern for most regions because the younger *Sw. subsymmetricus* is restricted to the Tethys and is only common in South China (Mei et al., 2002).

Resolving this issue is more important than just changing the name. As a result, the persistent reference to *Sweetognathus whitei* with the base of the Artinskian, means that the community has correlated two points that are separated by 4.4 Myrs. This suggests that cyclothems during LPIA P1 extend into the Artinskian (Barneston unit and above; Boardman et al., 2009). This would mean that the genus *Streptognathodus continues* in great numbers in the midcontinent USA Artinskian succession, when everywhere else, it becomes extinct during the Sakmarian. This would mean that a major pCO2 perturbation in north-central Texas related to the end of the LPIA is correlated with the late Sakmarian and early Artinskian (Holterhoff et al., 2013; Montanez et al., 2017). However, all of these events are associated with *Sw. whitei* and they are late Asselian events. *Sweetognathus whitei* is late Asselian! This is supported by astronomical tuning (see Henderson, 2018; note that the base-Sakmarian should be 293.5 Ma as ratified earlier this year) and by unpublished geochronologic data from Bolivia (Henderson et al., 2009). However, there are no cyclothems and no *Streptognathodus* associated with *Sweetognathus asymmetricus*, because it is Artinskian.

Finally, I have material from the GSSP bed 4b at Dalny Tulkas and can confirm the occurrence of *Sw. asymmetricus* in that sample (Fig. 1.2). Interestingly, the dominant form in that sample is *Sw. obliquidentatus.*

Base-Kungurian GSSP

Henderson et al. (2012) clearly demonstrated that there are two potential and accessible GSSP sections based on the exact same point, the FAD of *Neostreptognathodus pnevi* in a lineage with *N. pequopensis* as the ancestor. The first is at the Mechetlino section in Russia (Chernykh et al., 2012) and the second is at the Rockland section in Nevada (Henderson et al., 2012). The Mechetlino section was initially favoured because of the ash-beds in the section, but unfortunately the zircons all seem to be detrital. Ammonoids, fusulinaceans, carbon isotopes and strontium isotopes provide other means for potential correlation, but nothing stands out as especially definitive. The Kungurian is a problematic interval given the relative lowstand of sea-level and marked provincialism. The FAD of *N. pnevi* will serve as a good reference with high-resolution correlations achievable from the Uralian Basin to the Sverdrup Basin in the Canadian Arctic (Mei et al., 2002) to the Rockland section in Nevada. Unfortunately, this species is not present in South China, where fusulinaceans also differ by provincialism. It is likely there is not a definition that will provide a truly global signature. Chernykh et al. (2019) report considerable additional work at the Mechetlino section.

Conclusions

The base-Artinskian proposal for the GSSP at bed 4b at Dalny Tulkas is ready to proceed so long as we use the FAD of *Sweetognathus asymmetricus*. This level is readily recognizable in many regions because it occurs above a sequence boundary and within transgressive facies. It is critical that we resolve this GSSP, as defined, so that we can resolve the timing of the end of the LPIA and distinguish events that occurred in latest Asselian from those in the Artinskian. The Asselian is a time of ice ages and cyclothems, the Sakmarian is in transition, and the Artinskian is fully post ice-age.

It is probably time to make a compromise regarding the Kungurian. Given the historical importance and priority of the Kungurian to Russia, a reasonable compromise would be to set the GSSP at Mechetlino and make Rockland a supplementary reference section. The main question is whether we have enough additional data with strong correlation potential to ratify this choice. These proposals are scrutinized carefully by ICS and also by IUGS. I think it is important to make the choice so that we can focus more research on the entire Kungurian. This is an interval of lowstand, increased aridity, significant provincialism, major changes to terrestrial flora and fauna and is therefore an interval worth intensive research. The GSSP process has served us well to provide a refined Geologic Time Scale that can be correlated globally (more-or-less), but it has also meant that most of the research over the past couple of decades has focused on boundaries and not an entire stage. The same is true of the Artinskian, which is best known at the base and at the top. It is time to complete the Permian stage boundaries and then focus more on the entire Permian including correlation of the marine and terrestrial realms.

References

Beauchamp, B., Calvo Gonzalez, D., Henderson, C.M., Baranova, D.V., Wang, H.Y., and Pelletier, E. in press for 2020. Late Pennsylvanian–early Permian tectonically-driven stratigraphic sequences and carbonate sedimentation along northern margin of Sverdrup Basin (Otto Fiord Depression), Arctic Canada. In Henderson, C.M., Ritter, S., and Snyder, W.S. (eds.), Late Paleozoic Tectonostratigraphy and Biostratigraphy of western Pangea. SEPM Special Publication No. 113. doi: 10.2110/sepmsp.113.

Beauchamp, B., and Henderson, C. M., 1994. The Lower Permian Raanes, Great Bear Cape and Trappers Cove formations, Sverdrup Basin, Canadian Arctic: stratigraphy and conodont zonation: Bulletin of Canadian Petroleum Geology, v. 42, p. 562–597.

Boardman, D.R., Wardlaw, B.R. and Nestell, M.K. 2009. Stratigraphy and conodont biostratigraphy of uppermost Carboniferous and Lower Permian from North American Midcontinent. Kansas Geological Survey Bulletin, v. 255, 253 pp.

Chernykh, V.V., Chuvashov, B.I., Davydov, V.I., and Schmitz, M.D., 2012. Mechetlino Section a candidate for the Global Stratotype [Section] and point (GSSP) of the Kungurian Stage

(Cisuralian, Lower Permian): Permophiles, v. 56, p. 21–34.

Chernykh, V.V., Chuvashov, B.I., Shen, S., Henderson, C.M., Yuan, D.X., and Stephenson, M.H., 2020. The Global Stratotype Section and Point (GSSP) for the base-Sakmarian Stage (Cisuralian, Lower Permian): Episodes. https://doi.org/10.18814/epiiugs/2020/020059.

Chernykh, V.V., Galina V. Kotlyar, Boris I. Chuvashov, Tatiana V. Filimonova, Guzal M. Sungatullina, Gunar A. Mizens, Rafael Kh. Sungatullin, Tatiana N. Isakova, Maxim S. Boiko, Alexander O. Ivanov, Nuriia G. Nurgalieva, Yury P. Balabanov, Eduard V. Mychko, Bulat I. Gareev, and Georgii A. Batalin, 2019. Multidisciplinary study of the Mechetlino Quarry section (Southern Urals, Russia) — the GSSP candidate for the base of the Kungurian Stage (Lower Permian) / Palaeoworld Available online 1 June 2019.

Chuvashov, B.I., Chernykh, V.V., Shen, S., and Henderson, C.M., 2013. Proposal for the Global Stratotype Section and Point (GSSP) for the base-Artinskian Stage (Lower Permian): Permophiles, v. 58, p. 26–34.

Henderson, C.M., 2018. Permian conodont biostratigraphy. In Lucas, S.G. and Shen S.Z. (eds) The Permian Timescale. Geological Society, London, Special Publication 450, p. 119–142.

Henderson, C.M. and Shen, S.Z., in press 2020. Chapter 24-The Permian Period, in F.M. Gradstein, J.G. Ogg, M.D. Schmitz, and G.M. Ogg, eds., The Geologic Time Scale 2020. v. 2. Elsevier.

Henderson, C.M., Schmitz, M., Crowley, J., and Davydov, V.I., 2009. Evolution and geochronology of the *Sweetognathus* lineage from Bolivia and the Urals of Russia: Biostratigraphic problems and implications for Global Stratotype Section and Point (GSSP) definition. Permophiles (ICOS Abstracts), 2009 June, v. 53, supplement 1, p. 19.

Henderson, C.M., Wardlaw, B.R., Davydov, V.I., Schmitz, M.D., Schiappa, T.A., Tierney, K.E., and Shen, S.Z., 2012. Proposal for the base-Kungurian GSSP. Permophiles, v. 56, p. 8–21.

Holterhoff, P.F., Walsh, T.R. and Barrick, J.E., 2013. Artinskian (Early Permian) conodonts from the Elm Creek Limestone, a heterozoan carbonate sequence on the eastern shelf of the Midland Basin, West Texas, USA. In: Lucas, S.G., Nelson, W.J. et al. The Carboniferous–Permian Transition. New Mexico Museum of Natural History and Science Bulletin, v. 60, p. 109–119.

Mei, S., Henderson, C.M., and Wardlaw, B.R., 2002. Evolution and distribution of the conodonts *Sweetognathus* and *Iranognathus* and related genera during the Permian and their implications for climate change: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 180, p. 57–91.

Montañez, I.P., Tabor, N.J., Niemeier, D., DiMichele, W.A., Frank, T.D., Fielding, C.R., Isbell, J.L., Birgenheier, L.P., and Rygel, M.C., 2007. CO2-forced climate and vegetation instability during Late Paleozoic deglaciation. Science, v. 315, p. 87–91.

Petryshen, W., Henderson, C.M., de Baets, K., and Jarochowska, E., accepted pending edits 2020. Evidence of parallel evolution in the dental elements of *Sweetognathus* conodonts. Proceedings of the Royal Society B.

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

Schmitz, M.D., and Davydov, V.I., 2012. Quantitative radiometric and biostratigraphic calibration of the Pennsylvanian-Early Permian (Cisuralian) time scale and pan-Euramerican chronostratigraphic correlation: Geological Society of America Bulletin, v. 124, p. 549–577.

Sun, Y.D., Liu, X.T., Yan, J.X., Li, B., Chen, B., Bond, D.P.G., et al., 2017. Permian (Artinskian to Wuchiapingian) conodont biostratigraphy in the Tieqiao section, Laibin area, South China. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 465, p. 42–63.

Wang C.Y., Ritter S.M., and Clark D.L., 1987. The *Sweetognathus* complex in the Permian of China: implications for evolution and homeomorphy. Journal of Paleontology. v. 61 (5), p. 1047–1057.

Tetrapod biostratigraphy and the Permian-Triassic boundary

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Introduction

For about one century, vertebrate paleontologists equated the lowest occurrence (LO) of the dicynodont Lystrosaurus to the base of the Triassic (Fig. 1). This correlation was first developed in the Karoo basin of South Africa. But, it is now clear in the Karoo basin that the base of the Triassic is stratigraphically higher than the *Lystrosaurus* LO and also above the base of the traditional *Lystrosaurus* assemblage zone (e.g., Gastaldo et al., 2015, 2019a, b, 2020). Here, I first review some history to understand how the LO of *Lystrosaurus* came to be identified as the base of the Triassic. Then, I discuss relatively recent developments that have changed that long held conclusion. I end by discussing the way forward to a better understanding of the relationship between tetrapod biostratigraphy and the Permian-Triassic boundary.

Some concepts

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.

The Permian-Triassic boundary (= base of the Induan Stage, = base of the Triassic, hereafter PTB) is a chronostratigraphic boundary that is defined in marine strata. Mojsisovics et al. (1895)

proposed the longstanding definition of the PTB, equating it to the LO of the ammonoid *Otoceras* (Lucas, 2010). In 2001, the International Commission on Stratigraphy ratified a GSSP for the base of the Triassic at the Meishan D section in southeastern China, using the LO of the conodont *Hindeodus parvus* as the primary signal for correlation of the boundary (Yin et al., 1996, 2001). This conodont-based PTB is stratigraphically above the LO of Otoceras and very close to the stratigraphic level of the marine extinctions at the end of the Permian. However, this conodont signal at the Meishan D section is now known to be a relatively young occurrence of this taxon (not its FAD). Thus, the primary signal to correlate the base of the Triassic is diachronous (Jiang et al., 2011; Brosse et al., 2015; Lucas, 2018), and the GSSP needs to be redefined.

Nevertheless, vertebrate paleontologists need to understand that to identify the PTB using tetrapod biostratigraphy necessitates correlating a stratigraphic level in the tetrapod fossil record to a stratigraphic level in marine strata (very close to the LO of *Hindeodus parvus*) that encompasses that boundary. For about one century, that was not done to support equating the LO of *Lystrosaurus* to the PTB.

Forensic biostratigraphy

In 1838, Andrew Geddes Bain (1797-1864), a self-taught geologist, discovered fossils of dicynodonts in the Karoo basin of South Africa from strata that would later be called the Beaufort Group. Bain (1856) referred to the dicynodont-bearing strata as either the Reptiliferous strata (or deposits, beds or series), the Lacustrine(?) Formation or the Karoo series (Fig. 1). He considered them to be of Carboniferous or of immediately post-Carboniferous age (the same age as the British “New Red sandstone,” which in modern terms is Permian-Triassic) but did not use the terms Permian or Triassic to refer to them.

In 1892, British paleontologist Harry G. Seeley (1839-1909) presented the first biostratigraphic subdivision of Bain’s “Reptiliferous strata” (Fig. 1). He based his conclusions on fieldwork in the Karoo, as well as comparison of the Karoo reptile fossils to Permian and Triassic tetrapod records from Russia and western Europe. Thus, Seeley (1892) recognized five tetrapod fossil zones in the Karoo section (ascending order): (1) mesosaurian, no older than “lowest Permian;” (2) pareiasaurian (similar in age to the Russian Permian tetrapods); (3) dicynodonts; (4) theriodonts; and (5) zanclodonts, the Stormberg Series, no younger than Upper Triassic. This scheme did not precisely locate the PTB, but put the mesosaurian and pareiasaurian zones 1 and 2 in the Permian and the Stormberg Series in the Triassic (Fig.1).

Robert Broom (1866-1951) provided a more detailed zonation and first published (Broom, 1906) what he considered the level of the PTB in the Karoo section: (1) *Pareisaurus* beds; (2) *Endothiodon* beds; (3) *Kistecephalus* beds; (4) *Lystrosaurus* beds; (5) *Procolophon* beds; (6) *Cynognathus* beds; (7) Molteno beds; and (8) Upper Stormberg. Broom compared 1-3 to the Gordonia beds of Britain and the Russian Permian beds of the Dvina to support a Permian age assignment. He stated that 4 is “believed to be of Lower Triassic [sic] age,” no reason given, and he assigned 5 to the Middle Triassic. Broom considered 6 to be Late Triassic because he identified Erythrosuchus as a phytosaur and saw it and some of the other vertebrates from the South African *Cynognathus* beds as taxa similar to those of the German Keuper and the British “*Stagonolepis* beds, ” strata of Late Triassic age. Broom assigned 7, the Molteno Beds, a Rhaetian age based on its plant fossils; and 8, the Upper Stormberg, an Early Jurassic age because it contains the “true crocodile” *Notochampsa*. Broom’s placement of the PTB thus made no reference to a correlation to the marine PTB. Instead, Broom based the location of the PTB on strictly vertebrate biostratigraphic considerations.

In a longer exposition, Broom (1908) listed all of the vertebrate taxa from the following succession: Dwyka beds, Ecca beds, *Pareiasaurus*, *Endothiodon* and *Cistecephalus* beds encompassing the Permian, and the *Lystrosaurus*, *Procolophon* and *Cynognathus* (= “Burghersdorp”) beds of the Triassic, Rhaetic Molteno beds, and Lower Jurassic red beds/Cave Sandstone. (Fig. 1). Although Broom stressed the unique nature of the South African Permian and Triassic tetrapods, he again made comparison to European tetrapod faunas to justify his correlations.

Broom’s placement of the PTB was rapidly accepted (e.g., Watson, 1914; Von Huene, 1925). Thus, those who discovered *Lystrosaurus* in China (Yuan and Young, 1934a, b) and in India (originally in Huxley, 1865, recognized by Das Gupta, 1922) placed the base of the Triassic in those regions at a level just below the *Lystrosaurus* fossils (e.g., Young, 1946; Tripathi, 1961; Tripathi and Satsangi, 1963). A more nuanced discussion by Watson (1942, p. 116) concluded that “the *Lystrosaurus* zone lies somewhere about the Permo-Triassic boundary, the *Cistecephalus* zone being certainly upper Permian, the *Cynognathus* beds Lower Triassic.”

The first attempt to actually correlate tetrapod biostratigraphy of the PTB to marine biostratigraphy was by Efremov (1937) in his classic paper that first established a biostratigraphic zonation of Russian Permo-Triassic tetrapods. Thus, Efremov noted that the temnospondyl amphibian *Wetlugasurus*, characteristic of his zone V (this zone also includes the only Russian record of *Lystrosaurus*), had been found in Greenland stratigraphically above the marine Lower Triassic *Proptychites* beds. This justified correlating zone V to part of the Early Triassic. Efremov (1937) also clearly accepted Broom’s correlation of the *Lystrosaurus* zone in the Karoo basin, as he correlated Russian zone V to that zone.

In what may be the first evaluation of a possible PTB tetrapod extinction, Romer (1945) concluded that there was no major change in terrestrial vertebrates across the PTB (also see Simpson, 1952). The first extensive discussions of Permian extinctions (e.g., Schindewolf, 1953; Newell, 1956) focused on the extinction of marine invertebrates at the end of the Permian. However, Newell (1963, 1967) also identified a major drop in reptilian diversity at the PTB that was soon widely accepted as a substantial extinction (e.g., Tappan, 1968; Colbert, 1965, 1973; McAlester, 1973)

Colbert (1965) identified complete (no hiatuses) nonmarine PTB sections in the Karoo basin of South Africa and in northern Russia, and placed the PTB at the base of the *Lystrosaurus* zone. His placement was consistent with the idea that there was a mass extinction of tetrapods at the end of the Permian. Indeed, Colbert (1965, fig. 33) showed a drop in tetrapod diversity from 204 late Permian genera to only 48 genera during the Early Triassic. Thus, the correlation of the base of the Lystrosaurus zone to the PTB gained support as the stratigraphic level of supposed coeval mass extinctions of marine invertebrates and terrestrial tetrapods.

In the Karoo basin, the PTB tetrapod biostratigraphy evolved through the work of various paleontologists to reach its current state as summarized by Rubidge et al. (1995) (Fig. 1). Placement of the PTB between the *Dicynodon* and *Lystrosaurus* beds (later zones or assemblage zones) met little challenge. An exception was Cooper (1982), who placed the PTB above the *Lystrosaurus* zone, low in his overlying zone of *Kannemeyeria*. Cooper (1982) made an explicit attempt to correlate the tetrapod zones to marine faunas, arguing instead that times of high sea level are times of increased rainfall and warm climates on land, which would produce more terrestrial vegetation and promote tetrapod diversification (also see Cooper, 1977). Thus, he correlated the tetrapod diversification at the beginning of his *Kannemeyeria* zone to a perceived sea level rise at the beginning of the Triassic, though, as he admitted, the basis for this correlation was weak.

Work in the Karoo basin since Rubidge et al. (1995) continues to employ their tetrapod biostratigraphy with little modification (e.g., Smith et al., 2012; Viglietti et al., 2016, 2018). Some workers refer to the *Dicynodon* assemblage zone as the *Daptacephalus* assemblage zone (e.g., Viglietti et al., 2016, 2018; but see Lucas, 2018), and the validity and lower boundary of the *Pristerognathus* zone are open to question (Lucas, 2018). But, these are minor modifications.

Lucas (1998, 2006, 2009, 2010, 2017, 2018) based a succession of middle Permian-Early Triassic biochronological units called land-vertebrate faunachrons (LVFs) on the Karoo tetrapod biostratigraphy. Relevant to this discussion are the Platbergian, Lootsbergian, and Nonesian LVFs (Fig. 1). The beginning of Platbergian time is defined by the FAD of *Dicynodon*. The first appearance datum (FAD) of *Lystrosaurus* defines the beginning of the Lootsbergian LVF, and the FAD of *Cynognathus* defines the beginning of the Nonesian (Fig. 1).

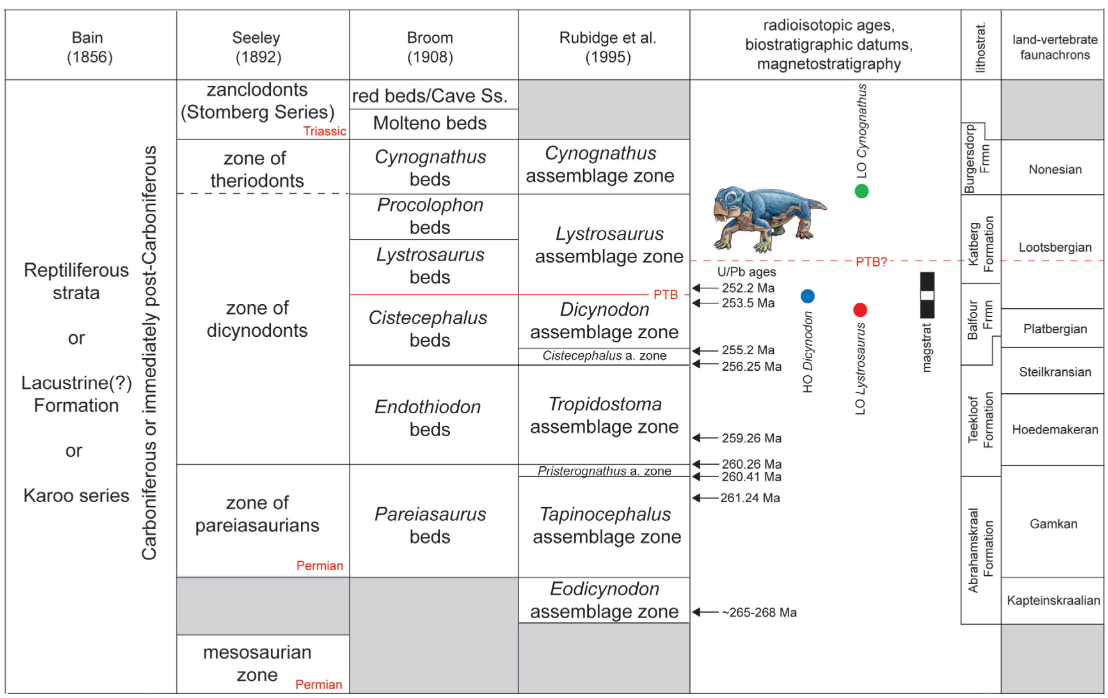

Fig. 1. Development of tetrapod bioistratigraphy across the Permo-Triassic boundary in the Karoo basin of South Africa from Bain (1856) through Rubidge et al. (1995), and selected radioisotopic dates, biostratigraphic datums of selected tetrapod genera, magnetostratigraphy, lithostratigraphy and vertebrate biochronology. Numerical ages are from Rubidge et al. (2013) and Gastaldo et al. (2015, 2020), magnetostratigraphy from Gastaldo et al. (2015, 2019b).

The changing LO of *Lystrosaurus*

Hotton (1967) first pointed out that there is a stratigraphic overlap between the HO of *Dicynodon* and the LO of *Lystrosaurus* in the Karoo basin of about 60 meters (e.g., Rubidge et al., 1995; Hancox et al., 2002; Retallack et al., 2003; Lucas, 2010). A similar (but stratigraphically shorter) overlap is also seen in the Junggur basin of northwestern China (Metcalfe et al., 2009 and references cited therein). In other words, the LO of *Lystrosaurus* in the Karoo basin is actually below the base of the classic *Lystrosaurus* assemblage zone (it is within the *Dicynodon* assemblage zone: Fig. 1). These stratigraphic overlaps led to some debate about whether to equate the Permo-Triassic boundary to the HO of Dicynodon or to the LO of *Lystrosaurus*, with the HO of *Dicynodon* generally chosen as the PTB (see Lucas, 2009, 2010 and references cited therein).

But, there has been no move to redefine the base of the *Lystrosaurus* assemblage zone downward to the LO of *Lystrosaurus* (e.g., Viglietti et al., 2016, 2018). However, the beginning of the Lootsbergian LVF has been moved downward, as its beginning is the FAD of *Lystrosaurus*, which cannot be younger than its LO. This means that the Lootsbergian LVF includes the PTB (Lucas, 2009, 2010, 2018) (Fig. 1).

More recent worked has further documented the stratigraphic overlap of *Dicynodon* and *Lystrosaurus* in the Karoo basin (Botha and Smith, 2007; Botha-Brink et al., 2014; Smith and Botha-Brink, 2014; Viglietti et al., 2016, 2018; Gastaldo et al., 2019b; Botha et al., 2020). As now understood, the LO of *Lystrosaurus* in different parts of the Karoo basin ranges from ~ 30 m to ~ 150 m below the HO of *Dicynodon*, and most South African paleontologists regard the HO of Dicynodon as the PTB (e.g., Smith and Botha-Brink, 2014; Viglietti et al., 2016, 2018). This is essentially the traditional PTB of Broom, as it is close to the base of the classic *Lystrosaurus* assemblage zone at the approximate base of the Katberg Formation (Fig. 1).

In the early 2000s, magnetostratigraphy and carbon-isotope stratigraphy were used in attempts to identify the PTB in the Karoo basin by correlation to the marine PTB in China (e.g., MacLeod et al., 2000; Smith and Ward, 2001; Retallack et al., 2003; Ward et al., 2005). However, the validity of the carbon-isotope data were challenged by Tabor et al. (2007) and Lucas (2009). At that time, the available magnetostratigraphic data in the Karoo basin indicated the LO of *Lystrosaurus* is in an interval of reversed polarity (DeKock and Kirschvink, 2004), so Lucas (2009) concluded that it is of late Permian age.

Gastaldo et al. (2015, 2019a, b, 2020; also see Neveling et al., 2016a, b) have presented stratigraphic, paleontological, radioisotopic, and magnetostratigraphic data that confirm that the LO of *Lystrosaurus* in the Karoo basin is of late Permian age. Thus, they reported a U-Pb age of 253.48 0.15 Ma of a silicified ash bed ~ 60 m below the inferred base of the *Lystrosaurus* assemblage zone (Fig. 1). This is an early Changhsingian age that predates the accepted age of the PTB of 251.91±0.037 (base) and 251.880±0.031 (top) Ma (Burgess et al., 2014) by more than one million years. New magnetostratigraphic data at the classic Lootsberg Pass locality in the Karoo basin indicate that much of the upper *Dicynodon* assemblage zone and the lower Lystrosaurus assemblage zone are of normal polarity, with a zone of reversed polarity encompassing the boundary between the two assemblage zones (Gastaldo et al., 2015). A similar pattern is reported, albeit a longer reverse polarity interval, that encompasses the boundary between the two assemblage zones, as currently defined, on the Bethel farm (Gastaldo et al., 2019b). Furthermore, Gastaldo et al. (2019b) reported what they regard as a latest Changhsingian palynoflora from well above the base of the *Lystrosaurus* assemblage zone.

Tying this polarity pattern to the numerical age pulls the upper *Dicynodon* assemblage zone and lower *Lystrosaurus* assemblage zone back in time to correlate to the later Changhsingian magnetochrons of Steiner (2006; also see Szurlies, 2013). Nevertheless, these results conflict with earlier magnetostratigraphic data so that Hounslow and Balabanov (2017) were dismissive of the correlation of Gastaldo et al. (2015), though they made no effort to question the reported radioisotopic age. Viglietti et al. (2016) did question that age, suggesting it may have been obtained from reworked material.

Marchetti et al. (2019a, b) documented tetrapod footprint assemblages from the Karoo basin, considering those from the uppermost Balfour Formation to be of Triassic age, relying on an U/Pb age of 252.5±0.7 of a single zircon crystal obtained from a stratigraphic level close to the HO of *Dicynodon* in the lower Palingkloof Member to place the PTB (Coney et al., 2007). Besides what may be stratigraphic problems with the locations of some of the footprint assemblages (Gastaldo and Neveling, 2019), the U/Pb age reported by Coney et al. (2007) is a legacy ID-TIMS age done by chemical abrasion on a single detrital zircon grain. Two other detrital zircon grains from the same bed yielded U/Pb ages of ~ 637 Ma and ~286 Ma. Therefore, the U/Pb ages reported by Coney et al. (2007) seem to me to have been based on two small of a sample of detrital grains to reliably indicate a (maximum) depositional age for the lower Palingkloof Member.

Similarly, Botha et al. (2020) recently reported LA-ICPMS U/Pb ages of detrital zircons from the lower part of the Palingkloof Member of the Balfour Formation that have a mean age of 251.7 ±0.3 Ma. This mean age is from a horizon considered Permian by Botha et al. (2010), even though it is an age younger than the estimated numerical age of the marine PTB of 251.9 Ma. I view the numerical ages reported by Botha et al. (2020) as low precision ages that are likely spuriously young due to lead loss. They are not reliable estimates of the age of the lower Palingkloof Member.

Indeed, Gastaldo et al. (2020) subsequently reported a high precision CA-ID-TIMS U/Pb age of 252.24±0.11 Ma on an airfall ash stratigraphically high in the Palingkloof Member, just above the base of the *Lystrosaurus* assemblage zone (Fig. 1). This date predates the PTB numerical age of 251.9 Ma by about 300,000 years and indicates that the base of the *Lystrosaurus* assemblage zone in the Karoo basin is of late Permian age.

Where is the PTB in the Karoo basin?

Clearly, the LO of *Lystrosaurus* and the HO of *Dicynodon* in the Karoo basin are not the PTB. This means that the LO of *Lystrosaurus* elsewhere (Russia, China, India, Antarctica) can no longer be assumed to mark the PTB. There are, nevertheless, records of Lootsbergian amphibian taxa (*Tupilakosaurus*, *Luzocephalus*) in Lower Triassic marine strata associated with ammonoids that suggest the PTB is within the Lootsbergian LVF. The Lootsbergian amphibians are from the late Griesbachian-early Dienerian interval of the Wordie Creek Formation in East Greenland (see Schneider et al., 2020 for a review of the details).

These observations plus the Karoo data place the PTB somewhere in the Lootsbergian well above the LO of *Lystrosaurus*; it is in the Katberg Formation as argued by Gastaldo et al. (2015, 2019a, b, 2020). However, a more precise placement cannot be made with current data (Fig. 1). There are various reasons that the early part of the Nonesian LVF is Olenekian (see Lucas, 2010; Schneider et al., 2020); hence, the PTB cannot be younger than Lootsbergian.

For about a century, the LO of *Lystrosaurus* served as a good approximation of the PTB. For about the last decade the HO of *Dicynodon* has been used to approximate the PTB. In retrospect, it is remarkable how close the LO of *Lystrosaurus* is to the PTB, considering that Broom (1906, 1908) did little more than "guess" that correlation. During the 20th Century it was "close enough" for most purposes. However, in terms of the temporal resolution needed for current studies, especially of the end-Permian extinctions, equating the LO of *Lystrosaurus*, the HO of *Dicynodon* or the base of the classic *Lystrosaurus* assemblage zone to the PTB is no longer defensible. The PTB in the Karoo basin is in the Katberg Formation in the *Lystrosaurus* assemblage zone.

References

Bain, A. G., 1856. On the geology of southern Africa. Transactions of the Geological Society, London Second Series, v. 7, p. 175–192.

Botha, J. and Smith, R. M. H., 2007. *Lystrosaurus* species composition across the Permo-Triassic boundary in the Karoo basin of South Africa. Lethaia, v. 40, p. 125–137.

Botha, J., Huttenlocker, A. K., Smith, R. M. H., Prevec, R., Viglietti, P. and Modesto, S. P., 2020. New geochemical and palaeontological data from the Permian-Triassic boundary in the South African Karoo basin test the synchronicity of terrestrial and marine extinctions. Paleogeography, Palaeoclimatology, Palaeoecology, v. 540, 1095467; doi.org/10.1016/j/palaeo.2019.109467

Botha-Brink, J., Huttenlocker, A. K. and Modesto, S. P., 2014. Vertebrate paleontology of Nooitgedacht 68: A *Lystrosaurus maccaigi*-rich Permo-Triassic boundary locality in South Africa. In Kammerer, C. F., Angielczyk, K. D. and Fröbisch, J., eds., Early evolutionary history of the Synapsida. Springer, Dordecht, p. 289–304.

Broom, R. S., 1906. On the Permian and Triassic faunas of South Africa. Geological Magazine, v. 5, n. 3, p. 29–30.

Broom, R., 1908. On the geological horizons of the vertebrate genera of the Karoo Formation. Records of the Albany Museum,v. 2, p. 156–163.

Brosse, M., Bucher, H., Bagherpour, B., Baud, A., Frisk, A. M., Kuang, G., and Goudemand, N., 2015, Conodonts from the Early Triassic microbialite of Guangxi (South China): Implications for the definition of the base of the Triassic System. Palaeontology, v. 58, p. 563–584.

Burgess, S. D., Bowring, S. and Shen, S., 2014. High precision timeline for Earth's most severe extinction. Proceedings of the National Academy of Science U.S.A., v. 111, p. 3316–3321.

Colbert, E. H. 1965. The age of reptiles. New York, W. H. Norton and Company, 228 p.

Colbert, E. H., 1973. Tetrapods and the Permian-Triassic transition. In Logan, A. and Hills, L. V., eds., The Pemian and Triassic systems and their mutual boundary. Canadian Society of Petroleum Geologists Memoir, v. 2, p. 481–492.

Coney, L., Reimold, W. U., Hancox, P. J., Mader, D., Koeberl, C., McDonald, I., Struck, U., Vajda, V. and Kamo, S. L., 2007. Geochemical and mineralogical investigation of the Permian-Triassic boundary in the continental realm of the southern Karoo basin, South Africa. Palaeoworld, v. 16, p. 67–104.

Cooper, M. R., 1977. Eustacy during the Cretaceous: Its implications and importance. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 22, p. 1–60.

Cooper, M. R., 1982. A mid-Permian to earliest Jurassic tetrapod biostratigraphy and its significance. Arnoldia Zimbabwe, v. 9, p. 77–102.

Das Gupta, H. C., 1922. Note on the Panchet reptile. Sir Asutsoh Mukherjee Silver Jubilee Volumes Science, v. 2, p. 237–241.

Efremov, I. A., 1937. On the stratigraphic subdivision of the continental Permian and Triassic of the USSR on the basis of the fauna of early Tetrapoda. Doklady Akademiya Nauk SSSR, v. 16, p. 121–126.

Gastaldo, R. A. and Neveling, J., 2019. Discussion of "Permian—Triassic vertebrate footprints from South Africa: Ichnotaxonomy, producers and biostratigraphy through two major faunal crises" by Marchetti, L., Klein, H., Buchwitz, M., Ronchi, A., Smith, R.M.H., DeKlerk, W.J., Sciscio, L., and Groenewald, G.H. (2019). Gondwana Research, doi 10.1016/j.gr.2019.08.003.

Gastaldo, R. A., Kamo, S. L., Neveling, J., Geissman, J. N., Bamford, M., and Looy, C. V., 2015. Is the vertebrate defined Permian-Triassic boundary in the Karoo basin, South Africa, the terrestrial expression of the end-Permian marine event? Geology, v. 43, p. 939–942.

Gastaldo, R. A., Neveling, J., Geissman, J. W. and Li, J., 2019a. A multidisciplinary approach to review the vertical and lateral; facies relationships of the purported vertebrate-defined terrestrial Permian-Triassic boundary interval at Bethulie, Karoo basin, South Africa. Earth-Science Reviews, v. 189, p. 220–243.

Gastaldo, R. A., Neveling, J., Geissman, J. W. and Looy, C. V., 2019b. Testing the *Daptacephalus* and *Lystrosaurus* assemblage zones in a lithostratigraphic, magnetostratigraphic, and palynological framework in the Free State, South Africa. Palaios, v. 34, p. 1–20.

Gastaldo, R. A., Kamo, S. L., Neveling, J., Geissman, J. N., Looy, C. V. and Martini, A. M., 2020. The base of the *Lystrosaurus* assemblage zone, Karoo basin, predates the end-Permian marine extinction. Nature Communications, v. 11, 1428, doi.org/10.1038/s41467-020-15243-7.

Hancox, P. J., Brandt, D., Reimold, W. U., Koerbel, C., Neveling, J., 2002. Permian-Triassic boundary in northwest Karoo basin: Current stratigraphic placement, implications for basin developmental models, and the search for evidence of an impact. Geological Society of America Special Paper, v. 356, p. 429–444.

Hotton, N. H., 1967. Stratigraphy and sedimentation in the Beaufort Series (Permian-Triassic), South Africa. In Teichert, C., ed., Essays in paleontology and stratigraphy. University of Kansas Department of Geology Special Publication, v. 2, p. 390–428.

Hounslow, M. W. and Balabanov, Y. P., 2017. A geomagnetic polarity timescale for the Permian, calibrated to stage boundaries. Geological Society London Special Publications, v. 450, p. 61–103.

Huxley, T. H. , 1865. On a collection of vertebrate fossils from the Panchet rocks, Raniganj coalfield. Palaeontologia Indica, series, 4, v. 1, p. 2–24.

Jiang, H., Aldridge, R. J., Lai, X., Yan, C., and Sun, Y., 2011, Phylogeny of the conodont genera *Hindeodus* and *Isarcicella* across the Permian-Triassic boundary. Lethaia, v. 44, p. 374–382.

Lucas, S. G., 1998. Global Triassic tetrapod biostratigraphy and biochronology. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 143, p. 347–384.

Lucas, S. G., 2006. Global Permian tetrapod biostratigraphy and biochronology. Geological Society London Special Publications, v. 265, p. 65–93.

Lucas, S. G., 2009. Timing and magnitude of tetrapod extinctions across the Permo-Triassic boundary. Journal of Asian Earth Sciences, v. 36, p. 491–502.

Lucas, S. G., 2010. The Triassic timescale based on nonmarine tetrapod biostratigraphy and biochronology. Geological Society London Special Publications, v. 334, p. 447–500.

Lucas, S. G., 2017. Permian tetrapod extinction events. Earth-Science Reviews, v. 170, p. 31–60.

Lucas, S. G., 2018. Permian tetrapod biochronology, correlation and evolutionary events. Geological Society London Special Publications, v. 450, p. 405–444.

MacLeod, K. G., Smith, R. M. H., Koch, P. L., and Ward, P. D., 2000. Timing of mammal-like reptile extinctions across the Permian-Triassic boundary in South Africa. Geology, v. 28, p. 227–230.

Marchetti, L., Klein, H., Buchwitz, M. Ronchi, A., Smith, R. M. H., De Klerk, W. J., Sciscio, L. and Groenwald, G. H., 2019b. Permian-Triassic vertebrate footprints from South Africa: Ichnotaxonomy producers and biostratigraphy through two major faunal crises. Gondwana Research, v. 72, p. 139–168.

Marchetti, L., Klein, H., Buchwitz, M., Ronchi, A., Smith, R.M., De Klerk, W.J., Sciscio, L. and Groenewald, G.H., 2019. Reply to discussion of "Permian—Triassic vertebrate footprints from South Africa: Ichnotaxonomy, producers and biostratigraphy through two major faunal crises" by Marchetti, L., Klein, H., Buchwitz, M., Ronchi, A., Smith, R.M.H., DeKlerk, W.J., Sciscio, L., and Groenewald, G.H. (2019). Gondwana Research, doi 10.1016/j.gr.2019.08.002

McAlester, A. L., 1973. Phanerozoic biotic crises. In Logan, A. and Hills, L. V., eds., The Pemian and Triassic systems and their mutual boundary. Canadian Society of Petroleum Geologists Memoir, v. 2, p. 11–15.

Metcalfe, I., Foster, C. B., Afonin, S. A., Nicoll, R. S., Mundil, R., Wang, X., and Lucas, S. G., 2009. Stratigraphy, biostratigraphy and C-isotopes of the Permian-Triassic non-marine sequence at Dalongkou and Lucaogou, Xinjiang Province, China. Journal of Asian Earth Sciences, v. 36, p. 503–520.

Mojsisovics, E. von, Waagen, W. H. and Diener, C., 1895. Entwurf einer Gliederung der pelagischen Sediments des Trias-Systems. Akademie Wissenschaft Wien, Mathematische-naturwissenschaftliche Klasse Sitzungsberichte, v. 104, p. 1279–1302

Neveling, J., Gastaldo, R. A. and Geissman, J. W., 2016a. The Permo-Triassic boundary in the Karoo basin. 35th International Geological Congress Field Trip Guide PRE 3, 79 p.

Neveling, J., Gastaldo, R. A., Kamo, S. L., Geissman, J. W., Looy, C. V., Bamford, M. K., 2016b. A review of stratigraphic, geochemical, and paleontologic data of the end-Permian terrestrial record in the Karoo basin, South Africa. In Linol, B., de Wit, M. J., eds., Origin and evolution of the Cape Mountains and Karoo Basin. Springer International Publishing, Switzerland, p. 151–157.

Newell, N. D., 1956. Catastrophism and the fossil record. Evolution, v. 10, p. 97–101.

Newell, N. D., 1963. Crises in the history of life. Scientific American, v. 208, p. 76–92,

Newell, N. D., 1967. Revolutions in the history of life. Geological Society of America Special Paper, v. 89, p. 63–91.

Retallack, G. J., Smith, R. M. H. and Ward, P. D., 2003. Vertebrate extinction across Permian-Triassic boundary in Karoo basin, South Africa. Geological Society of America Bulletin, v. 115, p. 1133–1152.

Romer, A. S., 1945. Vertebrate Paleontology. University of Chicago Press, Chicago. 687 p.

Rubidge, B. S., Johnson, M. R., Kitching, J. W., Smith, R. M. H., Keyser, A. W., and Groenewald, G. H., 1995. An introduction to the biozonation of the Beaufort Group. South African Committee for Stratigraphy Biostratigraphic Series, v. 1, p. 1–2.

Rubidge, B.S., Erwin, D.H., Ramezani, J., Bowring, S.A. and de Klerk, W.J., 2013. High-precision temporal calibration of late Permian vertebrate biostratigraphy: U-Pb zircon constraints from the Karoo Supergroup, South Africa. Geology, v. 41, p. 363–366.

Schindewolf, O. H., 1953. Über die Faunenwende vom Paläozoikum zum Mesozoikum. Zeitschrift der Deutsche Geologische Gesellschaft, v. 105, p. 153–183.

Schneider, J. W., Lucas, S. G., Scholze, F., Voigt, S., Marchetti, L., Klein, H., Opluštil, S., Werneburg, R., Golubev, V. K., Barrick, J. E., Nemyrovska, T., Ronchi, A., Day, M. O., Silantiev, V. V., Rößler, R., Saber, H., Linnemann, U., Zharinov, V. & Shen, S., 2020. Late Paleozoic-early Mesozoic continental biostratigraphy – links to the Standard Global Chronostratigraphic Scale. Paleoworld, doi10.016/j.pawor.2019.09.001.

Seeley, H. G., 1892. Researches on the structure, organization and classification of the fossil Reptilia. Further observations on *Pareiasaurus*. Philosophical Transactions of the Royal Society of London, B183, p. 311–370

Simpson, G. G., 1952. Periodicity in vertebrate evolution. Journal of Paleontology, v. 26, p. 359–370.

Smith, R. M. H. and Botha-Brink, J., 2014. Anatomy of a mass extinction: Sedimentological and taphonomic evidence for drought-induced die-offs at the Permo-Triassic boundary in the main Karoo basin, South Africa. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 396, p. 99–118.

Smith, R. M. H. and Ward, P. D., 2001. Patterns of vertebrate extinction across an event bed at the Permian-Triassic boundary in the Karoo basin of South Africa. Geology, v. 29, p. 1147–1150.

Smith, R. M. H., Rubidge, B. and van der Walt, M., 2012. Therapsid biodiversity patterns and paleoenvironments of the Karoo basin, South Africa. In Chinsamy-Turan, A., ed., Forerunners of mammals. Radiation. Histology. Biology. Indiana University Press, Bloomington & Indianapolis, p. 31–62.

Steiner, M. B., 2006. The magnetic polarity time scale across the Permian-Triassic boundary. Geological Society London Special Publications, v. 265, p. 15–38.

Szurlies, M., 2013. Late Permian (Zechstein) magnetostratigraphy in western and central Europe. Geological Society London Special Publications, v. 376, p. 73–85.

Tabor , N. J., Montañez, O. P., Steiner, M., and Schwindt, D., 2007. The d13C values of Permo-Triassic carbonates from South Africa reflect a stinking, sulfurous swamp, not atmospheric conditions. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 225, p. 370–381.

Tappan, H., 1968. Primary production, isotopes, extinctions and the atmosphere. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 4, p. 187–210.

Tripathi, C., 1961. On the remains of *Lystrosaurus* from the Panchets of Raniganj Coalfield. Records of the Geological Survey of India, v. 89, p. 407–419.

Tripathi, C. and Satsangi, P.P., 1963. *Lystrosaurus* fauna of the Panchet Series of the Raniganj coalfield. Palaeontologia Indica new series, v. 37, p. 1–65.

Viglietti, P.A., Smith, R.M.H. and Rubidge, B. S., 2018. Changing palaeoenvironments and tetrapod populations in the *Daptocephalus* assemblage zone (Karoo basin, South Africa) indicate early onset of the Permo-Triassic mass extinction. Journal of African Earth Sciences, v. 138, p. 102–111.

Viglietti, P.A., Smith, R.M.H., Angielczyk, K.D., Kammerer, C.F., Fröbisch, J. and Rubidge, B.S., 2016. The *Daptocephalus* Assemblage Zone (Lopingian), South Africa: A proposed biostratigraphy based on a new compilation of stratigraphic ranges. Journal of African Earth Sciences, v. 113, p. 153–164.

Von Huene, F., 1925. Die Südafrikanische Karroo-Formation als geologisches und faunistisches Lebensbild. Fortschritt Geologie und Paläontologie 12, 124 p.

Ward, P. L., Botha, J., Buick, R., De Kock, M. O., Erwin, D. H., Garrison, G. H., Kirschvink, J. L., and Smith, R., 2005. Abrupt and gradual extinction among Late Permian land vertebrates in the Karoo basin, South Africa. Science, v. 307, p. 709–714.

Watson, D. M. S., 1914. The zones of the Beaufort Beds of the Karroo System in South Africa. Geological Magazine New Series 1, Decade VI, p. 203–208.

Watson, D. M. S., 1942. On Permian and Triassic tetrapods. Geological Magazine, v. 79, p. 81–116.

Yin, H.F., Sweet, W. C., Glenister, B. F. et al., 1996. Recommendation of the Meishan section as global stratotype section and point for basal boundary of Triassic System. Newsletters on Stratigraphy, v. 34, p. 81–108.

Yin, H.F., Zhang, K.X., Tong, J.N., Yang, Z.Y. and Wu, S. B., 2001. The global stratotype section and point (GSSP) of the Permian-Triassic boundary. Episodes, v. 24, p. 102–114.

Young, C. C., 1946. The Triassic vertebrate remains of China. American Museum Novitates, v. 1324, p. 1–14.

Yuan, P. L. and Young, C. C., 1934a. On the discovery of a new *Dicynodon* in Sinkiang. Bulletin of the Geological Society of China, v. 13, p. 563–573.

Yuan, P. L. and Young, C. C., 1934b. The occurrence of *Lystrosaurus* in Sinkiang. Bulletin of the Geological Society of China, v. 13, p. 575–580.

The Permian of the Budva Zone, Montenegro, western Tethys

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Introduction

In the recent geological literature, it is postulated that the sedimentary record of the Budva zone, southwestern Montenegro, starts with the Early Triassic (Dimitrijević 1995; Schmid et al. 2020). This is astonishing as Upper Carboniferous sediments from there have been already mentioned more than 100 years ago (Bukowski, 1904; 1912). Also, Permian fossil assemblages have been known from the region of Sustaš, near Bar, for more than half a century (Kochansky-Devidé 1954, 1956; Kostić-Podgorska 1954, 1958, 1965; Pešić 1972; Pešić et al. 1989). The diverse macrofaunas consist of brachiopods, bivalves, gastropods, cephalopods, corals and rare crinoids indicating a Middle to Late Permian age; and microfossil assemblages further contain foraminifera and algae of Middle and Late Permian age. When describing these Permian fossils, the above mentioned authors considered them as isolated from their Permian host rocks and redeposited within Middle Triassic sediments presently known as the Tuđemili Formation.

Fusulinids of Middle and Late Permian age have also been described from pebbles found within the former "Muschelkalk-Konglomerat" now called the Crmnica Formation of Middle Triassic age (Kochansky-Devidé 1958a, 1958b). These pebbles, representing shallow water facies of varying colour and lithology, have however never been found in rock-forming bodies within the Budva zone.

Geological setting and description of localities

Sustaš and Crni Potok, two localities close to each other to the east of Sustaš village (Fig. 1) have already been known from the literature (Kochansky-Devidé 1954; Kostić-Podgorska 1958). Turčini, near Stari Bar, is a new section and also, with a thickness of nearly 80 m, by far the largest outcrop of Permian sediments in the Budva Zone. All three localities are located in the wider surroundings of the town of Bar (Fig. 1). A further Permian locality is situated near Limljani, southeast of Virpazar (Fig. 1) amid of vegetated and covered area, and another one, also known from the literature, is Kaluđerac section near the coast in the vicinity of Petrovac (Milovanović 1954).

Sustaš

Lower Triassic sediments close to Sustaš have been described by Krystyn et al. (2019). Dark gray to almost black, partly marly micritic limestones in beds of of 5 to 20 cm are exposed approximately two hundred meters to the south of that locality

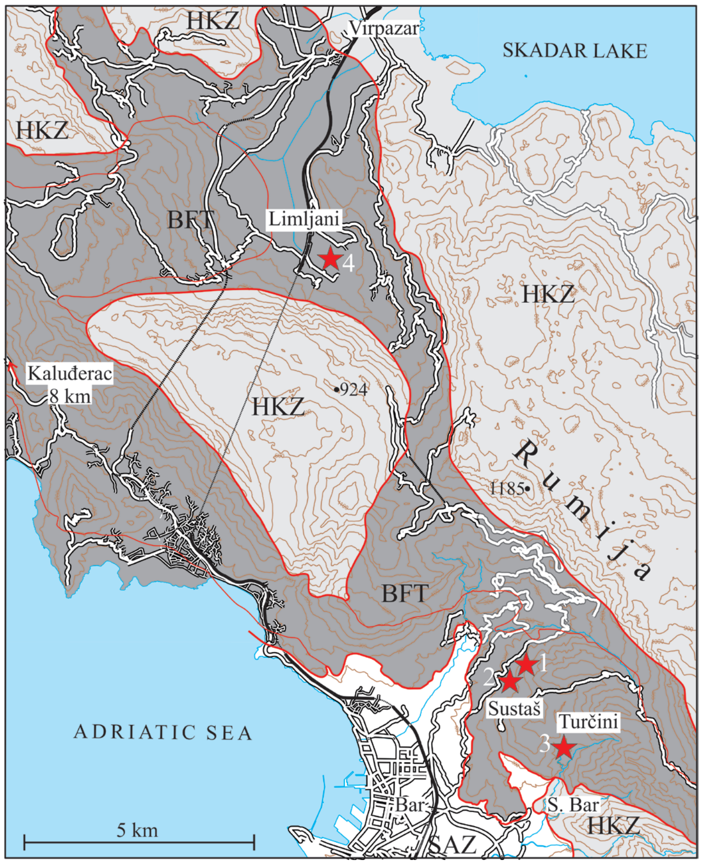

Fig. 1. Position of Permian sections in the Budva Zone, Montenegro. 1: Sustaš; 2: Crni Potok; 3: Turčini; 4: Limljani Polje. HKZ: High Karst Zone; BFT: Budva fold and thrust belt; SAZ: South Adriatic zone; S. Bar: Stari Bar.

and about 40 m higher in altitude (Fig. 2). Though fossils are rare, from certain levels, algae (*Vermiporella nipponica, Gymnocodium bellerophontis*) and foraminifera (*Hemigordius* sp.) were identified. According to Ghaderi et al. (2016) the cited algae indicate Middle to Late Permian age. The thickness of the outcrops is approximately 12 m and the contact towards the closeby exposed Lower Triassic rocks is unclear due to vegetation cover. No conodonts could be recovered from the limestones.

Crni Potok

During recent investigations of the Crni Potok creek near Sustaš, small and isolated outcrops of Upper Permian limestones have been found along its northern slope (Fig. 2). They host a series of 5 to 20 cm thick dark to black micritic limestone beds. Kostić-Podgorska (1958) described a rich fauna from several places in the creek, comprising brachiopods, bivalves, gastropods and cephalopods. In recent years, only scarce ammonoid fragments were found in one locality of which just *Cyclolobus* sp. was determinable (Krystyn et al., 2014). Thickness of the exposed rocks is limited to ca. 5 m.

Turčini

The newly discovered Upper Permian outcrop at Turčini is located 1.5 km northeast of Stari Bar (Fig. 1, Fig. 2) at 330 m asl and represents a comparably undisturbed succession of ca.

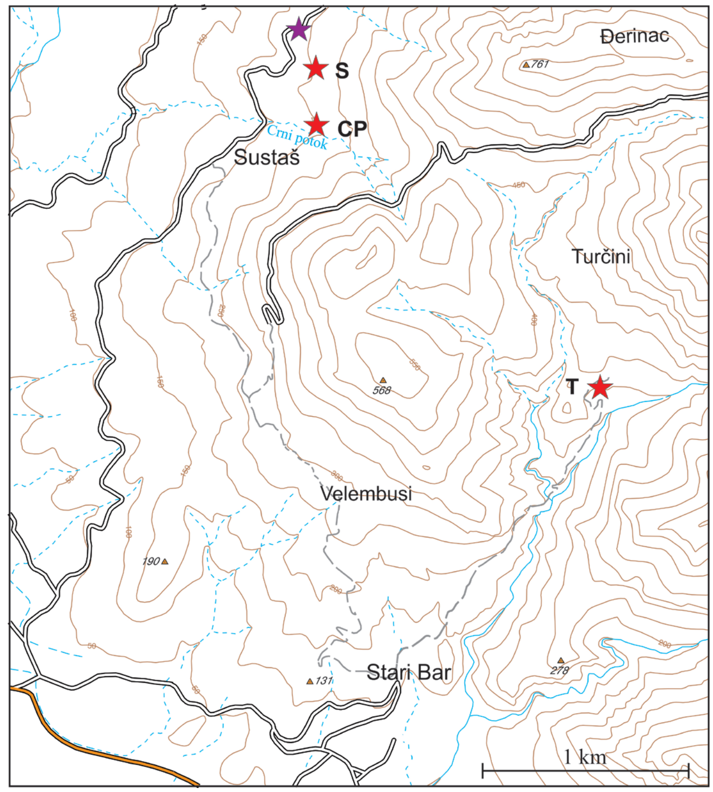

Fig. 2. Topographic map of Sustaš, Crni Potok and Turčini Permian localities (red stars). S: Sustaš section; CP: Crni Potok section; 3: Turčini section. The violet star indicates the Lower Triassic Sustaš section.

80 m thickness. It is tectonically sandwiched between light gray detrital limestones with chert nodules of Late Cretaceous age (Basic Geological Map of Yugoslavia, sheet Bar, Mirković et al. 1978) below and Middle-Upper Triassic cherty limestone above. The easterly dipping rocks can be followed on strike northward until a local mountain road and may from there continue down to Crni Potok. Further investigations will show whether these two occurrences are directly connected.

The succession starts with laminated brownish shales with rare thin mudstone intercalations followed by dark gray bioclastic, graded, pack- and grainstones in cm- to dm-thick beds, sometimes with thin chert layers, and with abundant foraminifera, algal and brachiopod fragments, and crinoids. Some of the coarse-grained calciturbiditic (?) beds reach up to 40 cm in thickness. The limestones alternate with thin-bedded gray marls or are separated by very thin shale layers. Of five arenitic limestone samples, two contained rare but age-diagnostic conodonts.

Limljani Polje

The locality is here called "Limljani-Polje" to distinguish it from the nearby Lower Triassic section north of the Limljani train station (Krystyn et al., 2019). The outcrop is situated ca. 500 meters southeast of the train station near some farmhouses (Fig. 3).

Exposures are restricted to a narrow lengthy strip surrounded by farm land and thus without visible sedimentary contact to other rocks. The series consists of several tens of metres of dark-

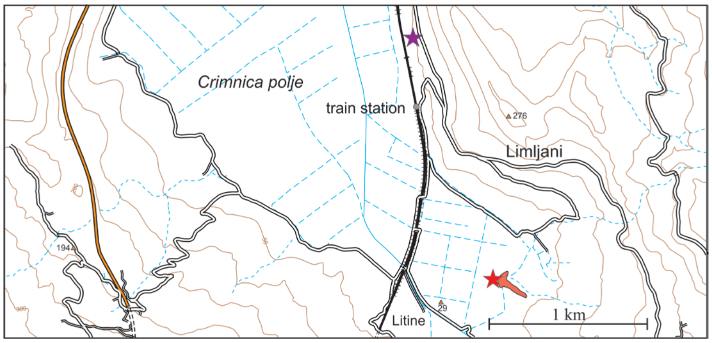

Fig. 3. Topographic map of Limljani Polje Permian section (red star). The violet star indicates the Lower Triassic Limljani section.

gray shale, silt- and sandstone with rare intercalations of up to 40 cm thick dark-gray calciturbiditic limestones containing Middle Permian conodonts. A preliminary age determination has been presented in Krystyn et al., 2019. Thickness of the section is ca. 40m.

Kaluđerac

An outcrop of Palaeozoic age was reported from the area of Kaluđerac near Buljarica (Fig. 1) by Milovanović (1954) with a discordant contact towards the overlying Crmnica conglomerate, a record that the mentioned author used to introduce and define the Middle Triassic (Anisian) Montenegrinian orogenic phase. Kostić-Podgorska (1954) described the Middle Permian coral species *Stylidophyllum denticulatum* from this area, collected from yellow recrystallized limestone. Upon visiting the area recently, only Crmnica conglomerate were observed, whereas the area that should represent the Permian succession is overgrown by vegetation and now misses any visible outcrop.

Ammonoid and conodont biostratigraphy

Crni Potok

Several ammonoids have been found among which the age-diagnostic *Cyclolobus* sp. has been mentioned in Krystyn et al. (2014) and is documented here (Fig. 4). *Cyclolobus* has long been held as stratigraphic marker for the early Late Permian (Wuchiapingian), but according to more recent conodont data from the Himalayas (Horacek et al., 2019), it seems to be common in lower Changshingian rocks as well.

Turčini

Most of the collected ammonoid specimens are poorly preserved and compressed, respectively two-dimensionally flattened. Determinations are therefore preliminary and in open nomenclature. Better preparation of the material might result in more exact identifications, which is currently not possible. Nevertheless, the identified taxa indicate a Changhsingian age fitting 1) with ammonoid data from Iran and Azerbaijan, recently published by Ghaderi et al. (2014) and Korn et al. (2016) and 2) with the lower Changhsingian record of Guangxi in Southern China (Ehiro and Shen 2010).

Only two levels provided determinable ammonoids: one at 8 m and the second at 12 m below the top, the latter, however, only with Laibinoceras sp. Most of the material was collected from loose blocks found in the scree between these two levels.

At section meter 8 below the top, *Phisonites* cf. *triangulus* Shevyrev, *Xenodiscus* sp., *Abichites* sp and *Huananoceras* sp. were collected. The presence of *Phisonites* and *Huananoceras* indicates basal Changhsingian.

A loose block found between 8 and 12 meters below the top of the section contains *Xenodiscus* cf. *dorashamensis*, *Sinoceltites*? sp. and *Penglaites* sp., indicating again basal Changhsingian. From the same interval along strike of the measured section in a closeby outcrop, *Shevyrevites* cf. *shevyrevi*, *Xenodiscus* cf. *dorashamensis*, *Xenodiscus* cf. *carbonarius*, *Xenodiscus* sp. and *Penglaites* sp. were identified, all suggesting an early Changhsingian age.

Two productive conodont samples, one from the middle (20/37) and one from the top (20/4) of the section, have delivered rare specimens of *Clarkina subcarinata* (Sweet). Sample 20/37 yielded further a single *Clarkina* cf. *orientalis* (Kozur & Patjakova) pointing to an earliest to early Changshinginian age for the lower to upper part of the section (Kozur, 2004; Ghaderi et al., 2014) in accordance with the ammonoid data described above. As the lowermost part of the section has not been dated yet, the Turčini section might actually reach down to the Upper Wuchiapingian.

Some of the mentioned ammonoid taxa are known from the *Clarkina subcarinata* conodont zone of Iran and Azerbaijan (Ghaderi et al., 2014), whereas others are present within the same zone in Guangxi (Ehiro and Shen 2010). The presence of *Shevyrevites* cf. *shevyrevi* together with basal Changsingian forms is somewhat problematic, however, because this species appears in stratigraphically higher in Iran, within the topmost *Clarkina subcarinata* Zone.

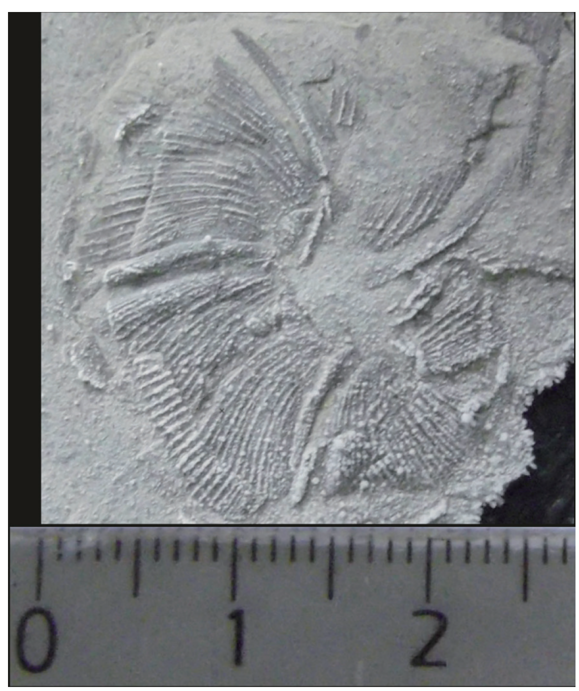

Fig. 4: *Cyclolobus* sp. from Crni Potok. Scale in cm.

Limljani Polje

A single sample (16/24) from one of the rare calciturbidite(?) beds delivered a rich association of *Mesogondolella siziliensis* (Kozur) that indicates a Middle Permian (Wordian) age according to Kozur (1995).

Discussion

Presently, an early Changhsingian age can be inferred for most of the Turčini section, whereas *Cyclolobus* proves a Wuchiapingian or early Changhsingian age for Crni Potok. For the algae of Sustaš, according to Ghaderi et al. (2016), only a general Middle to Late Permian age is supported. Finally, the conodont *Mesogondolella siziliensis* proves the presence of Middle Permian (Wordian) rocks in the Limljani-Polje section.

Altogether, these rare and at present geographically restricted occurrences provide a new, relatively continuous and unique record of Middle and Upper Permian strata within the Budva zone (Fig. 5). The specific facies and the open-marine ammonoid and conodont fauna offer an important opportunity to narrow down the faunistic, bio- and palaeogeographic knowledge gap between eastern and western Tethys regions during this critical time interval for the evolutionary history of the Tethyan realm.

Krystyn et al. (2019) documented a (hemi-)pelagic, open marine development for the Budva Zone, from the late Early Triassic (Olenekian) onward and interpreted it as an indication of a direct connection of Budva with the Palaeotethys. This presumed neighbourhood can now be traced back to at least the Middle Permian and supports the previously proposed palaeogeographic connections of the Budva zone with its long-distance continuation into Albania and the Pindos zone of the Hellenids.

The described sections Limljani Polje, Crni Potok and Turčini represent Permian basinal distal marine environments. Considering otherwise the exclusively Werfen-type shallow marine facies of the presently known lowermost Triassic (Induan) rocks, one has to assume a sudden shallowing of the Budva basin at some time during the latest Permian to Induan. This shallowing event could explain the present absence of uppermost Permian to lowermost Olenekian pelagic sediments, which so far have been neither found as pebbles in the widespread Middle Triassic conglomerates nor as rock-forming bodies. From the later Early Triassic (Olenekian) onward a continuous re-deepening followed,

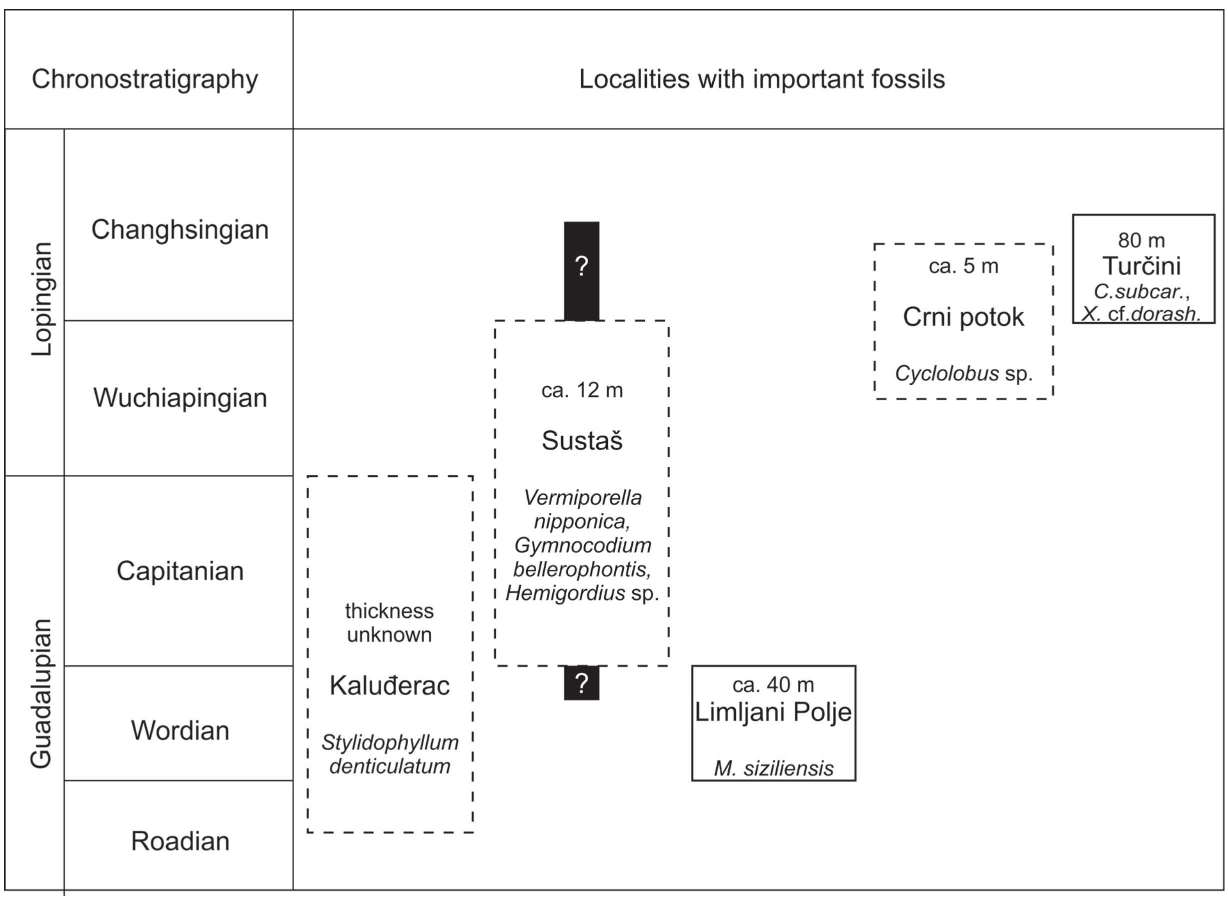

Fig. 5. Maximum stratigraphic range of the Permian sections of the Budva Zone. Kaluđerac, data from literature, could not be verified in the field. Sustaš section, data from literature, has been found and verified in the field. Limljani Polje section, stratigraphy ranges within the Wordian. Crni Potok section has Wuchiapingian or early Changhsingian age. The lower Changhsingian Turčini section might reach down to the upper Wuchiapingian, as the lowermost part of the section has not been dated yet. Turčini ammonoids (1) and conodonts (2): (1) *Laibinoceras* sp., *Phisonites* cf. *triangulus*, *Xenodiscus* sp., *Abichites* sp., *Huananoceras* sp., *Xenodiscus* cf. *dorashamensis*, *Sinoceltites*? sp., *Penglaites* sp., *Shevyrevites* cf. *shevyrevi*, *Xenodiscus* cf. *dorashamensis*, *Xenodiscus* cf. *carbonarius* and *Penglaites* sp.; (2) *Clarkina subcarinata*, *Clarkina* cf. *orientalis*.

as documented in Krystyn et al. (2019).

Investigations are still ongoing and detailed descriptions of the materials will be published in the future, when the preparation of all specimens so far collected is done; hopefully also further additional sections and fossils can thereby be found.

Acknowledgments

This study was supported by a grant of the Austrian Academy of Science to M. H., and is a contribution to the IGCP projects 630 and 710. M.Đ. thanks Novo Radulović for his assistance in finding the Turčini locality. We thank L. Angiolini and Y. Zhang for skillful editorial handling.

References

Bukowski, G., 1904, Erläuterunge zur geologischen Detailkarte von Süddalmatien im Massstab 1:25:000, Blatt Budua. Verlag der k. & k. Geologischen Reichsanstalt, Wien.

Bukowski, G., 1912, Erläuterunge zur geologischen Detailkarte von Süddalmatien im Massstab 1:25:000, Blatt Spizza. Verlag der k. & k. Geologischen Reichsanstalt, Wien.

Dimitrijević, M.D., 1995. Geologija Jugoslavije. Geoinstitut, Belgrade (in Serbian), 205 pp.,

Ehiro, M. and Shen, S.Z., 2010. Ammonoid succession across the Wuchiapingian/Changhsingian boundary of the northern Penglaitan Section in the Laibin area, Guangxi, South China. Geological Journal, v. 45, p. 162–169.

Ghaderi, A., Abad, M.T.K., Ashouri, A.R. and Korn, D., 2016. Permian calcareous algae from the Khachik Formation at the Ali Bashi Mountains, NW of Iran. Arabian Journal of Geosciences, v. 9, p. 699.

Ghaderi, A., Leda, L., Schobben, M., Korn, D. and Ashouri, A.R., 2014. High-resolution stratigraphy of the Changhsingian (Late Permian) successions of NW Iran and the Transcaucasus based on lithological features, conodonts and ammonoids. Fossil Record, v. 17, p. 41–57.

Horacek, M., Krystyn, L., Brandner, R. and Parcha, S., 2019, New conodont and stable isotopic data from the Guryul Ravine (Kashmir, India) Permian-Triassic boundary (PTB): a stratigraphic update. Strati, p. 402.

Korn, D., Ghaderi, A., Leda, L., Schobben, M. and Ashouri, A.R., 2016. The ammonoids from the Late Permian *Paratirolites* Limestone of Julfa (East Azerbaijan, Iran). Journal of Systematic Palaeontology, v. 14, no. 10, p. 841–890.

Kochansky-Devidé, V. 1954. Permske foraminifere i vapnenačke alge okolice Bara u Crnoj Gori [Permische Foraminiferen und Kalkalgen aus der umgebung von Bar in Montenegro]. Geološki vjesnik, v. 5-7, p. 295–298 (in Serbo-Croatian, with German summary).

Kochansky-Devidé, V. 1956. Donjopermske fuzulinide Sustaša kod Bara u Crnoj Gori [Unterpermische Fusuliniden von Sustaši bei Bar in Crna Gora (Montenegro)]. Geološki vjesnik, v. 8-9, p. 7–12 (in Serbo-Croatian and German).

Kochansky-Devidé, V. 1958a. Nalazišta neošvagerinskih fauna južne Crne Gore [Die fundorte der Neoschwagerinen faunen in südlicher Crna Gora]. Geološki vjesnik, v. 11, p. 21–44 (in Serbo-Croatian, with German summary).

Kochansky-Devidé, V. 1958b. Die Neoschwagerinen faunen der südlichen Crna Gora (Jugoslawien). Geološki vjesnik, v. 11, p. 45–75.

Kostić-Podgorska, V., 1954. *Stylidophyllum denticulatum* Huang iz perma crnogorskog primorja [Stylidophyllum denticulatum Huang aus dem Perm von Montenegrische Küstenzone]. Geološki anali Balkanskog poluostrva, v. 22, p. 115–120 (in Serbo-Croatian, with German summary).

Kostić-Podgorska, V., 1958. Paleontološki prikaz permskih fauna Crnog Potoka u Sustašima kod Bara (Crna Gora) [Paläontologische Bearbeitung der Permischen Faunen von Crni Potok bei Bar (Montenegro)]. Geološki glasnik, v. 2, p. 31–75 (in Serbo-Croatian, with German summary).

Kostić-Podgorska, V., 1965. Permski korali iz Crnog Potoka u Sustašima (Crna Gora) [Les coraux Permiens de Crni Potok a Sustaši (Monténégro)]. Geološki glasnik, v. 4, p. 235–240 (in Serbo-Croatian, with French summary).

Kozur, H.W.. 1995: Permian conodont zonation and importance for the Permian Stratigraphic Standard Scale. Geolog.-Paläont. Mitt. Innsbruck, v. 20, p. 165–205.

Kozur, H.W., 2004: Pelagic uppermost Permian and the Permian-Triassic boundary conodonts of Iran. Part 1: Taxonomy. Hallesches Jahrbuch für Geowissenschaften, Reihe B: Geologie Paläontologie Mineralogie, v. 18, 39–68.

Krystyn, L., Brandner, R., Đaković, M. and Horacek, M., 2019. The Lower Triassic of Budva Zone. Geološki glasnik, v. 17, p. 9–22.

Krystyn, L., Đaković, M., Horacek, M., Lein, R., Čađenović, D. and Radulović, N., 2014. Pelagically influenced Late Permian and Early Triassic deposits in Montenegro: remnant of Internal Dinarid Neotethys or Paleotethys relict? Berichte des Institutes für Erdwissenschaften Karl-Franzens-Universität Graz, v. 20, no. 1, p. 114.

Milovanović, B., 1954. O jednoj trijaskoj orogenoj fazi u Crnogorskom primorju [Über eine triassische orogene Phase im Montenegrinischen Küstenland]. Vesnik Zavoda za geološka i geofizička istraživanja NR Srbije, v. 11, 5–29 (in Serbo-Croatian, with German summary).

Mirković, M., Kalezić, M., Pajović, M., Živaljević, M. and Škuletić, D., 1978. Tumač za listove Bar i Ulcinj K 34-63 i K 34-75. Zavod za geološka istraživanja SR Crne Gore, p. 5–55 (in Serbo-Croatian, with English and Russian summary).

Pešić, L., 1972. O povredama skeleta kod vrste Linoproductus cora (d'Orbigny) [Sur les blessures des squelettes chèz l'éspèce Linoproductus cora (Orb.)]. Geološki anali Balkanskog poluostrva, v. 37, no. 1, p. 141–145 (in Serbo-Croatian, with French summary).

Pešić, L., Radulović, V. and Anđelković, D., 1989. Unutrašnja struktura vrste *Scacchinella gigantea* Schellwien iz perma Crne Gore [Internal structure of the species *Scacchinella gigantea* Schellwien from the Permian of Montenegro]. Geološki anali Balkanskog poluostrva, v. 53, p. 359–366 (in Serbo-Croatian and English).

Schmid, S.M., Fügenschuh, B., Kounov, A., Matenco, L., Nievergelt, P., Oberhänsli, R., Pleuger, J., Schefer, S., Schuster, R., Tomljenović, B., Ustaszewski, K. and van Hinsbergen, D.J.J., 2020. Tectonic units of the Alpine collision zone between Eastern Alps and western Turkey. Gondwana Research, v. 78, p. 308–374.

Guadalupian Working Group Report (GWG)

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Introduction

During an excellent SPS Voting Members Zoom meeting this morning (Oct 22, 2020) SPS Chair Lucia Angiolini and Vice-Chair Michael Stephenson discussed the working groups among other items. It was suggested that a last report from the Guadalupian Working Group was forthcoming. This is it.

Report

Considerable effort has been made to improve our knowledge of Guadalupian correlations led by Shuzhong Shen of the Nanjing University. The result is a paper currently in press (Shen et al., in press) in Earth Science Reviews entitled "Progress, problems, and prospects: An overview of the Guadalupian Series of South China and North America". The paper provides a high-resolution biostratigraphic, cyclostratigraphic, chemostratigraphic and high-precision geochronologic framework for the Guadalupian, mostly for the warm-water successions of South China and West Texas. It was demonstrated that there are a few issues regarding the GSSPs for the Roadian, Wordian and Capitanian stages. These stages were proposed to constitute the Guadalupian by Glenister et al. (1992) and the timescale was adopted by SPS by Jin et al. (1997) and the three GSSPs were ratified by IUGS in 1999 (Glenister et al., 1999). The type region was within Guadalupe Mountains National Park in West Texas. Those proposals primarily mentioned the conodont definitions and indicated some correlation with China. However, these proposals were never revised and published in Episodes. As time has passed, GSSP proposals are now more closely scrutinized and numerous means of global correlation, beyond the actual definition, are now required. As a result, a large team has worked on the sections of GMNP and South China and the Shen et al. paper is the culmination of that work. A plan is currently being developed to refine the GSSP proposals and publish in Episodes, probably starting with the base-Capitanian. Some minor revisions and repositioning are necessary, but the GSSPs will remain in GMNP. Please look at the Shen et al. paper for details.

Next Steps

The first step is to complete the GSSP articles for Episodes. The second step is to consider other aspects of the Guadalupian succession. The mandate of the working group is essentially complete now, but going forward greater effort should be focused on the entire Guadalupian, not just the boundaries. Correlations with cool-water marine successions (e.g. Phosphoria Basin) should be further examined and correlations made between marine and continental successions. In fact, the integration of a continental-marine time scale for the entire Permian should be a major goal of SPS going forward.

References

Glenister, B.F., Boyd, D.W., Furnish, W.M., Grant, R.E., Harris, M.T., Kozur, H., Lambert, L.L., Nassichuk, W.W., Newell, N.D., Pray, L.C., Spinosa, C., Wardlaw, B.R., Wilde, G.L., Yancey, T.E., 1992. The Guadalupian: Proposed international standard for a Middle Permian series. Int. Geol. Rev., 34, p. 857–888.

Glenister, B.F., Wardlaw, B.R., Lambert, L.L., Spinosa, C., Bowring, S.A., Erwin, D.H., Menning, M., Wilde, G.L., 1999. Proposal of Guadalupian and component Roadian, Wordian and Capitanian Stages as international standards for the Middle Permian. Permophiles, 34, 3–11. Get it at http://permian.stratigraphy.org/pub/pub.asp?PageNo=1

Jin, Y.G., Wardlaw, B.R., Glenister, B.F., Kotlyar, C.V., 1997. Permian chronostratigraphic subdivisions. Episodes, 20, 6–10.

Shen, S.Z., Yuan, D.X., Henderson, C.M., Wu, Q., Zhang, Y.C., Zhang H., Mu, L., Ramezani, J., Wang X.D., Lambert, L.L., Erwin, D.H., Hearst, J.M., Xiang L., Chen, B., Fan, J.X., Wang, Y., Wang W.Q., Qi, Y.P., Chen, J., Qie, W.K., Wang T.T., 2020 in press. Progress, problems and prospects: An overview of the Guadalupian Series of South China and North America. Earth Science Reviews, https://doi.org/10.1016/j.earscirev.2020.103412.

Summary report of the Nonmarine-Marine Correlation Working Group and notes from the former Vice-Chair of the SPS

Joerg W. Schneider

Dear Permian community, as the former Vice-Chair of the Subcommission on Permian Stratigraphy (SPS) from 2012 to 2020, I would like to thank you for my election to this position in 2012. This provided me the chance in cooperation with the Chair Shuzhong Shen (Fig. 1) to set a focus of the work of our commission on the connection of nonmarine deposits, which are very widespread during the sea level low stand of Late Palaeozoic Pangea, to the marine Standard Global Chronostratigraphic Scale (SGCS). Pushed forward by many colleagues I started to organize a corresponding working group. After some previous activity the first crucial step was done during a business meeting of the Subcommission on Carboniferous Stratigraphy (SCCS) and the SPS linked to the International Meeting on the "Carboniferous-Permian Transition" at the New Mexico Museum of Natural History and Science, Albuquerque, that was held in May 2013 and organized by Spencer G. Lucas (Lucas et al., 2013). During this meeting the chairs of the Subcommissions on Carboniferous and on Permian Stratigraphy, Barry Richards and Shuzhong Shen, agreed to constitute a formal Nonmarine-Marine Correlation Working Group (NMCG) between both subcommissions in order to obtain more man power (Schneider et al., 2014a,c). As a kick-off for this working group, a Field Meeting on Carboniferous and Permian Nonmarine-Marine Correlation was held at the Technical University Bergakademie Freiberg in July 2014 in Germany, organized by Joerg W. Schneider, Olaf Elicki, Stanislav Opluštil, and Spencer G. Lucas (Elicki et al., 2014; Schneider et al., 2014a). About 70 participants from Western and Eastern

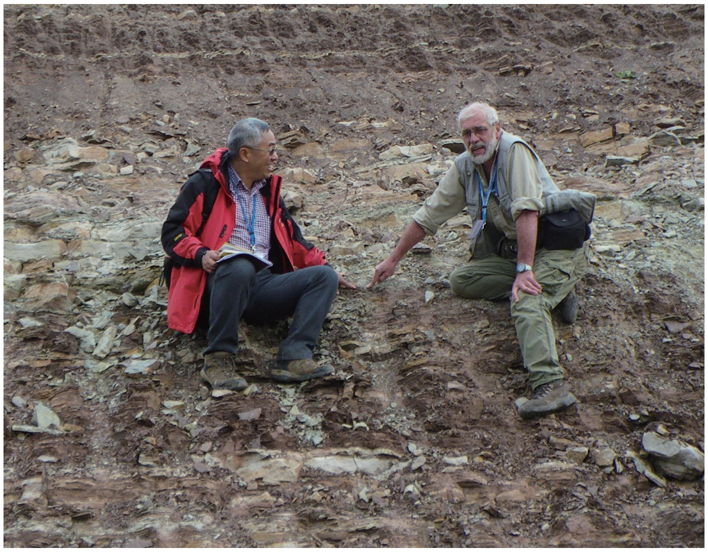

Fig. 1. The Chair of the SPS, Shuzong Shen, and his Vice-Chair, Joerg W. Schneider, in 2014 at the continental Permian-Triassic boundary in Central Europe, Caaschwitz quarry in Thuringia, East Germany. This quarry is an exceptional outcrop of the European late Permian Zechstein basin in transition to the early Triassic Germanic basin (see Scholze et al., 2017).

Europe, North and South America, North and South Africa, and Asia joined this meeting. In September of the same year, a collaborative field work of the Sino-German Cooperation Group and a SPS workshop chaired by Shuzhong Shen, Joerg W. Schneider, Hans Kerp, and supported by the Vice Chair of the SCCS, Xiangdong Wang, was carried out in NW China. It focused on Late Permian and Permian/Triassic boundary nonmarine-marine correlations. The fieldwork during these two weeks and the preceding four weeks of fieldwork of a Sino-German team (PhD students from Nanjing and Freiberg) in South and North China provided a wealth of samples around the nonmarine PT-boundary for conchostracan and fossil plant biostratigraphy, isotopic ages and geochemistry (e.g. Scholtze et al., 2017, 2020). A first report on results and future tasks of the working group was given during the international "Kazan Golovkinsky Stratigraphic Meeting" held from the 20 to 23 of October 2014 at the Kazan Federal University, Russian Federation, Republic of Tatarstan (Schneider et al., 2014b). This meeting was dedicated to "Carboniferous and Permian Earth systems, stratigraphic events, biotic evolution, sedimentary basins and resources" (Nurgaliev et al., 2014). It was followed in August 2015 by the XVIII International Congress on the Carboniferous and Permian at the Kazan Federal University with 165 attendants from 33 countries, among them numerous members of the NMCG. As a result of the "Call for global cooperation" (Schneider & Lucas, 2015), 18 members of the NMCG presented a common compilation of nonmarine reference sections for the Carboniferous and the Permian at this congress. Very stimulating for the work of the NMCG have been the congress excursions to the marvelous and excellently investigated outcrops of fossiliferous marine-continental and purely continental middle Permian to early Triassic sediments on the banks of the rivers in the Vologda region as well as in the Volga and Kama Region of the East European platform (Arefiev et al., 2015; Nurgaliev et al.2015). Earlier, in April 2015, the Moroccan members of the NMCG, Hafid Saber, Abdelouahed Lagnaoui, Abouchouaïb Belahmira and Abdelkbir Hminna, had organized the First International Congress on Continental Ichnology (ICCI-2015) at the University of El Jadida, Morocco, a bi-annual meeting that very much promoted since then tetrapod biostratigraphy of the late Palaeozoic and the Mesozoic (Saber et al., 2015; Lagnaoui et al., 2015). In 2015, the then chair of the Subcommission on Triassic Stratigraphy, Marco Balini, agreed to include the continental Triassic in the tasks of the NMCG. The years 2016 and 2017 were mainly devoted to research and a wealth of publications as reported by the working group members (Schneider et al. 2017). Some further research results on nonmarine Permian biostratigraphy and biochronology were published in the volume on the Permian timescale edited by Lucas and Shen (2018). In 2018 and 2019, 18 members of the working group were busy on the internally so-called "monster manuscript," a compilation of current methods of non-marine long-range biostratigraphy and of current data from 24 regions on Pangea (Schneider et al., 2020a,b). The results have been published in the special issue 29 of Palaeoworld, which summarized the contributions to and the results of the Second Golovkinsky Stratigraphic Meeting devoted to "Late Palaeozoic high-precision biostratigraphy, geochronology, climates and environments," which took place at Kazan Federal University, Russia, in 2017 (Nurgaliev et al. 2020). The international team of Schneider et al. (2020a) provides a concise up-to-date synthesis of nonmarine biostratigraphic methods suited for interregional and intercontinental correlations. Most importantly, these methods are calibrated with each other for the first time by cross correlations, and calibrated to the Standard Global Chronostratigraphical Scale by co-occurrences of continental and marine guide fossils as well as by using radioisotopic ages and multistratigraphic methods (Schneider et al., 2020a, fig. 3). This contribution shows the progress of the last two decades, and provides a solid basis for further research, which should focus on the following tasks of the SPS and the NMCG as already discussed in Permophiles 68 (Schneider et al., 2020b; partially repeated here), and during the 19th International Congress on the Carboniferous and Permian in Cologne, August 2019 (Herbig, 2020): First, 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 suitable for radioisotopic age determinations are nearly missing in this interval, even in marine deposits. 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. Day et al., 2018). The correlation of the Karoo tetrapod zones with those of the East European platform in Russia, as proposed in Schneider et al. (2020a), will possibly be improved by isotopic ages from the latter basin. The second and most challenging future task for nonmarine-marine correlations in the Late Carboniferous–Middle Triassic is the currently unsatisfactory biostratigraphic correlation among the biotic provinces of Euramerica, Angara, Cathaysia, and

Gondwana. Sections of the East European Platform and Siberia in Russia, those of the Karoo basin in South Africa, sections in North China, in Jordan and North Africa as well as in the Paraná basin of South America should be in the focus of further research of the NMCG.

To promote progress in nonmarine-marine correlations a call for global cooperation in the correlation of the most important and well investigated 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 in Schneider et al. (2020a) to a nearly global scale. This is the only way to understand abiotic and biotic processes in the coupled marine-continental system on Earth as demonstrated here in Fig. 2, which only applies thus far to the Euramerican region of the paleo-equatorial belt. We need a much wider global view...

References

Arefiev, M.P., Golubev, V.K., Balabanov, Yu.P., Karasev, E.V., Minikh, A.V., Minikh, I.I. Molostovskaya, M.G., Yaroshenko, O.P. and Zhokina-Naumcheva, M.A., 2015. Type and reference sections of the Permian–Triassic continental sequences of the East European Platform: main isotope, magnetic, and biotic events. XVIII International Congress on the Carboniferous and Permian, Sukhona and Severnaya Dvina Rivers field trip August 4–10, 2015, 103 p.

Day, M.O., Benson, R.B.J., Kammerer, C.F. and Rubidge, B.S., 2018. Evolutionary rates of mid-Permian tetrapods from South Africa and the role of temporalresolution in turnover reconstruction. Paleobiology, v. 44 (3), p. 347–367.

Elicki, O., Schneider, J.W. and Spindler, F. eds, 2014. CPC-2014 Field Meeting on Carboniferous and Permian Nonmarine-Marine Correlation. Abstract Volume. Wissenschaftliche Mitteilungen, Institut für Geologie, v. 45, 80 p.

Herbig, H.G., 2020: Report on the 19th International Congress on the Carboniferous and Permian Cologne, July, 29th–August, 2nd, 2019. Permophiles 68, p. 40–44.

Lagnaoui, A., Saber, H., Belahmira, A., Hminna, A., Schneider, J.W., Klein, H. and Voigt, S., 2015. Ichnological trail, Western Meseta – Western High Atlas (Morocco). In Lagnaoui A. and Saber H. eds. Field-Excursion Guidebook, First International Congress on Continental Ichnology (ICCI-2015), Chouaïb Doukkali University, Faculty of Sciences (April, 21st – 25th 2015, El Jadida, Morocco)

Lucas, S.G., DiMichele, W. A., Barrick, J. E., Schneider, J. W. and Spielmann, J. A., eds, 2013. The Carboniferous-Permian transition. New Mexico Museum of Natural History and Science, Bulletin v. 60, 465 p.

Lucas, S. G. and Shen, S. eds, 2018. The Permian Timescale. Geological Society, London, Special Publications, v. 450, 458 pp.

Nurgaliev, D. K., Silantiev, V.V. and Urazaeva, M.N. eds, 2014. Kazan Golovkinsky Stratigraphic Meeting “Carboniferous and Permian Earth systems, stratigraphic events, biotic evolution, sedimentary basins and resources” (October, 20–23 2014). Abstract volume, 104 p.

Nurgaliev, D.K., Silantiev, V.V. and Nikolaeva, S.V. eds, 2015. Type and reference sections of the Middle and Upper Permian of the Volga and Kama River Regions. A Field Guidebook of XVIII International Congress on Carboniferous and Permian. Kazan, August, 16–20, 2015,Kazan University Press, 208 p.

Nurgaliev, D.K., Silantiev, V.V., Schneider, J.W., Alekseev, A.S. and Nikolaeva, S., 2020. Late Palaeozoic high-precision biostratigraphy, geochronology, climates and environments. Palaeoworld, v. 29, p. 183–185.

Saber, H., Lagnaoui, A., and Belahmira, A., eds, 2015. First International Congress on Continental Ichnology (ICCI-2015), EL Jadida, Morocco, April 21-25, Proceeding of Abstracts, 13 pp.

Schneider, J.W. and Lucas, S.G., 2015. Late Carboniferous-Permian-Early Triassic Nonmarine-Marine Correlation: Call for global cooperation. Permophiles, v. 61, p. 28–35.

Schneider, J.W., Opluštil, St. and Scholze, F., 2014a. CPC-2014 Field Meeting on Carboniferous and Permian Nonmarine-Marine Correlation. Excursion Guide. Wissenschaftliche Mitteilungen, Institut für Geologie, v. 46, 121 p.

Schneider, J.W., Lucas, S.G., Barrick, J., Werneburg, R., Shcherbakov, D.E., Silantiev, V., Shen, S.Z., Saber, H., Belahmira, A., Scholze, F. and Rößler, R., 2014b. Carboniferous and Permian nonmarine-marine correlation – methods, results, future tasks. In: Nurgaliev, D. K., Silantiev, V.V. and Urazaeva, M.N. eds., 2014. Kazan Golovkinsky Stratigraphic Meeting “Carboniferous and Permian Earth systems, stratigraphic events, biotic evolution, sedimentary basins and resources” (October, 20–23 2014). Abstract volume, p. 73–77.

Schneider, J.W., Shen, S., Richards, B.C., Lucas, S.G, Barrick, J., Werneburg, R., Wang, X-D., Kerp, H., Nurgaliev, D.G., Davydov, V., Golubev, V., Urazaeva, M.N., Rößler, R., Voigt, S., Saber, H., Götz, A. E., Ronchi, A., Oplustil, S., Scholze, F. and Belahmira, A., 2014c. Report on the activities of the Nonmarine-Marine Correlation Working Group for 2014 – program for 2015 and future tasks. Permophiles, v. 60, p. 31–36.

Schneider, J.W., Scholze, F., Voigt, S., Götz, A.E., Opluštil, S., Ronchi, A., Bordy, E.M., Silantiev, V.V., Zharinova, V., Marchetti, L., Lucsa, S.G., Shen, S.Z., Barrick, J., Werneburg, R., Rößler, R., Kerp, H., Golubev, V., Saber, H., López-Gómez, J., 2017. Report on the activities of the Late Carboniferous – Permian – Early Triassic Nonmarine-Marine Correlation Working Group for 2016 and 2017. Permophiles, v. 65, p. 16–24.

Schneider, J.W., Lucas, S.G., Scholze, F., Voigt, S., Marchetti, L., Klein, H., Opluštil, S., Werneburg, R., Golubev, V.K., Barrick, J.E., Nemyrovska, T., Ronchi, A., Day, M.O., Silantiev, V.V., Rößler, R., Saber, H., Linnemann, U., Zharinova, V., and Shen, S.Z., 2020a. Late Paleozoic-early Mesozoic continental biostratigraphy – Links to the Standard Global Chronostratigraphic Scale: Paleoworld, v. 531, p. 186–238. oi.org/10.1016/j.palwor.2019.09.001.

Schneider, J.W., Lucas, S.G., Scholze, F., Voigt, S., Marchetti, L., Klein, H., Opluštil, S., Werneburg, R., Golubev, V.K., Barrick, J.E., Nemyrovska, T., Ronchi, A., Day, M.O., Silantiev, V.V., Rößler, R., Saber, H., Linnemann, U., Zharinova, V. and Shen, S.-Z., 2020b: Report on the activities of the Late

Carboniferous – Permian – Early Triassic Nonmarine-Marine Correlation Working Group for 2018 and 2019. Permophiles, v. 68, p. 35–40.

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

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

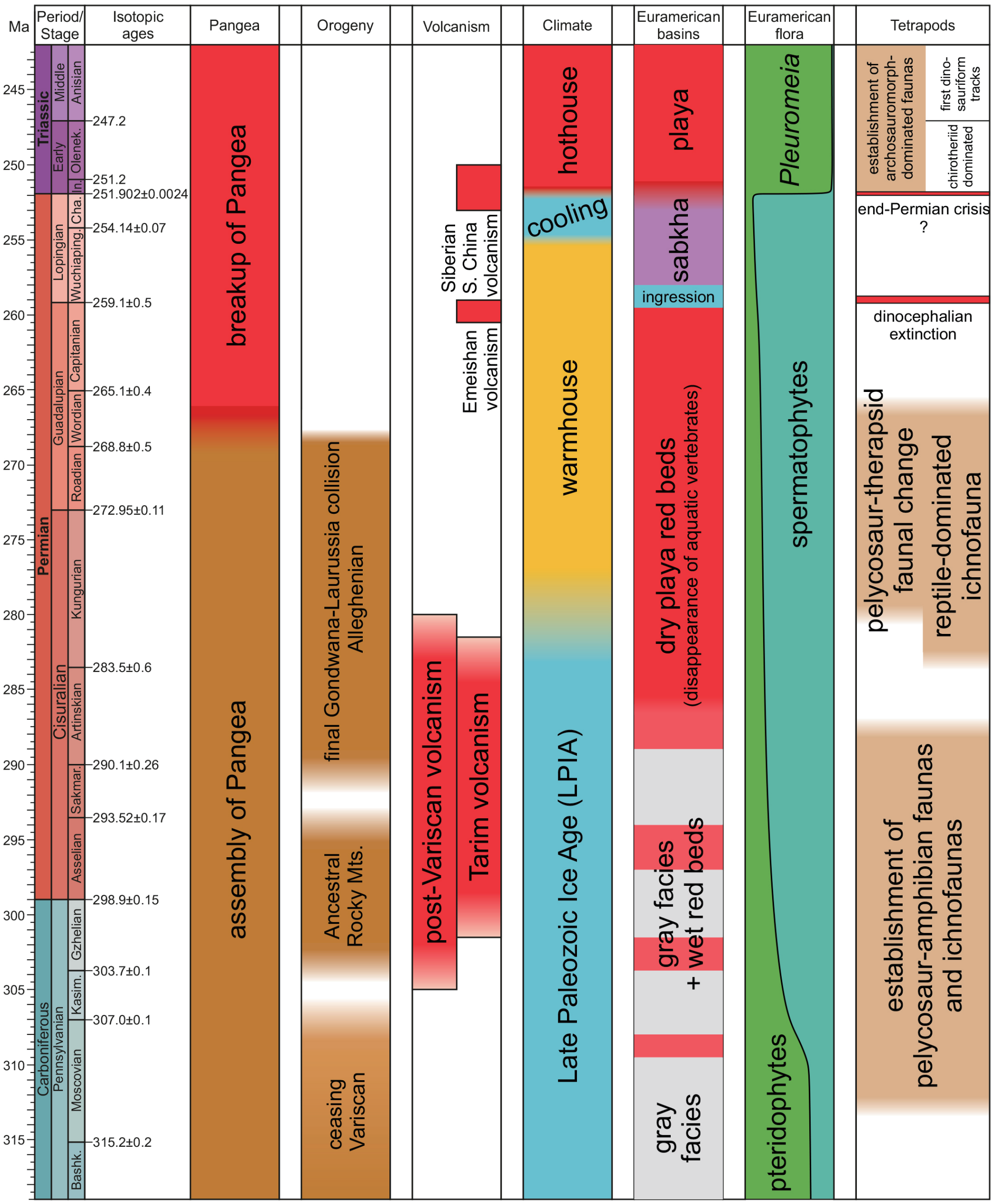

Fig. 2 (from Schneider et al., 2020a; modified): Synopsis of significant global and regional processes of geotectonics, paleoclimate, depositional environments and biota during the Late Carboniferous to Middle Triassic. For the post-Variscan orogenies, their culminations are shown - the Variscan–Mauretanide–Ancestral Rocky Mountains–Alleghenian (Appalachian–Ouachita–Sonora–Marathon belt) orogenies are a confluent collisional process of Gondwana and Laurussia through time that happened from east to west. The "post-Variscian volcanism" refers mainly to Europe. In the column Euramerican basins "ingression" designates the Zechstein ingression in the Central European basin as well as the Bellerophon transgression of the Southern Alps. The change between gray facies and wet red beds in the Euramerican basins, especially in Central Europe, coincides roughly with the glaciation/deglaciation cycles in the Karoo basin. In higher latitudes, e.g., on the East European platform (Angara biota) and especially in China (Cathaysia biota), and in the Karoo basin, the facies patterns are completely different, i.e., wet conditions (with coals close to the PTB) prevailed much longer.

Obituary
Randall Penney 1951 – 2019

Michael H Stephenson
British Geological Survey, mhste@bgs.ac.uk
Graham Booth
Retired palynologist, graham.a.booth@hotmail.com
Gordon Forbes
Retired palynologist, gordforb@gmail.com

It is with great sadness that we announce the death of Randall Penney a palynologist who worked tirelessly on Permian stratigraphic problems for many decades in the oil industry. Randall published few papers, but his reputation was of the highest within the companies and consultancies where he worked, and his opinions on stratigraphy and correlation matters were highly valued. His work in Petroleum Development Oman on the Permian parts of the Al Khlata Formation, and the Gharif and Khuff formations no doubt had an enormous influence on the company's drilling strategies and on its business 'bottom line'.

Randall Alexander Penney was born in December 1951 and grew up in Blackrock, County Dublin, Ireland. He was the eldest son of Norman and May Penney. He completed a BA Honours degree in Natural Sciences at Trinity College Dublin in 1976 and an MS at Toronto University in 1979. It was this latter degree, which was gained through the study of palynomorphs from Quaternary lake sediments of Ontario that was to set Randall on his palynological career path.

Randall spent the bulk of his professional palynological career in Oman (1995 - 2016) working for Petroleum Development Oman. During this period, he made a very significant contribution to updating the palynostratigraphy, particularly of the Palaeozoic Haushi Group, and undertook many complex regional reviews for the exploration and development teams, which assisted the understanding of source rock and reservoir distribution. His greatest expertise was the palynology of the Permian-Carboniferous Al Khlata Formation.

Randall left Oman in December 2016 for Gawler in South Australia for planned semi-retirement and to be closer to family members. There he resurrected his consultancy name 'Under The Microscope Stratigraphic Consultants Pty Ltd'. Tragically, within little more than a year he was beset by serious health problems from which he never recovered. He died peacefully on March 15th, 2019.

Randall was a remarkable and enthusiastic man with a wide range of interests including art, music and astronomy. He is sadly missed by his family and many friends and colleagues.

SUBMISSION GUIDELINES FOR ISSUE 70

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

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

Prof. Yichun Zhang (SPS secretary)

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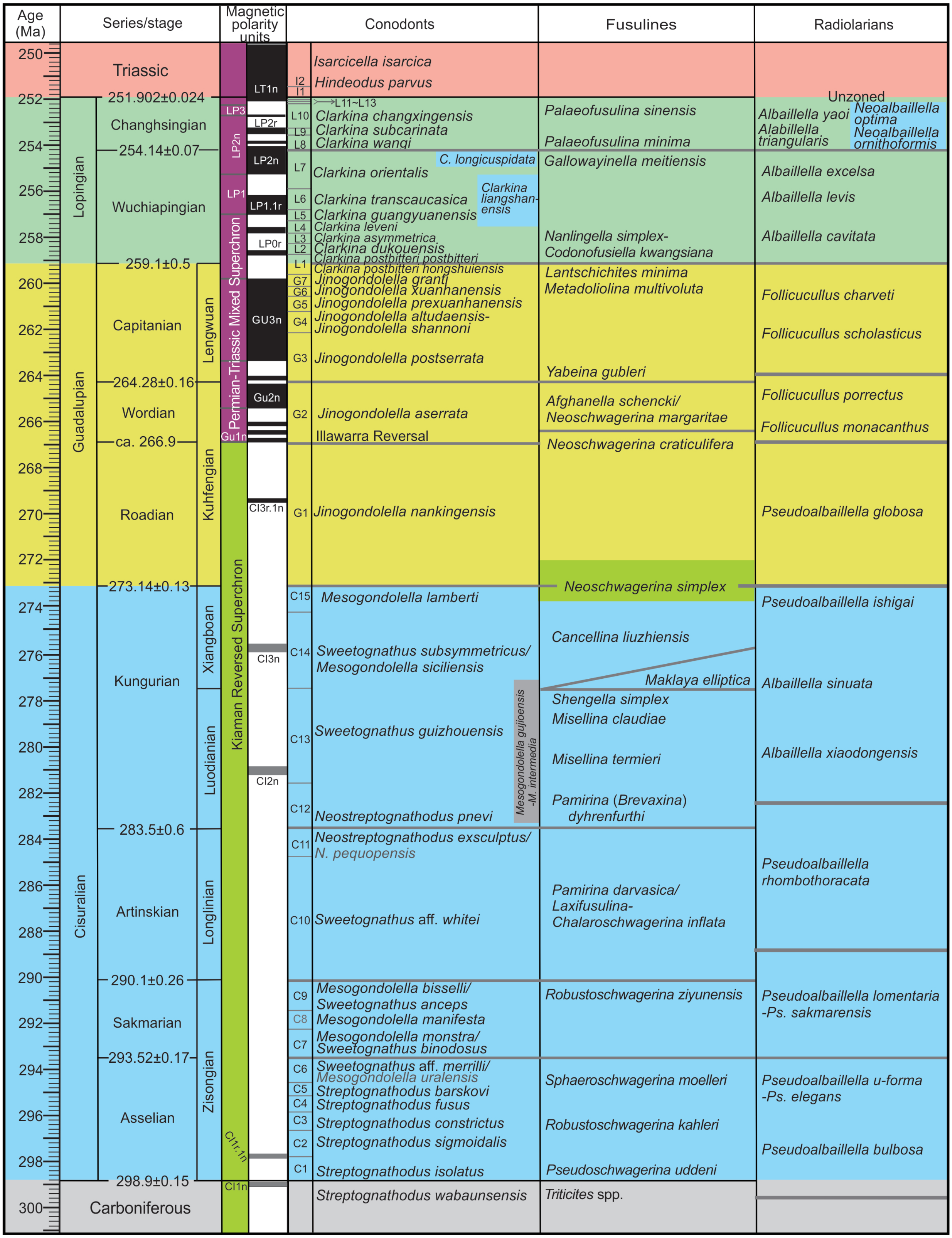
The deadline for submission to Issue 70 is December, 31th, 2020



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. Guadalupian ages modified after Shen et al., 2020. Progress, problems and prospects: An overview of the Guadalupian Series of South China and North America. Earth-Science Reviews, https://doi.org/10.1016/j.earscirev.2020.103412.