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Photo 1: Group photo of the participants to the excursion of the 35th International Geological Congress on the Permian-Triassic sequences of the Karoo Basin, South Africa, taken from the Old Wapadsberg Pass section. The field excursion was guided by Johann Neveling, Robert A. Gastaldo and John W. Geissman (courtesy S. Shen).
Photo 2: Photo of the newly excavated Mechetlino Quarry section (Kotlyar et al., this issue).
Photo 3: 1976, B. Wardlaw with UT Arlington student D. Caldwell at Permian section, Las Delicias, Mexico.
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EXECUTIVE NOTES

Notes from the SPS Secretary

Lucia Angiolini

Introduction and thanks

This foreword is in memory of the victims of the earthquake that hit central Italy on the 24 August 2016, caused by one of the numerous active extensional faults cross-cutting the western part of the Apennines Range. We are palaeontologists and stratigraphers, but, first of all, we are earth scientists and we are aware of the importance of our research for its theoretical and practical implications. Our duty is to make this research evident to governments and funding agencies.

This issue was prepared via email, as Shu-Zhong Shen and I did not have the opportunity to meet *de visu*. As you know, we had to delay its publication in order to report about the voting of new members of the SPS during the 35th INTERNATIONAL GEOLOGICAL CONGRESS, 27 August - 4 September 2016, Cape Town, South Africa.

This delay had multiple advantages: to allow more contributions for this issue, in particular the Sakmarian-base proposal; and to let the Permian community know about the IGC in Cape town and the names of the new voting and honorary members of the SPS. I would like to welcome Valeriy K. Golubev, Spencer Lucas, Mark Schmitz, Mike Stephenson and Yichun Zhang among the voting members, and Galina Kotlyar among the honorary members. The outgoing members Vladimir Davydov, Clinton Foster, and Xiangdong Wang are thanked for their services to the SPS.

My warm thanks go also to the contributors to this issue: Valery Chernykh and co-authors, Charles Henderson, Simon Bodorkos and co-authors, Eudald Mujal and co-authors, Spencer Lucas, Galina Kotlyar and co-authors, Joerg Schneider and Frank Scholze, John Rigby, Gerhard Bachmann and Jiang Da-Yong, and Stephen Kershaw.

I would like to thank Claudio Garbelli for his assistance in editing this and previous issues of Permophiles.

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

Previous and forthcoming SPS Meetings

During the last 35th International Geological Congress, 27 August - 4 September 2016, Cape Town, South Africa there was no formal business meeting. However, Shu-Zhong Shen did meet a few voting members during the congress and discussed the priority and other ongoing issues in SPS with them.

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This issue starts with a revised version of the proposal for the Global Stratotype Section and Point (GSSP) for the base-Sakmarian Stage (Lower Permian) by Valery Chernykh and co-authors. The

goal of presenting this version in this issue of Permophiles is to stimulate discussions among the voting members and the Permian community, as explained in the Chair's note.

A novelty of this issue is represented by the harangues of Charles Henderson who is introducing a new (and we hope successful) way to stimulate the debate inside the Permian community. In his first harangue, Charles starts recalling the simplified version of sequence stratigraphy by Ashton Embry which, in his opinion, makes it accessible for everyone; then he comments on detailed research on the Anthropocene presented at the IGC, underscoring the differences between a 'before-Quaternary' perspective and a 'Quaternary perspective'.

The next contribution is by Simon Bodorkos and co-authors who calibrated the local eastern Australian palynostratigraphic scheme (Price, 1997) with radioisotopic dates. The forthcoming results (in press by Laurie et al. in the Australian Journal of Earth Sciences) indicate that the palynozones in the Guadalupian and Lopingian of Australia are significantly younger than currently calibrated. One of the most significant results is the recalibration of the base of the *Dulhuntyispora parvithola* (APP5) Zone, which – lying near the Permian-Triassic boundary - is about 6 million years younger than previously suggested.

The report by Eduald Mujal and co-authors introduces a multi-disciplinary approach to the study of the Permian and Triassic successions of the Catalan Pyrenees, based on stratigraphic/sedimentological descriptions, the systematic study of the tetrapod bones and ichnites, and palynological analyses. The authors show that the Pyrenees biostratigraphical data are correlateable with those of the nearby Western Tethys basins and that a widespread distribution of large synapsids and parareptiles occurred during the Middle-?Late Permian.

Spencer Lucas discusses the possibility that mis-correlations and poor stratigraphic resolution may produce an incorrect record of a mass extinction. He focuses on tetrapod extinctions during the Early and Middle Permian. The Texas-Oklahoma record of tetrapods shows no mass extinction at the base of the Artinskian or the base of the Kungurian. Instead, stratigraphic data indicate extinctions within the Kungurian. The global record of Permian tetrapods shows a hiatus in part of the Kungurian-Roadian time interval (Olson's gap) which is underlined by very different tetrapod assemblages below and above. However, the interpretation of this gap is very controversial, as summarized by the author.

Galina Kotlyar and co-authors report the spectacular excavations of the Dalny Tulkas and Mechetlino Quarry sections performed last summer, following the request made during the XVIII International Congress on the Carboniferous and Permian 2015 held in Kazan, Federal Republic of Tatarstan, Russia, on August 11-15, 2015. The two sections, respectively considered as the GSSP candidate for the Artinskian and Kungurian lower boundaries, have been additionally sampled for conodonts, foraminifera, brachiopods, ammonoids, palynology, carbon and oxygen isotopes, magnetic susceptibility, TOC, X-ray fluorescence spectral analysis, and volcanic ashes.

The next report by Joerg Schneider and Frank Scholze uses

conchostracan assemblage zones as a tool for local to interregional biostratigraphic subdivision and correlation of continental deposits. The authors define 12 biozones from the Pennsylvanian to the Early Triassic. Due to increasing aridization, the time resolution of the biozones is lower in the late Early to Middle Permian.

John Rigby presents an interesting focus on the term 'Gondwana', which originally belonged to an ancient Indian kingdom. The author recounts the history of the use of the name Gondwana in geology and concludes with some suggestions on its use in geology. In particular, the use of the name Gondwana in Indian history and archaeology is to be continued, as should be the usage of the adjective Gondwanan when referring to a fossil biota found within Gondwana. Instead, the term Gondwanaland has priority for usage in palaeogeography.

Gerhard Bachmann and Jiang Da-Yong report on the 13th International Field Workshop which was held in Xingyi/Guizhou, Southwestern China and was geographically and geologically strikingly different to last year's 12th International Workshop on the Permian-Triassic / Boreal Triassic II Conference, held in Longyearbyen/Svalbard, Norway (Permophiles 62). During the workshop, the spectacular outcrops of the thick limestones of Permian and Triassic ages were visited, as well as the Middle and Upper Triassic fossil lagerstätten with outstandingly preserved marine reptiles, fish, and crinoids. Particularly attractive is the Guanling National Geopark where well preserved ichthyosaurs, thalattosaurs, placodonts, fishes, and the pseudoplanctonic crinoid *Traumatocrinus* are beautifully exposed.

The last contribution is by Stephen Kershaw who sums up recently published topics concerning processes of pyrite formation in the end Permian and processes of formation of calcite cements associated with the end-Permian and end-Triassic mass extinctions.

Finally, the Charles Henderson, Merlynd and Galina Nestell and the Chinese colleagues of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, remember, in an obituary, the famous Permian scientist Bruce Wardlaw, who sadly passed away in March 2016.

Future issues of Permophiles

The next issue of Permophiles will be the 64th issue.

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

The deadline for submission to **Issue 64** is a **31th December, 2016**. We may postpone it to early 2017 depending upon how many contributions we receive. We particularly welcome any comments and suggestions to improve the Sakmarian-base-proposal for the next issue. Manuscripts and figures can be submitted via email address (lucia.angiolini@unimi.it) as attachments.

To format the manuscripts, please follow the TEMPLATE that you can find on the new SPS webpage at http://permian.stratigraphy. org/ under Publications.

We welcome your contributions, your letters, comments, answers (for example to the Henderson harangues of this issue) and advices to improve our communication as we move forward.

Notes from the SPS Chair

Shu-Zhong Shen

First of all, I am very sad to say that we lost a giant Permian leader, former SPS Chair Bruce R. Wardlaw suddenly passed away on Wednesday, March 23, 2016 from injuries due to a fall. Bruce led the establishment of the three Guadalupian GSSPs, and also made significant contributions to the two GSSPs of the Lopingian and GSSP candidates of the Cisuralian Series in southern Urals. Bruce has been very productive with over 200 publications on his broad knowledge of geology, in particular on the Carboniferous and Permian conodonts. The sample population concept advocated by Bruce still has deep impact on the taxonomy of conodonts. Bruce will be missed as an intellectual leader, a colleague and a friend by all of us (see a memorial in this issue).

The Subcommission on Permian Stratigraphy (SPS) has taken a new 4-year term under International Commission on Stratigraphy. We have updated our voting members for the SPS. We thank Vladimir Davydov, Clinton Foster, Xiangdong Wang and Bruce Wardlaw for their great contribution to SPS. We also welcome V. K. Golubev, Spencer Lucas, Mark Schmitz, Michael Stephenson and Yichun Zhang as the new SPS voting members. The new SPS has taken action since the 35th International Geological Congress which was held in late August in Cape Town. Four SPS voting members, Alexander Biakov, Charles Henderson, Guang Shi, and myself, attended the congress. We had some conversation on what the main tasks are in the next 4-year term although a formal SPS business meeting was not organized. I would thank Johhan Neveling, Robert Gastaldo, John Geissman and Roger Smith who organized two field excursions on the Permian-Triassic sequences (see a photo on the cover of this issue) and the terrestrial end-Permian mass extinction in the Karoo Basin, South Africa. We all enjoyed the excursions very much.

In this issue, we are circulating the Sakmarian-base GSSP proposal again. The proposal has been greatly updated based on the version published in 2013 with the addition of more conodonts data, figures and discussions. The proposal is still far from being complete yet in the following aspects. 1) We have not completely reached an agreement among the conodont specialists about which species lineage we should use for the definition of the Sakmarian-base GSSP (*Mesogondolella uralensis* or *Sweetognathus merrilli* lineages). Even we agree with one of the two lineages, we still have some problems for the FAD of either species. Both *Mesogondolella uralensis* and *Sweetognathus merrilli* appear at the base of an event bed which is probably a sequence boundary. Thus, it is quite possible that the GSSP of the index species may not represent the real FAD at the section. 2) We do not have enough discussion on the global correlation in the proposal based on these two lineages. It is also necessary to review all the related species globally, in particular many related species from the Cisuralian Series of China. 3) There is very little discussion on the sedimentary characters on the Sakmarian and Asselian at the Usolka section. The sequence is mainly composed of clastic turbiditic deposits. 4) Some other studies (e.g., magnetostratigraphy) have not been available yet. I would call all SPS voting members to read the proposal carefully. I appreciate your comments/discussions on what we should add

for the proposal. Your input will be very important for improving the proposal. I think that the current version is still not good enough to be submitted for voting among SPS and ICS.

The priority for the new SPS is still to move forward for the establishment of the three remaining GSSPs in the Cisuralian. In addition to the Sakmarian-base GSSP proposal published in this issue, our Russian colleagues organized a research group led by Galina Kotlyar to excavate the two other potential GSSP candidate sections, that is the Dalny Tulkas section (Artinskian-base) and the Mechtlino Quarry section (Kungurian-base) (see a report by Galina Kotlyar in this issue). This is a great chance to carry out new studies and sampling. I would call all international colleagues to investigate these two sections. SPS got a small amount of money from ICS every year. We can use a part of the money to support voting members to go there for their field collecting.

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REPORTS

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

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(Note: This proposal is far being complete to be submitted for voting in SPS and ICS in the present form. The purpose to release this revised version is mainly to stimulate the discussions among the voting members and the whole Permian community. We welcome any comments and suggestions how to improve the proposal and what we should add to make the proposal better. More detailed information see Shu-Zhong Shen's Chair note in this issue).

Introduction

The Sakmarian Stage is the second lowest stage of the Permian System. It probably recorded the acme stage of the Late Paleozoic Ice Age (LPIA) (Isbell et al., 2003; Fielding et al., 2008). Two sections were used for studying the lower boundary of the Sakmarian Stage on the western slope of the South Urals: the section along Usolka River and the historical Russian stratotype for the Sakmarian Stage – the Kondurovsky section (Fig. 1). Concerning the comparative characteristic of these sections, it is possible to note that the Usolka section was formed under the condition of deep shelf or slope, whereas the Kondurovsky section is undoubtedly a shallow-water succession. The Kondurovsky section as an earlier candidate represents a thick series of deposits, in which local fossils are accompanied frequently by redeposited forms. In spite of the attractiveness of the Kondurovsky section because of the wide variety of paleontological remains (conodonts, ammonoids and fusulinaceans), we nevertheless prefer to use it as the auxiliary stratotype - the percentage of redeposited fossil forms

Fig. 1. Location of the Usolka and Kondurovsky sections in southern Urals, Russia.
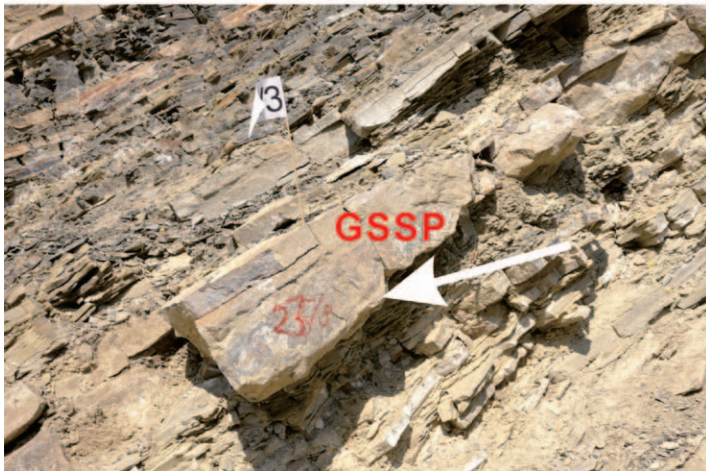
Fig. 2. Photos showing the outcrop and proposed GSSP position at the Usolka section in southern Urals, Russia (Valery Chernykh for scale).

Usolka section
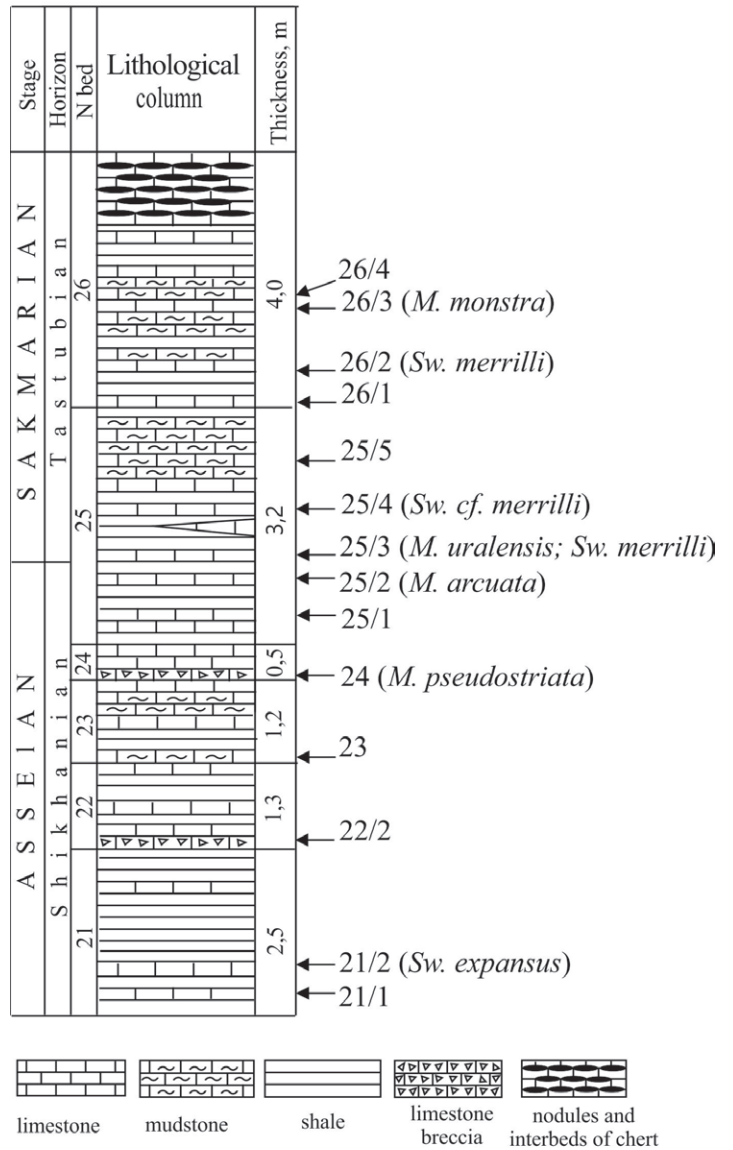
Fig. 3. Stratigraphic column with distribution of samples taken for conodonts in Usolka section

proves to be too significant.

A section of carbonate mudstone deposits on the right bank of the Usolka River (Fig. 2), located near the health resort Krasnousol'sky is well known to stratigraphers from the time of the International Congress "Permian System of the World" in 1991. It served as a potential site for developing the boundary between the Carboniferous and Permian systems on the basis of conodonts and it can be used as an auxiliary section for determining this boundary. The Usolka section is herein also proposed by us as the Global Stratotype Section and Point (GSSP) for the base of the Sakmarian Stage for the International Permian Time Scale (Figs. 2, 3).

The detailed description of the Usolka and Kondurovsky sections was given before (Chuvashov et al., 1991a; Chuvashov et al., 1991b). A brief proposal was published on Permophiles (Chernykh

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et al., 2013). We herein give an updated version to provide the description of the Usolka section and the lithologic columns for both sections, in which are indicated the levels of the first appearance of the most important forms of conodonts (Figs. 2, 3).

General characteristic of the Usolka section

The section on the Usolka River largely correlates with the section on the Dal'ny Tulkas stream where carbonate mudstone strata of Upper Carboniferous, Asselian, Sakmarian and Artinskian deposits occur. The Gzhelian-Asselian interval at Usolka is condensed and has a continuous series of deposits, with abundant conodonts (Chernykh, 2006). Practically all rocks in this part of the section, in which it was possible to dissolve in acetic or formic acids, contain more than 200 conodont specimens per kilogram. In the continuous deposits of the Sakmarian part of the section the quantity and variety of conodonts is reduced (25-50 specimens per kilogram).

The continuity of the Usolka section is proven by the occurrence of all stratigraphic subdivisions (Stages) listed above as established by fusulinacean and ammonoid zonation (Figs. 3, 4). The nature of change of sedimentation cycles and the absence of significant tec-

tonic disturbances and interruptions also testifies to the continuity of sedimentation. In addition to this, the analysis of conodont lineages and morphologic trends within the prevailing genera make it possible to interpret the absence of any post-sedimentary processes like rewashing and redeposition in this section. The most significant deficiency of the section is the relatively weak characterization of the Asselian part by fusulinaceans and for ammonoids over the entire interval.

The total thickness of the succession at Usolka is somewhat more than 90 metres (Figs. 3, 4). The condensed nature of sedimentation and the corresponding reduced thickness of the stratigraphic subdivisions have positive and negative effects on the construction of the conodont sequence. The possibility of obtaining information about the distribution of conodonts over such a significant stratigraphic range in one section is considered of merit. It is also valuable that the slowly accumulated sediments are enriched in fossils, which is probably connected with the abundance of conodonts at Usolka.

This section provides complete information about the stratigraphic sequence and the composition of conodonts (Figs. 5, 6).
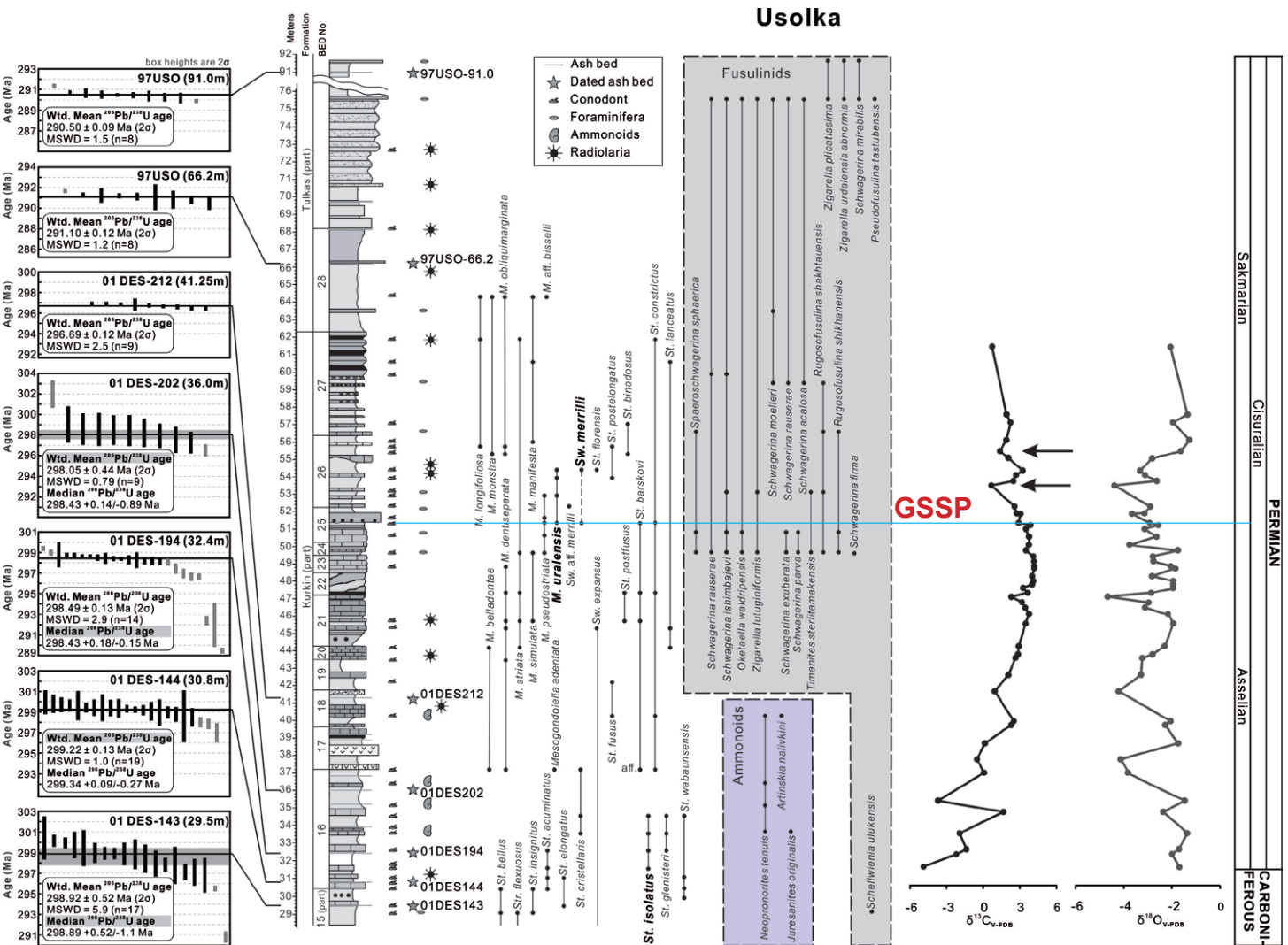
Fig. 4. Composite data of the Usolka section showing the biostratigraphy and geochronology (after Schmitz and Davydov, 2012) and chemostratigraphy (after Zeng et al., 2012)

Fig. 5. Key *Mesogondolella* species from the Asselian/Sakmarian boundary at the Usolka and Kondorovsky sections in southern Urals. 1. *Mesogondolella striata* (Chernykh); Specimen U34-8; Usolka section, Bed 22/2; 2. *M. pseudostriata* (Chernykh); Specimen U37-21, Usolka section, bed. 25/2;3. *M. uralensis* Chernykh; Speciment U38-7; Usolka section, Bed 25/3;4. *M. uralensis* Chernykh. Specimen K35-14, Kondurovsky section, Bed 13. 5-8. *Mesogondolella striata* (Chernykh): 5 – Specimen U34-4; 6 – sp. U34-5; 7 – sp. U34-6; 8 – sp. U34-7; Usolka section, Bed 21/1; 9,10. *Mesogondolella pseudostriata* (Chernykh): 9 – Specimen U37-19; 10 – sp. U37-31; Usolka section, bed. 25/2. 11 *Mesogondolella pseudostriata* (Chernykh) (transitional to *M. obliquimarginata* (Chernykh), sp. U37-33; Usolka section, Bed. 25/2. 12-18. *Mesogondolella arcuata* Chernykh: 12 – sp. U34-47; Usolka section, Bed 25-2; 13- sp. K35-5m;14 – sp. K35-4; 15 – sp. K35-2; 16 –sp. K35-1; Kondurovsky section, Bed 10; 17 – sp. K35-9; 18 – sp. K35-10; Kondurovsky section, Bed 12. 19-24. *Mesogondolella uralensis* Chernykh: 19 – sp. U38-9; 20 – sp. U38-2;21 – sp. U38-6; 23 – sp. U38-5; Usolka section, Bed - 26/1; 22 – sp. U37-21; Usolka section, Beds - 25/5. 24-26. *Mesogondolella monstra* Chernykh: 24 – sp. K36-8; Kondurovsky section, Bed 16; 25 – sp. U32-14; 26- sp. U32-15; Usolka section, Bed. 26/3.
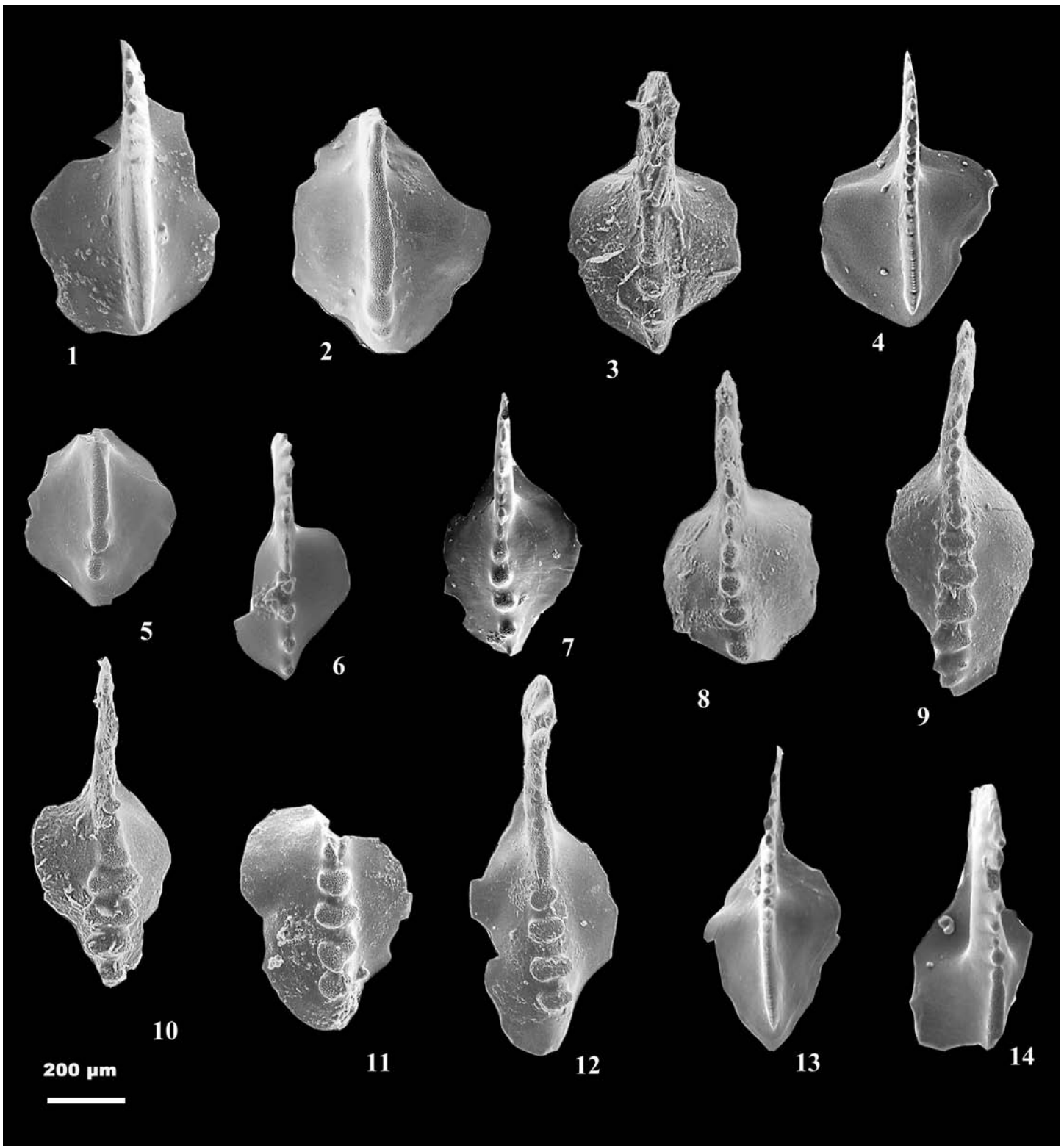
Fig. 6. Key *Sweetognathus* species from the Asselian/Sakmarian boundary at the Usolka and Kondorovsky sections in southern Urals. 1, 2, *Sweetognathus expansus* (Perlmutter): 1- Specimen U17-25, Usolka section, Bed 14; 2 – sp. U37A-1, Usolka section, Bed 21. 3. *Sweetognathus merrilli* Kozur: 3 – sp. U32A-2; 4. *Sweetognathus* aff. *stevensi* (Clark and Carr), sp. K36-18, Kondurovsky section, Bed 18. 5-7. *Sweetognathodus merrilli* Kozur: 5 – sp. K36-16 (form transitional from *Sw. stevensi* to *Sw. merrilli*); Kondurovsky section, Bed 16; 6 – sp. K36-20; 7 – sp. K36-20b; Kondurovsky section, Bed 18. 8-12. *Sweetognathus binodosus* Chernykh: 8 – Specimens U32A-3; 9 – holotype U32A-6; 10 – sp. U32A-7; 11 – sp. U32A-4; 12 – sp. U32A-5; Usolka section, Bed 26/3. 13– *Sw.* aff. *stevensi* (Clark and Carr), the middle part of Bed 16; 14 – forms transitional from *Sw.* aff. *stevensi* (Clark and Carr) to *Sw. merrilli* Kozur, upper part of Bed 16, Kondurovsky section.

Reducing the spacing of sampling and increasing sample volume as needed, allows the series of information necessary for reconstruction of the development of conodont lineages. The study of conodonts in these condensed sediments is manifested only in those lithologies in which it is possible to conduct continuous testing. In some rocks (claystone, dolostone, silicified limestone, *etc.*) the extraction of conodonts is nearly impossible and this probably leads to the appearance of errors.

Thus, if even a half-metre interval in this section is missing, it can involve the disappearance of the essential part of a conodont sequence right up to the loss of an entire zone. In this connection we tried to replicate conodont sequence data at the Usolka section by testing other facies types that were deposited more rapidly. The study of such "diluted" sections makes it possible to move away from a narrow time frame, within which is concluded the picture of the historical morphogenesis of conodonts at Usolka, to a more detailed study of the process of a gradual change of conodonts. To this effect, the section of Upper Asselian-Sakmarian flysch deposits on the right bank of the Sakmara River near Kondurovsky settlement (Figs. 5-7) was studied.

The Usolka section made it possible to build the zonal scale on conodonts in the stratigraphic range of Upper Carboniferous to the Irginian horizon of the Artinskian Stage (Fig. 4). To validate this zonal scale we also studied in detail the distribution of conodonts in the Kondurovsky section (Fig. 7), where thick flysch deposits crop out.
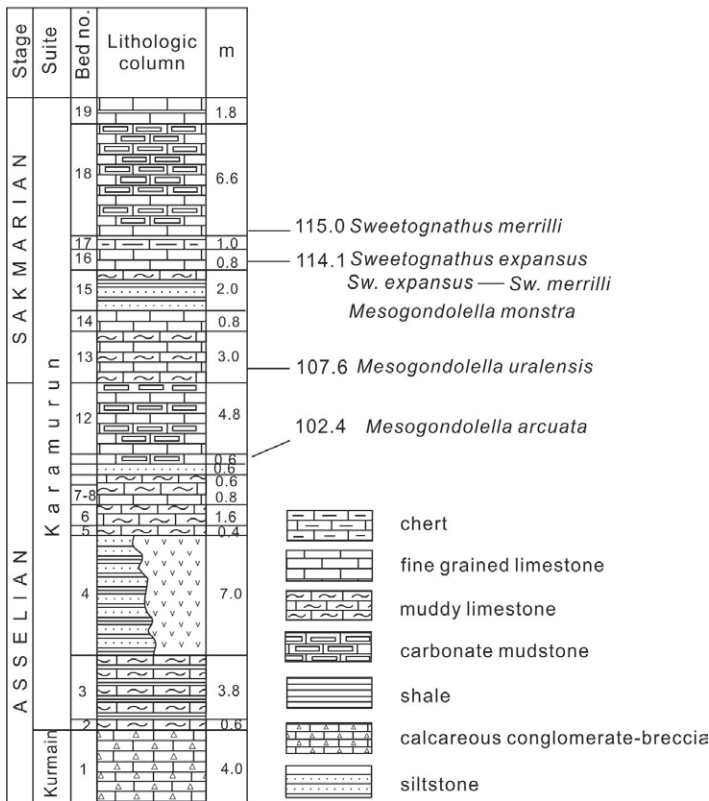
Kondorovsky section

Fig. 7. Stratigraphic column with distribution of samples taken for conodonts in the Kondurovsky section

The boundary deposits between the Asselian and Sakmarian stages at the Usolka section comprise low rock cliff exposure in the roadside groove and are thus completely accessible for study and sampling at any point (Fig. 2). The description of the transitional Asselian-Sakmarian deposits of the Usolka section (Fig. 3); indication of productive levels and the determinations of fossil remains is given below (Figs. 3, 4).

Usolka Section description (in brackets after the conodont sample number is an indication of the distance of the sample from the base of section in metres, Fig. 3)

Upper Asselian
Shikhanian horizon
Zone *Mesogondolella striata*

Bed 21. Alternation of carbonate and clay-rich rocks. The calcareous interbeds with a thickness from 4 to 25 cm have greenish-grey or dark-grey colour, are fine-grained to aphanitic. The interbeds (4-5 cm) of mudstone frequently have fragmental structure and are divided by dark-grey fissile argillite and marl (from 2.5 to 20 cm). Oval concretions of greenish-grey marl with size from 1 to 7 cm, and interbeds of dark-grey chert occur in some argillite levels. The fossil remains include brachiopods, bivalves, fish-scales, and conodonts .... 3 m

Sample 21/1 (45.3 m) is taken 1 m above the base of the bed, and includes the following conodonts: *Streptognathodus anaequalis* Chernykh, *S.* aff. *anaequalis* Chernykh, *S. lanceatus* Chernykh, *Sweetognathus* aff. *expansus* (Perlmutter), *Mesogondolella dentiseparata* (Reshetkova and Chernykh).

Sample 21/2 (45.7 m). Conodonts: *Streptognathodus barskovi* Kozur, *S. postfusus* Chernykh and Reshetkova, *Mesogondolella dentiseparata* (Reshetkova and Chernykh), *M. simulata* (Chernykh), and *M. striata* (Chernykh).

Bed 22. A 5-7 cm thick breccias occurs at the base of the bed and is composed of angular fragments of green marl, 1 cm limestone fragments, and also by different organic remains including crinoid ossicles, brachiopods, bryozoans, and "small" foraminifera. The breccia changes gradually to resistant bioclastic limestone (20 cm) that includes fragments of brachiopod shells, bryozoans and crinoids ossicles. The upper part of the bed is composed of brownish-light-grey aphanitic limestone with platy partings.. 0.9 m

Sample 22/2 (47.3 m). The sample is selected from the detrital limestone directly above the breccia, in it are the following conodonts: *Streptognathodus barskovi* Kozur, *S. postconstrictus* n. sp*., S. postfusus* Chernykh and Reshetkova, *S. constrictus* Reshetkova and Chernykh, *Mesogondolella dentiseparata* (Reshetkova and Chernykh), *M. striata* (Chernykh), and *Adetognathus paralautus* Orchard and Forster.

Bed 23. Alternation of dark grey marl with grassy-green spots and light-grey aphanitic limestone; there are layers of argillite in the middle part of the bed.. 1.2 m

Sample 23/1 (48.8 m). The sample is selected from the middle part of the bed from the brecciated marl interbed (3 cm). Here are found the conodont *Mesogondolella dentiseparata* (Reshetkova and Chernykh).

Zone *Mesogondolella pseudostriata*

Bed 24. This greenish-grey breccia changes in thickness (0-20 cm), and includes angular or poorly rounded fragments of light-brownish-grey limestone with size from 1 to 2 cm at the base of the bed. These fragments include fossils of fusulinaceans, brachiopods, crinoids ossicles and are surrounded by greyish-green marl. In places the breccia is friable and easily broken by hand. The breccia rapidly changes upward into light grey fine-detrital thick-plated limestone .... 0.45 m

Upper Asselian fusulinaceans are identified in the base of the bed: They include *Rugosofusulina serratashikhanensis* Suleimanov, *R. intermedia* Suleimanov, *Pseudofusulina sulcata* Korzhenevsky, *P. decurta* Korzhenevsky, *P. idelbajevica* Korzhenevsky, *P. ishimbajevi* Korzhenevsky, *P. rauserae* Korzhenevsky, *P. baschkirica* Korzhenevsky, *P. sphaerica* (Beljaev), *P. sphaerica timanica* Grozd.*, P. exuberate* Shamov, *P. exuberate luxuriosa* Shamov, *P. firma* Shamov, *P. differta* Shamov and *P. parva* Beljaev.

Sample 24 (49.7 m) was taken in the lower part of the bed in the first thick interlayer of limestone above the breccia. Conodonts here included: *Mesogondolella* aff. *camilla* Chernykh, *M. simulata* (Chernykh), *M. pseudostriata* (Chernykh), and *M. striata* (Chernykh).

Bed 25. The large part of this bed represents interbedded brownish-grey mudstone (1-3 cm) with characteristic conchoidal fracture and the dark grey fissile or thin-platy argillite, rarely marl. The thin interlayers of mudstone are frequently silicified. In the layer there are three interbeds (respectively from bottom to top 15, 20 and 12 cm) of the brownish-light- grey bioclastic limestone; it is resistant and partially silicified with "small" foraminifera, fusulinaceans, bryozoans, crinoids, and algae *Tubiphytes* sp. The thin interlayers of mudstone contain sometimes radiolarian and sponge spicules. Rare brachiopods, small straight nautiloids, and fish bones are encountered in the argillite and marl………............... 3.8 m

The fusulinaceans, 2 m higher than base of the layer include: *Pseudofusulinella usvae plicata* (Shamov and Shcherbovich), *Schubertella paramelonica* Suleimanov, *Rugosofusulina shaktauensis* Suleimanov, *R. pulchrella firma* Suleimanov, *P. ishimbajevi* Korzhenevsky, *Sphaeroschwagerina* cf. *sphaerica* Shcherbovich. This complex indicates an Upper Asselian age.

Sample 25/1 (50.6 m) is taken from the dark cream-coloured organic-detrital limestone with visible fusulinaceans and there are conodonts including *Mesogondolella* cf. *pseudostriata*

Sample 25/2 (51.4 m): *Streptognathodus* aff. *barskovi* Kozur, *S. constrictus* Reshetkova and Chernykh, *Mesogondolella arcuata* Chernykh, *M. pseudostriata* (Chernykh), *Mesogondolella arcuata* transitional with *M. uralensis*.

Sakmarian
Tastubian horizon
Zone *Mesogondolella uralensis*

Sample 25/3 (51.6 m): *Mesogondolella arcuata* Chernykh, *M. pseudostriata* (Chernykh), *M. uralensis* (Chernykh). This is the FAD of the index species *M. uralensis*.

Sample 1250-9 (52.05 m): *Mesogondolella uralensis* (Chernykh), *Sweetognathus postelongatus* Wardlaw, Boardman and Nestell.

Sample 25/4 (52.3 m): *Sweetognathus* aff. *merrilli* Kozur, *Diplognathodus* sp.

Sample 1250-11 (52.65 m): *Sweetognathus* aff. *merrilli* Kozur (transitional with *Sw. binodosus*, *S.* cf. *postfusus* (Chernykh), *Mesogondolella uralensis* (Chernykh).

Sample 25/5 (53.0 m): *Mesogondolella arcuata* Chernykh, *M. camilla* Chernykh, *M. pseudostriata* (Chernykh), *M. uralensis* (Chernykh), and *Diplognathodus* sp.

Bed 26: This bed comprises thin alternations of limestone, marl, and argillite. Limestone is brownish-grey and dark-grey, aphanitic with thicknesses of 2-5 cm and rarely up to 10 cm. Limestone interlayers frequently are completely silicified. In the lower part of the bed the brownish-grey and ash-grey thinly platy or fissile interbeds of argillite and marl attain a thickness of 15-20 cm, and above, their thickness decreases to 5-7 cm.

A thin (1-2 cm) crust of bioclastic limestone, including segments of crinoids, bryozoan fragments, foraminifers, and the algae *Tubiphytes* sp. is encountered in the lower part of the limestone interbeds. Plant microfossils in the argillite include abundant acritarchs of satisfactory and poor preservation..........................4.4 m.

Sample 26/1 (54.0 m) is undertaken 1 m higher than base of the bed; there are determined the following conodonts: *Streptognathodus postelongatus* Wardlaw, Boardman and Nestell, *Mesogondolella uralensis* (Chernykh), *Mesogondolella* aff. *uralensis* (Chernykh).

Zone *Sweetognathus* aff. *merrilli*

Sample 26/2 (54.3 m). This bed includes the conodonts *Streptognathodus florensis* Wardlaw, Boardman and Nestell, *S. postconstrictus*, *Sweetognathus* aff. *merrilli* Kozur, *Mesogondolella camilla* Chernykh, *M.* cf. *monstra* Chernykh and *M.* aff. *uralensis* (Chernykh).

Zone *Sweetognathus binodosus* (=*Mesogondolella monstra*)

Sample 26/3 (55.4 m). This bed includes the conodonts *Sweetognathus binodosus* Chernykh, *Mesogondolella obliquimarginata* (Chernykh), and *M. monstra* Chernykh.

Sample 26/4 (55.7 m). This bed includes the conodonts *Streptognathodus postelongatus* Wardlaw, Boardman and Nestell, *Mesogondolella obliquimarginata* Chernykh, and *M. longifoliosa* (Chernykh).

Bed 27. Brownish-grey marl with platy separation at a thickness of 3-5 cm. Upper 4 m of layer includes three interlayers of bioclastic limestone with a bed thickness up to 15 cm, which consist of small foraminifers, bryozoans, crinoids, the algae *Tubiphytes*, and other fossil detritus. Tastubian fusulinaceans are determined in the limestones and include *Rugosofusulina shakhtauensis ellipsoidalis* Suleimanov, *R.* ex gr. *shakhtauensis* Suleimanov, *Pseudofusulina ischimbajevi* Korzhenevsky, *P. baschkirica acuminata* Kireeva, *P. verneuili* (Moeller), *P. conspiqua* Rauser-Chernousova, *P.* cf. *fixa* Kireeva, and *P. angusta* Kireeva.

The thin (5-10 cm) interbeds of aphanitic limestone are distributed throughout the unit.

Sample 27 (57.4 m). This bed includes the conodont *Mesogondolella manifesta* Chernykh.

Thus, the interval between the levels of the lower boundary of Sakmarian Stage, determined by the conodonts (51.6 m) and the first definite Tastubian (Lower Sakmarian) fusulinaceans (57.4 m), is a little less than 6 m in the Usolka section. The bioclastic limestone in Bed 26 lacks fusulinaceans.

Conodonts

The Asselian-Sakmarian conodonts in the section Usolka, which we propose to use as the stratotype of the lower boundary of Sakmarian Stage, are characterized by high frequency of occurrence (from 75 and more per kilogram of sample) and good preservation. Almost all the obtained P1 elements are complete and transparent with CAI 1.0-1.5, without adhering particles and can be used for determining strontium isotopes.

Conodonts of the genus *Mesogondolella* are most abundant in this interval at both the Usolka and the Kondurovsky sections. Systematic composition and stratigraphic distribution of mesogondolellids in both sections is surprisingly monotonous (Figs. 5-6). The characteristic form *Mesogondolella uralensis* Chernykh, which is considered by us as the member of evolutionary lineage *M. pseudostriata - M. arcuata - M. uralensis - M. monstra* (Chernykh, 2006) (Fig. 8), first appears near and somewhat below the traditionally adopted (on the basis of fusulinaceans) boundary of Sakmarian Stage.

This sequence of conodonts is established in both Usolka and Kondurovsky sections despite differences in facies, and proves the reality of evolutionary nature of the revealed chronomorphocline, which is used by us as the basis for the zonation of the transitional deposits between the Upper Asselian and Sakmarian. We propose to define the position of the lower boundary of the Sakmarian Stage with an evolutionary event - the appearance of the characteristic species *Mesogondolella uralensis* within the chronomorphocline *M. pseudostriata- M. monstra* (Fig. 8). Asselian-Sakmarian species of *Mesogondolella* are recognized in many localities in North America including Nevada, western Canada and arctic Canada, but often were lumped into *M. bisselli*. Work in progress will show that these species can be differentiated.

As an auxiliary, we use data about the evolutionary development of the representatives of the genus *Sweetognathus** (Fig. 9), which can
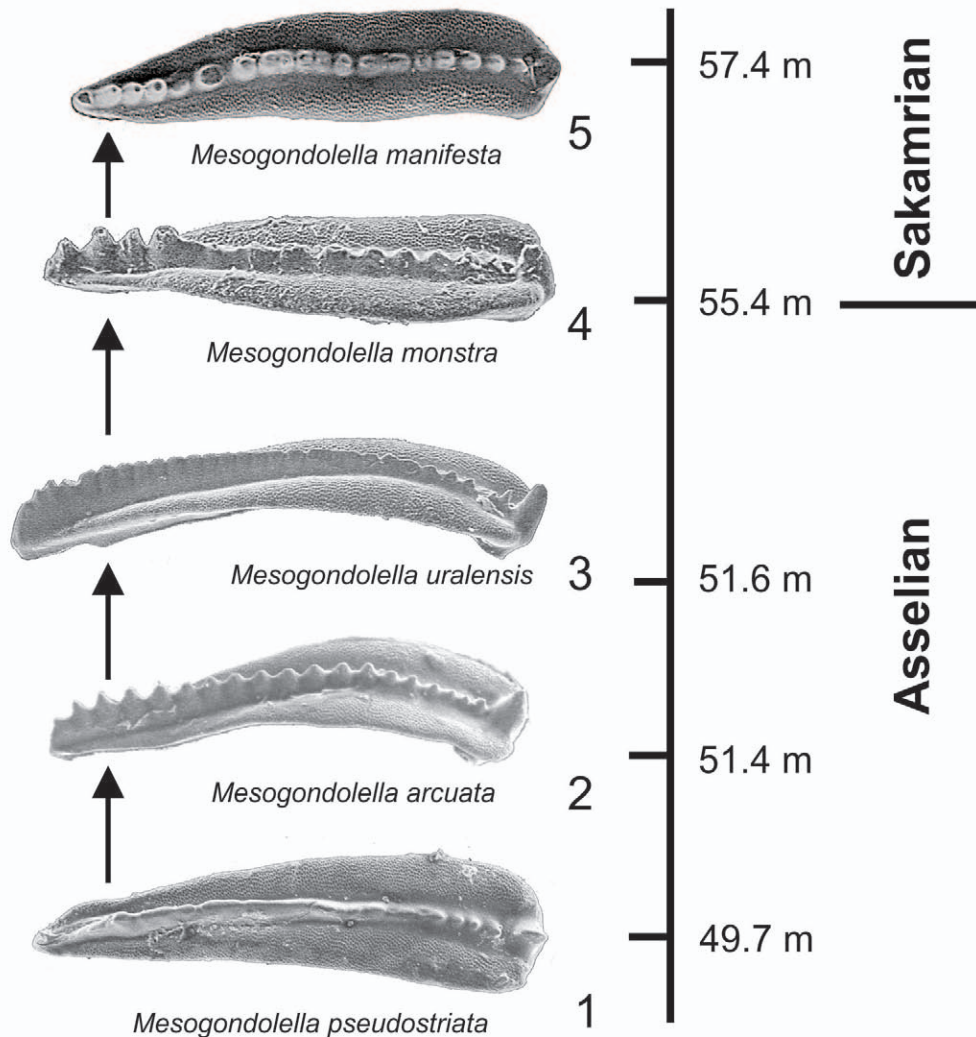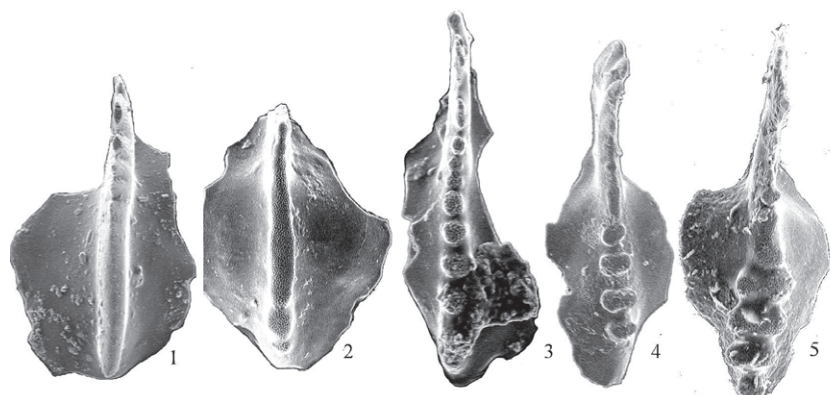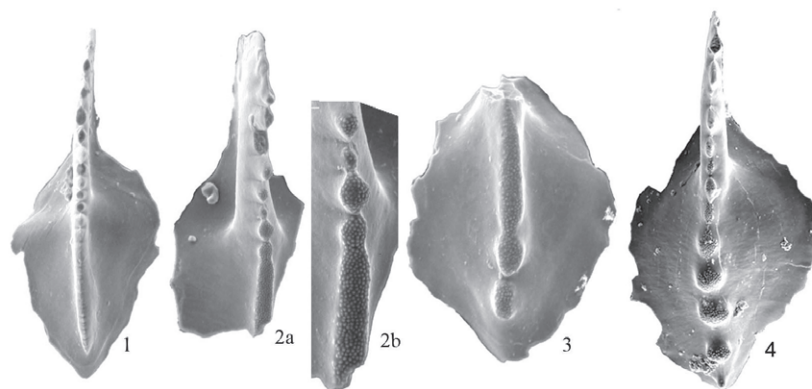

Fig. 8. The evolutionary lineage of the Asselian-Sakmarian species of the genus *Mesogondolella*.

A Evolutionary trend of species of genus *Sweetognathus* in Usolka section

B Evolutionary trend of species of genus *Sweetognathus* in Kondurovsky section

Fig. 9. A, the evolutionary lineage *Sweetognathus expansus – Sw. binodosus* in the Usolka section. 1 – *S. expansus* (Perlmutter), Bed 14; 2 – transitional from *Sw. expansus* to *Sw. merrilli* Bed 21/2; 3 – *Sweetognathus merrilli* Kozur, Bed 26 (54.3 m from the beginning of section); 4, 5 – *Sweetognathus binodosus* Chernykh, Bed 26 (55.4 m from the beginning of the section).
B. The evolutionary lineage *Sweetognathus aff. stevensi – Sweetognathus merrilli* in the Kondurovsky section. 1 – *Sw.* aff. *stevensi* (Clark and Carr), the middle part of Bed 16; 2, 3 – forms transitional from *Sw.* aff. *stevensi* (Clark and Carr) to *Sw. merrilli* Kozur (Fig. 2b is the increased fragment of Fig. 2a), upper part of Bed 16; 4 – *Sw. merrilli,* Bed 18.

also be used to approximate the lower boundary of Sakmarian (Mei *et al*., 2002). The first representative of this genus in the Uralian succession, *Sweetognathus* aff. *expansus* (Perlmutter), appears in the Usolka section in Bed 21 (Upper Asselian). These forms possess the continuous undifferentiated carina with the pustulose surface. Further evolution of this conodont group follows the path of the differentiation of the carina, and leads to the appearance of *Sweetognathus* aff. *merrilli* Kozur, which is characterized by a few carinal nodes (Fig. 9). The identical evolutionary sequence of this species has been established also in the Kondurovsky section (Fig. 9).

The level of appearance of *Sweetognathus* aff. *merrilli* in the Usolka section nearly coincides with the first appearance of *Mesogondolella uralensis*. We found the typical *Sw.* aff. *merrilli* in the Usolka section in the upper part of Bed 25 and lower part of Bed 26. The same example of this form from Bed 25/3 was found and demonstrated to us by Bruce Wardlaw at the session of the Permian working group in January 2003 in Boise (USA, Idaho). The first appearance of *Mesogondolella uralensis* at 51.6 m is only 70 cm lower than the first occurrence of *Sw*. aff. *merrilli*, and this fact makes it possible to consider the levels of the first appearance

of these species nearly identical. In the Kondurovsky section *M. uralensis* appears somewhat earlier than *Sw.* aff. *merrilli* (Fig. 7), but the 5 m interval between them is small in temporal expression, taking into account the rapid deposition of flysch sedimentation in this section. The species *Sw.* aff. *merrilli* may be widespread* (Urals, North America, China), but care must be taken before it can be used as an auxiliary indicator of lower boundary of Sakmarian. *Sweetognathus* aff. *merrilli* has not been recovered in the Canadian Arctic, but its descendant *Sw. binodosus* has (Fig. 9). Furthermore, a strong correlation can be made on the basis of other conodonts and the nature of cyclothem cyclicity. Figure 11 shows a potential correlation between Arctic Canada (Beauchamp and Henderson, 1994) and Usolka. The Asselian-Sakmarian GSSP is correlated with a level in the Nansen Formation where cyclothems change in character. This level also coincides with the apparent extinction of *Streptognathodus* including the species *S. fusus*. Carboniferous holdovers like *Adetognathus* occur for a short distance above. The first *Sweetognathus* species occurs where cyclicity is lost and instead the lithology forms a broad third order sequence into the Artinskian. The remarkable changes of lithologic pattern as shown in figure 9 occur in many other sites as well.
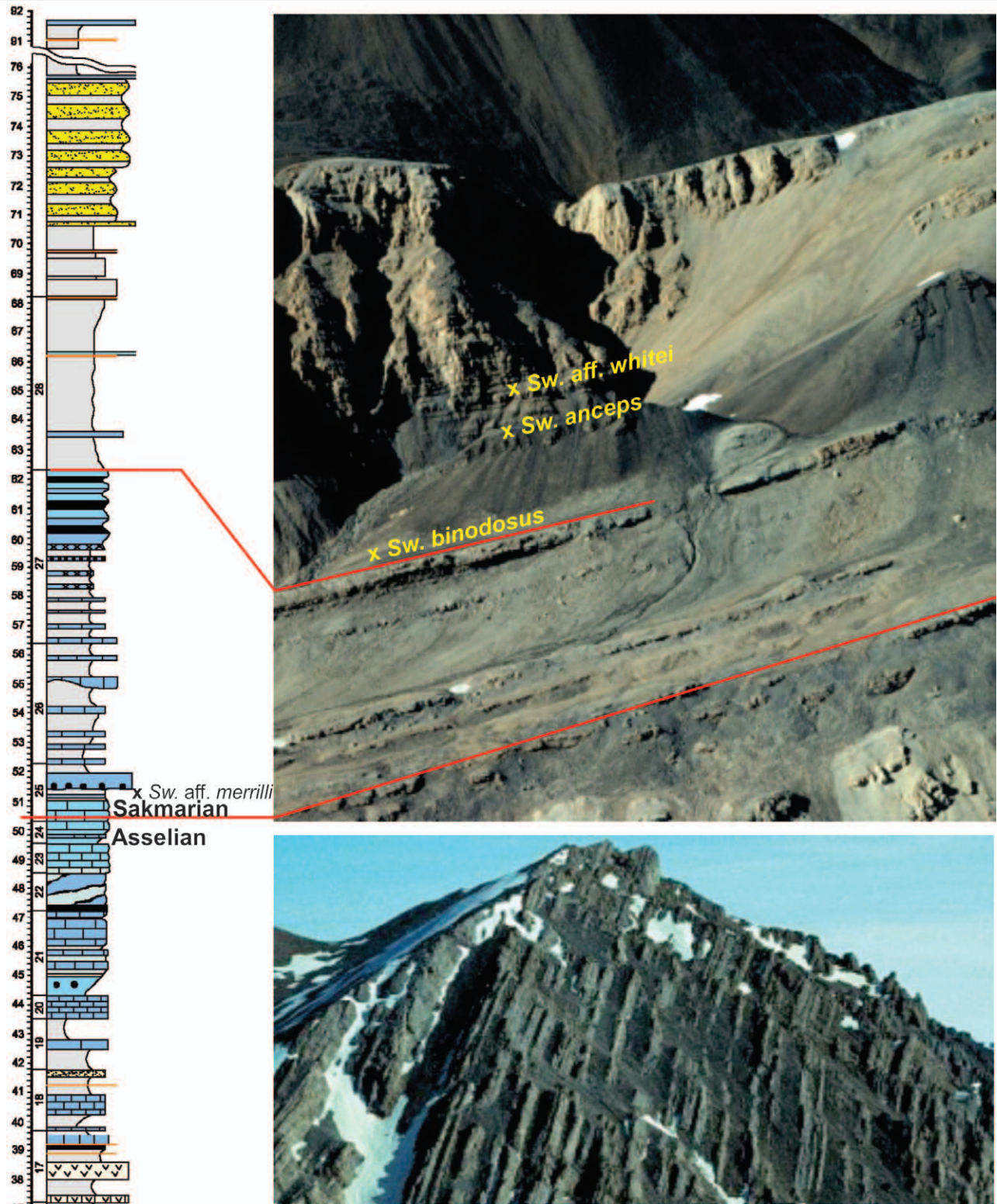
Fig. 10. A combination of lithologic pattern and biostratigraphy as a means of correlation. A strong correlation can be made on the basis of conodonts and the nature of cyclothem cyclicity. Potential correlation between Arctic Canada (Beauchamp and Henderson, 1994; photos by C. Henderson) and Usolka (section modified from Schmitz and Davydov, 2012) is depicted. The lower photo shows the Kasimovian to Asselian Nansen Formation cyclothems and the upper photo shows the units immediately above. The Asselian-Sakmarian GSSP level is correlated with a level in the upper Nansen Formation where cyclothems change in character; this level also coincides with the apparent extinction of *Streptognathodus* including the species *S. fusus*. Immediately below are species of *M. dentiseparata*. Carboniferous holdovers like *Adetognathus* occur for a short distance above. The first *Sweetognathus* species occurs where cyclicity is lost and instead the lithology forms a broad third order sequence into the Artinskian Great Bear Cape Formation as correlated by the FO of *Sw*. aff. *whitei* (see base-Artinskian GSSP proposal of Chuvashov et al., 2013).

The first sweetognathids defined as *Sw. merrilli* Kozur are found in East Kansas (USA) in the upper part of the Eiss limestone of the Bader Limestone Formation, which occurs in the upper part of the Council Grove Group. A comparable occurrence of *Sw. merrilli* Kozur is recognized in west Texas in the Neal Ranch Formation of the Glass Mountains - 52 m above the base of the section. These occurrences are older than the base-Sakmarian*. Elsewhere in the USA, Wardlaw and Davydov (2000) showed results of a fusulinacean study that provide a basis for correlation of the lower boundary of the Sakmarian in the basal part of the Carbon Ridge Formation (Nevada); in California the interval, in which this boundary can be correlated, is within the limits of zones B and C of the McCloud Limestone.

Boardman et al. (2009) demonstrated a zone breakdown of Upper Carboniferous and Lower Permian on midcontinent conodonts including the zones *Streptognathodus barskovi*, *S. postconstrictus* and *S. trimulus*. The lower boundary of the *barskovi* Zone coincides with the level of the appearance of *Sweetognathus merrilli* Kozur*. The upper boundary of the *trimulus* Zone is noted by the first appearance of *Sw. whitei* (Rhodes)*.

The Ziyun County section in Guizhou (Kang et al., 1987) contains Asselian deposits, including beds 17-21, where *Mesogondolella*

striata Chernykh is recognized (according to the author's determination - *M. bisselli*) and *Adetognathus paralautus* Orchard. The first forms close to *Sw. anceps* Chernykh, in this section are found in Bed 22. Probably, this short interval, which includes parts of beds 21 and 22, corresponds to the Asselian-Sakmarian boundary deposits. Fusulinaceans obtained in these layers do not contradict this conclusion.

The abundance of conodonts at all levels, noted on the lithologic-stratigraphic columns for the Usolka and Kondurovsky sections is from 50 to 100 specimens per kilogram. However, the quantity of specimens of the genus *Sweetognathus* is small in comparison. Evidence has emerged that the holotype of *Sweetognathus whitei* from the Tensleep Sst in Wyoming (Rhodes, 1963) represents part of an older lineage and may in fact be Late Asselian as suggested by the associated species of *Streptognathodus*. This older lineage is also indicated for the Florence Limestone in Kansas and the Yaurichumbi Formation in Bolivia (Henderson and Schmitz, in preparation) where *Streptognathodus* also overlaps the *Sweetognathus* lineage. The older lineage is thus marked by *Sweetognathus expansus* to *Sweetognathus merrilli* to *Sweetognathus whitei*. The younger lineage in Russia, which represents an ecologic replacement of *Streptognathodus*, includes
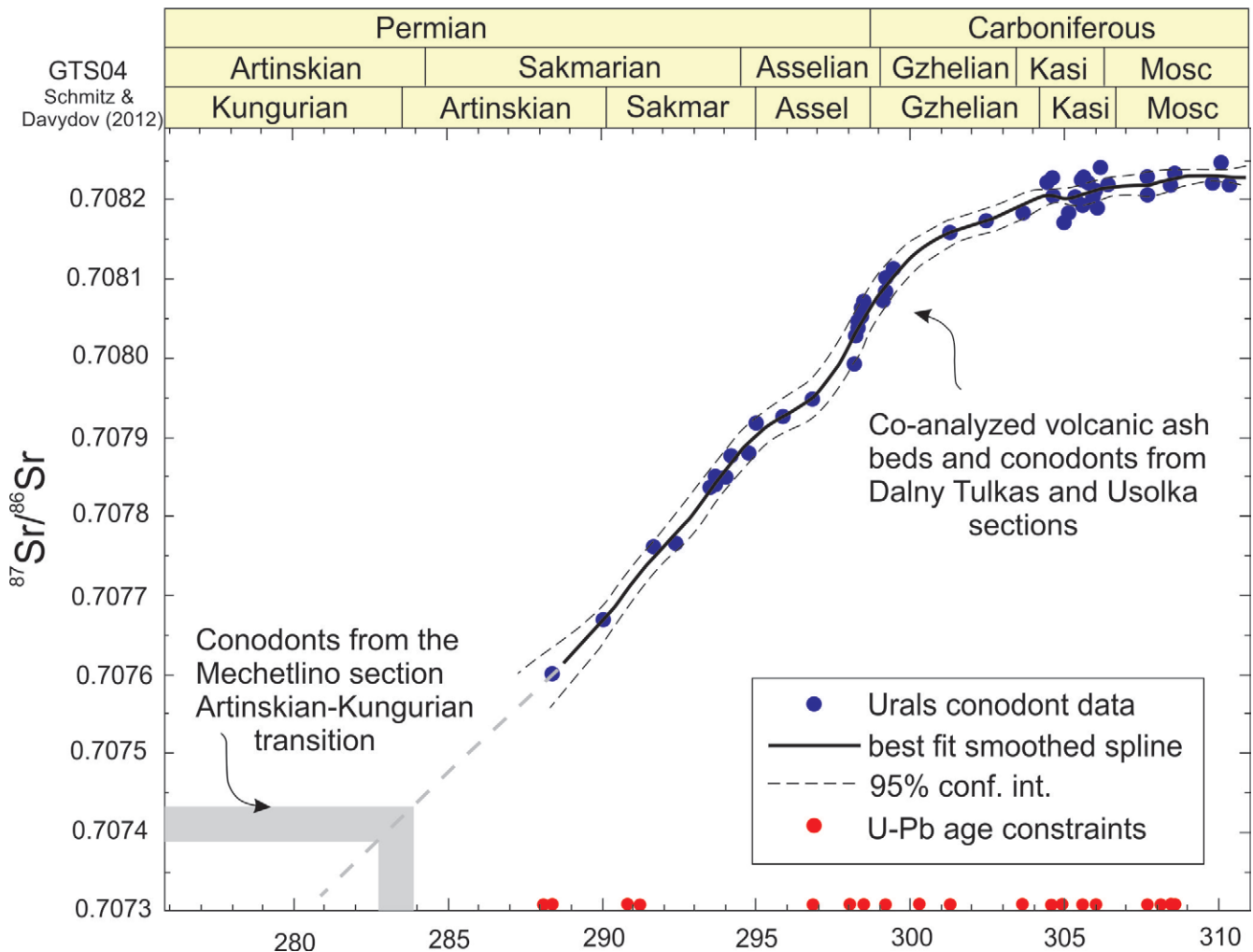

Fig. 11. Age model for Sr-isotopic work by Mark Schmitz Russian sections (after Henderson et al. (2012)
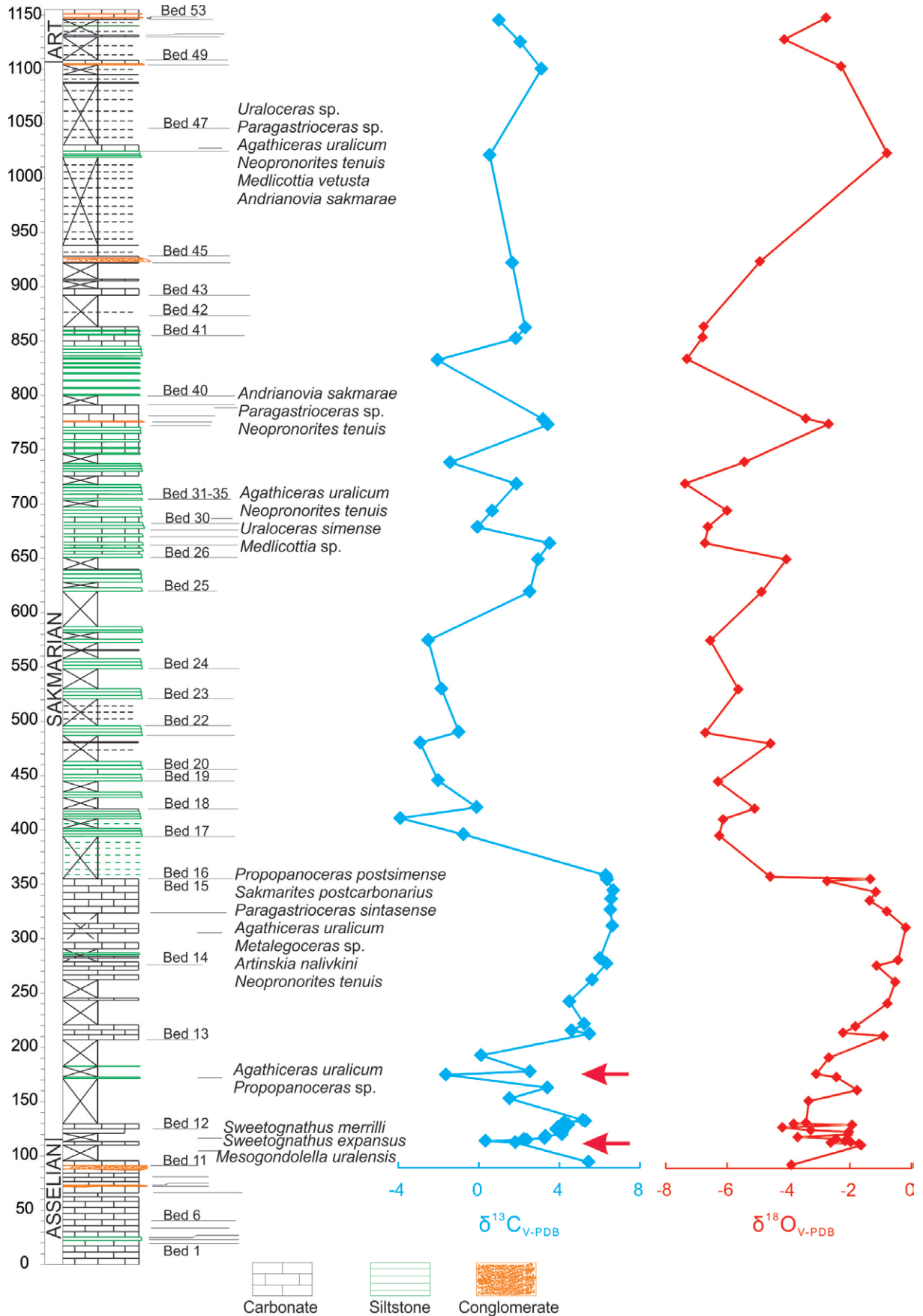
Fig. 12. Biostratigraphy and carbon and oxygen isotopic trends of the Kondorovsky section (after Zeng *et al.*, 2012).
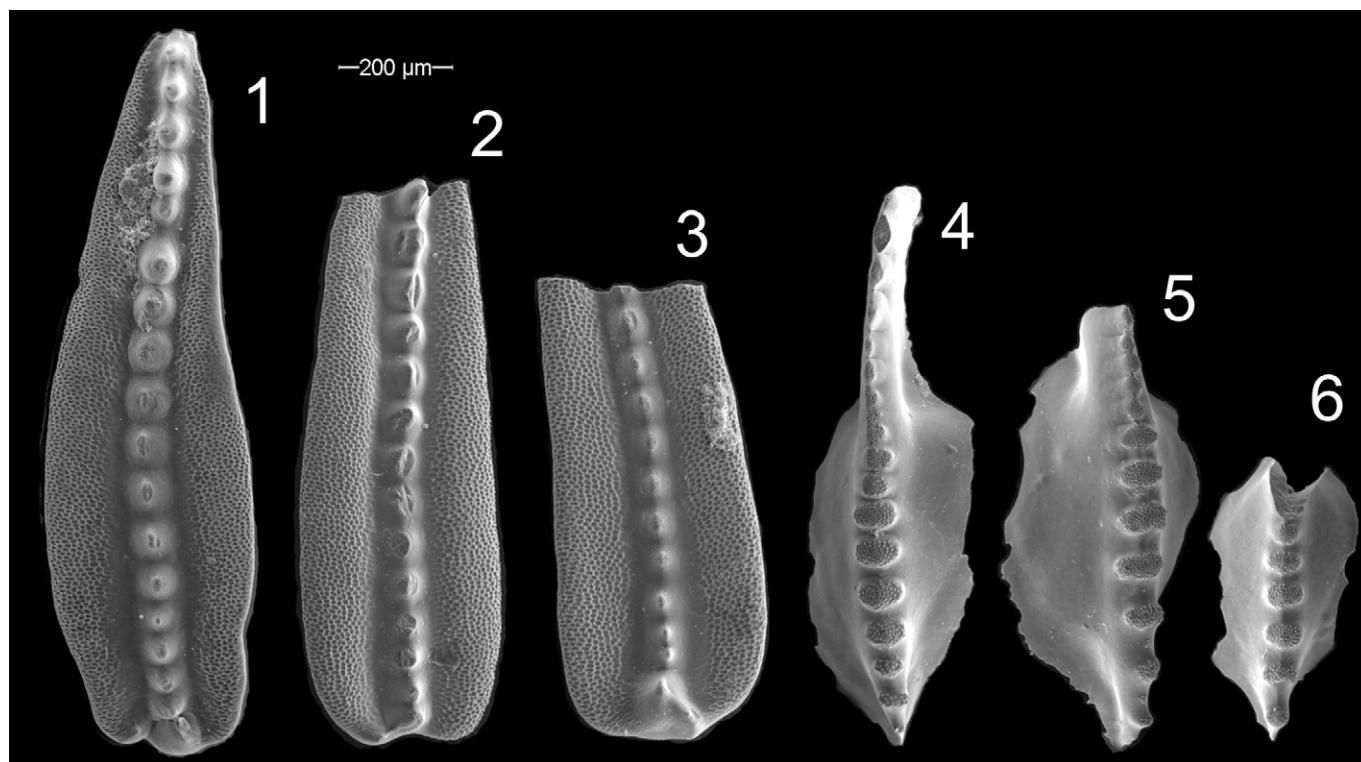
Fig. 13. Conodonts around the base of Sakmarian at Carlin Canyon in northern Nevada, USA. 1. *Mesogondolella monstra* (transitional? with *M. striata*), sample 684; 2. *Mesogondolella monstra*, sample 684; 3. *M. monstra* (transitional? with *M. obliquimarginata*, samples 685; 4. *Sweetognathus binodosus*, sample 685; 5. *Sweetognathus binodosus*, sample 685; 6. *Sweetognathus binododus*, sample 684. Material is from the MSc thesis of Elinda Dehari which is in progress under my supervision. Sample 685 is about 2 metres higher than 684 in a section that is several hundred metres thick; both are from the lower Buckskin Mountain Formation. These specimens are above the last *Streptognathodus* in the section including *S. fusus* and *S. postfusus*.

Sweetognathus expansus (a long ranging form species), *Sw*. aff. *merrilli*, *Sw. binodosus*, *Sw. anceps* and finally *Sw*. aff. *whitei*; *Sw*. *merrilli* is thus early Asselian, whereas *Sw*. aff. *merrilli* is 3.5 Myrs younger occurring near the Asselian-Sakmarian boundary. The carinal differentiation in *Sw. merrilli* is very irregular in contrast to *Sw*. aff. *merrilli*. Despite the nomenclatural issue these two lineages are clearly separated in time as determined by strontium isotopes and geochronology (Henderson and Schmitz, in preparation).

Fusulinaceans

Fusulinaceans in this section do not form a continuous series, but they are found at several levels (Fig. 4), separated by large intervals, which makes it necessary to use an assemblage of fossil organisms for correlation (fusulinaceans, conodonts, miospores), especially given lithologic compositional variations of the deposits. Rare levels with radiolarians only were fixed on the initial stage of study, subsequently they were used, but they did not influence the existing position of boundaries.

Fusulinaceans are found only in two upper beds of the Kholodnolozhskian horizon in the thin interbeds of fine bioclastic limestone. This is in essence the species of the genus *Pseudofusulina*, which forms the characteristic complex of the upper part of the horizon. The almost complete absence of *Schwagerina* is also noteworthy, as it occurs often in shallow carbonate facies. One example of *Sphaeroschwagerina* cf. *sphaerica* is found only in the upper part of Bed 25.

The lower boundary of the Tastubian horizon (10 m) is determined according to a change in the species. In the upper 4 m of the 10 m layer there are three interbeds with an impoverished, but significant complex of *Rugosofusulina* and *Pseudofusulina* with the presence of the characteristic Sakmarian form- *Pseudofusulina verneuili* (Moeller).

U-Pb geochronology

Schmitz and Davydov (2012) carried out a radiometric study, based upon high-precision, isotope dilution-thermal ionization mass spectrometer (ID-TIMS) U-Pb zircon ages for interstratified ash beds in the southern Urals sections (Fig. 4). Here we provide the results of analysis of two ash-beds from Usolka section, that bracket the Asselian-Sakmarian transition under consideration in this proposal. Zircons of ash-bed from the Kholodnolozhskian horizon (Bed 18; 41.25 m above the base were analyzed, nine single grains of zircon yielded a weighted mean $^{206}Pb/^{238}U$ age of 296.69 ± 0.12 Ma. The second studied ash-bed 25 metres higher in the section (Bed 28; 66.2 m above base) relates to Sakmarian, a number of equant zircons from this ash sample gave a weighted mean of $^{206}Pb/^{238}U$ date of 291.10 ± 0.12 Ma for eight crystals, excluding three antecrysts. The extrapolated age for bed 25.2 at 51.4 metres is 295.5 Ma (Fig. 4).

Strontium Isotopes

Schmitz et al. (2009) in a presentation at the International Conodont Symposium indicated a consistent secular trend of $^{87}Sr/^{86}Sr$ isotopic values from conodont elements through the Early Permian. The $^{87}Sr/^{86}Sr$ isotopic value for the base-Sakmarian was approximately 0.70787 (Schmitz et al., 2009). Strontium isotopes from individual conodont elements have been integrated with geochronologic ages to produce a time model (Schmitz in progress). The strontium isotopic composition of seawater at the base of the Sakmarian Stage is now calculated at $^{87}Sr/^{86}Sr = 0.70787$ (Fig. 11).

Carbon isotope chemostratigraphy

A group of Chinese researchers with the participation V. Davydov (USA, Boise State University) conducted a study of stable carbon and oxygen isotopes in the south Urals sections - Usolka, Dal'ny Tulkas and Kondurovsky (Zeng et al. 2012). The basic results, obtained at the Usolka section are of interest to this proposal (Figs. 4, 12).

1. A gradually increasing trend in carbonate carbon isotope ($\delta^{13}C_{carb}$) values has been observed in the interval from the base of Asselian to early Sakmarian, which is generally consistent in timing with the increasing development of Glacial III or P1 from the latest Carboniferous to early Sakmarian (Early Permian) which prevailed in southern Gondwana (Fig. 4).

2. An excursion with double negative shifts in $\delta^{13}C_{carb}$ value is documented immediately above the Asselian/Sakmarian boundary in both the Usolka and Kondurovsky sections (Figs. 4, 9, 12), which may have potential to serve as chemostratigraphic markers for intercontinental correlation (Zeng et al., 2012). However, more work in different areas is necessary to confirm this pattern.

3. The following highly positive excursion of $\delta^{13}C$ in early Sakmarian indicates the maximum expansion of Glacial III or P1. The negative $\delta^{13}C$ shift in the early to middle Sakmarian is possibly related to the quick collapse of Glacial III or P1 on Gondwana; this also accounts for the cyclothemic pattern change (see Fig. 10). This negative shift is largely correlative with those documented in other areas of Russia, the North American craton and South China, but further precise biostratigraphic and geochronologic constraints are necessary to confirm this global signal.

4. The late Sakmarian is characterized by a strong oscillation stage of $\delta^{13}C$, which probably indicates a complex climate transition marked by smaller alternating glacial–interglacial transitions during Glacial P2 superimposed on an overall warming trend (Figs. 4, 12).

Alternative position at the FAD of *Mesogondolella monstra*

It is proposed herein that the GSSP position should be placed at the base of bed 25/3 at 51.6 m and the apparent FAD of *M. uralensis*. There are at least three problems for this position: 1) the point is at the base of a coarser event bed which may have reworked or concentrated conodonts and not within the background thin-bedded strata; 2) according to CMH *Mesogondolella uralensis* has not yet been recognized outside of the Uralian region; and 3) the taxonomic issues with associated *Sweetognathus* species. A higher position that provides good correlation between the Urals and North America is the first appearances of *Mesogondolella monstra* and *Sweetognathus binodosus* in Bed 26/3 at 55.4 m. CMH provides a few specimens from Carlin Canyon in northern Nevada to compare to the Uralian material (Fig. 13). These specimens come from the lower Buckskin Mountain Formation, which is a broad 3rd order sequence above the cyclic Upper Strathearn Formation. Similar material has been recovered in Western Canada and the Sverdrup Basin in the Canadian Arctic. This may well be the first level in the "Sakmarian" in which the named species compare very well and may signal interregional migration of taxa associated with the near-termination of P1 glaciation. This position is very close to the extinction of *Streptognathodus* and above a sample at Bed 26/2 in which *Streptognathodus florensis* is listed. This taxon occurs in the Florence Limestone in Kansas, which has been correlated with the base-Artinskian (instead of the near base-Sakmarian as indicated here). One potential disadvantage is that this new level would be at least a million years younger than the current interpolated base-Sakmarian. We welcome some discussion on this alternative position.

Summary

We propose that the base-Sakmarian stage be defined by the FAD of *Mesogondolella uralensis* in Bed 25 at 51.6 mab at the Usolka section. An extrapolated geochronologic age of 295.5 Ma, strontium isotope values near 0.70787, and a double negative shift in $\delta^{13}C_{carb}$ value just above the boundary serve as additional methods to correlate the boundary. Furthermore, *Sweetognathus* aff. *merrilli* appears immediately above the defined boundary and additional fossils including fusulinaceans provide additional data to assist correlation.

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Henderson's Harangue #1

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Introduction

I have edited many issues of *Permophiles* and submitted a number of articles over the years, which I hope allows me to make some remarks about some things that concern me, in an attempt to stimulate debate – in other words, to deliver a harangue. In Italian, it would be "L' arringa di Henderson" (the double "r" is important). I may do this a few times.

Why don't we place our biostratigraphic data within a sequence stratigraphic context on a regular basis, and when we try, why don't we get it right?

I recently checked out the paper by Catuneanu et al. (2011; Newsletter of Stratigraphy, v.44/3, 173-245), which provides an excellent summary of all of the methods and types of sequence stratigraphy. While this is an excellent paper, in my view, it makes the whole process seem complex and daunting with a plethora of terminology that will leave only the sequence stratigrapher satisfied. I suspect many of us would like a simplified practical version of sequence stratigraphy. It exists in the form of the T-R sequences as recognized in the work of Ashton Embry of the GSC (Fig. 1). This is reviewed in Catuneanu et al. (2011), but largely, in my view, negatively. This is partly because Embry was not the greatest ambassador of his own method – suggesting all other methods were theoretical and his, the only material-based method. A few years ago, Embry provided a series of well-illustrated figures and text in the Canadian Society of Petroleum Geologists Reservoir (in 2008 and 2009) that I think make sequence stratigraphy accessible for everyone (ask him or me for a copy by email). The classic sequence boundary has two components; a subaerial unconformity (SU) linked to a marine maximum regressive surface (MRS). The point where these two components connect is synchronous, but the rest of the MRS is younger than the rest of the SU. Lithofacies show evidence of shallowing (e.g. thicker beds and coarser) toward the MRS and deepening (e.g. thinner beds and fining) above and would be recognized as a bedding surface or a surface within a narrow interval of strata where this lithofacies trend is observed. During the initial transgression, non-marine deposits will accumulate on the SU because the change in base-level provides accommodation in which those deposits may be preserved (but, they could be later eroded by the advancing shoreline – see SR in Fig. 1). Therefore, those non-marine lithologies occur above the SB (not below, as I have seen occasionally in my reviews of manuscripts). Subsequently, the deepest lithofacies in any given section will mark the MFS (maximum flooding surface) – above which, lithofacies show evidence of shallowing within the RST (Regressive Systems Tract). The biostratigrapher looking at deeper marine sections may recognize a sudden influx of shallow-water taxa around the MRS and a sudden abundance of deeper-water taxa at the MFS – these factors need to be considered as a biozonation is developed. I think all of us could do better and this leads into my second harangue.

We live during a transgressive systems tract, but do we really need a new stratigraphic unit to mark this moment in time, when perhaps marking the initial transgression and subsequent MFS would be sufficient?

I speak of the proposal by mass media flooding (MMF), to name the Anthropocene. I listened to several presentations on the Anthropocene at the recent IGC meeting in Cape Town and was very impressed by the types of research being conducted. As a general concept to advance research, I think the Anthropocene is a winner. But, it doesn't belong in the Geological Time Scale! The Geological Time Scale should not be advanced by MMF activity, but rather by very careful and detailed stratigraphic research. I was relieved to hear that the latest proposal to name the Anthropocene
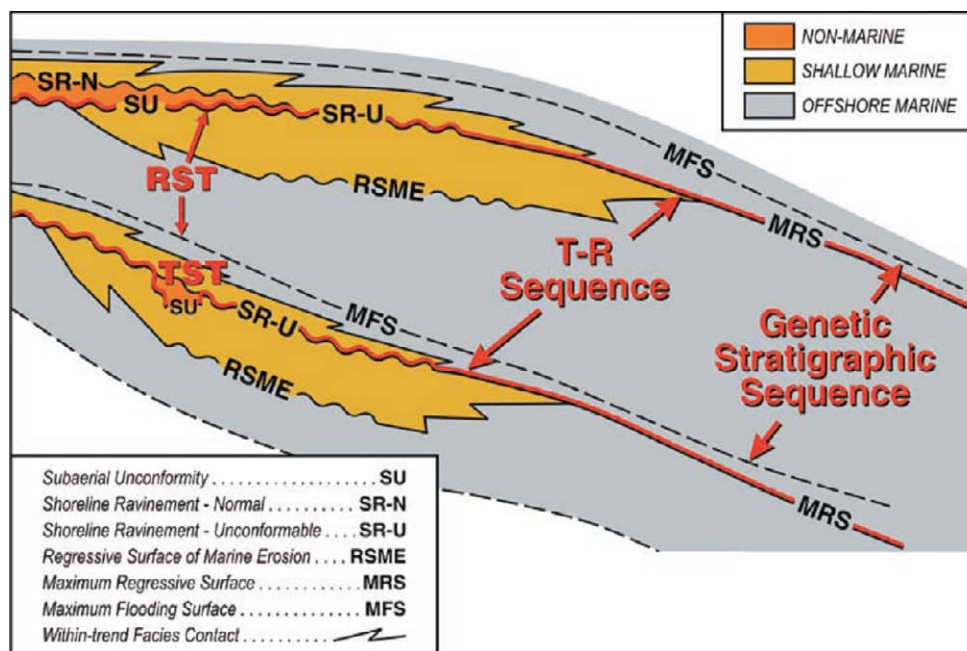
Fig. 1. Shows genetic sequence model of Galloway (sequence boundaries = MFS) and T-R model of Embry (sequence boundaries = SU + MRS; may also include SR-U if advancing shoreline eroded all of the non-marine facies). From Embry's series in CSPG Reservoir (Fig. 2 of Reservoir issue 7 in 2008).

is to have the year 1950 as its base – relieved to know, that while I may no longer be young, I am at least young enough to have lived only in one geologic epoch. I fear for that single lamina marking 1950, sitting precariously on the seafloor, hoping that it won't be wiped out by the next storm in the Pacific or the Baltic Sea or for that bit of ice formed in 1950 about to melt on Antarctica or Greenland. I was incredibly impressed by the levels of resolution considered normal in Quaternary research as presented at IGC – it cannot be matched in deep-time. This does affect the way 'Quaternary and Before-Quaternary (BQ)' researchers view the practice of stratigraphy. In my BQ-view we live during the Holocene transgression (even if there have been a few minor cycles or parasequences along the way, as I learned at IGC). The next potential stratigraphic-based surface upon which to hang a geologic epoch could be the MFS. If it is as great (or high) as some models predict, then there may be significant condensation in offshore marine locations or sufficient extinctions to mark this point. Unfortunately, the events leading to this MFS could hasten our own extinction, in which case the whole debate will be moot, as we might not be around to see the subsequent RST. I agree with Stan Finney, former ICS Chair, that to name the Anthropocene as a chronostratigraphic unit will require a unit with material both below and above the chosen surface. We just aren't there yet, but we do have a high-resolution place to record the events of the Anthropocene (just as the Renaissance) – it is a calendar.

Permophiles used to have more letters and comments. It could again, if you wish to reply to my harangue. Or beat me to the punch with my next topics, which will likely be: 1) when is a species a species or the *H. parvus* issue; 2) all biostratigraphy, even Unitary Associations, depend on good taxonomy; and 3) why do geologists fear conforming to definitions of geologic terms and of GSSPs.

New dates for Permian palynostratigraphic biozones in the Sydney, Gunnedah, Bowen, Galilee and Canning basins, Australia

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Australia has some of the best documented Permian basins in Gondwana, but much of the succession is nonmarine. Calibration of the local palynostratigraphic scheme (Price, 1997) to the global timescale was indirect and very difficult, having traditionally relied on correlations from relatively sparse, high-latitude, marine strata, within which ammonoids and conodonts are rare, fusulinids are unknown, and much of the other fauna (brachiopods, bivalves) is endemic. Tie points are rare and often tenuous (Mantle et al., 2010): one example is the record of a single specimen of the ammonoid *Cyclolobus persulcatus* from the Cherrabun Member of the Hardman Formation, in the Canning Basin, Western Australia (Foster and Archbold, 2001), dated as 'post-Guadalupian' by Glenister et al. (1990) and 'Capitanian–Dzhulfian' by Leonova (1998).

In eastern Australia, the Permian succession is replete with felsic ash beds, many of which contain zircons. Ash beds are rare in Western Australia, but some have been found in the Canning Basin. Sampling of ash beds has been coupled with sampling of adjacent clastics for palynomorphs, mostly from drillcore and coalmines in the Sydney, Gunnedah, Bowen and Galilee basins in eastern Australia, and drillcore in the Canning Basin in Western Australia. The zircons have been subjected to the Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry (CA-IDTIMS) technique for U-Pb dating (Mattinson, 2005). The resultant radioisotopic dates, with associated palynostratigraphic determinations, permit the direct calibration of the Price (1997) scheme to the numerical timescale. Some of the data has been cited previously (Smith and Mantle, 2013; Nicoll et al., 2015, 2016; Metcalfe et al., 2015; Phillips et al., 2016). A more detailed synthesis of the Guadalupian and Lopingian will be published soon (Laurie et al., in press) and a study of the Cisuralian is in progress.

The results of Laurie et al. (in press) indicate that the palynozones in the Guadalupian and Lopingian of Australia are significantly younger than currently calibrated (Fig. 1). The recalibrations indicate:

the top of the *Praecolpatites sinuosus* (APP3.2) Zone lies in the early Roadian; the top of the *Microbaculispora villosa* (APP3.3)
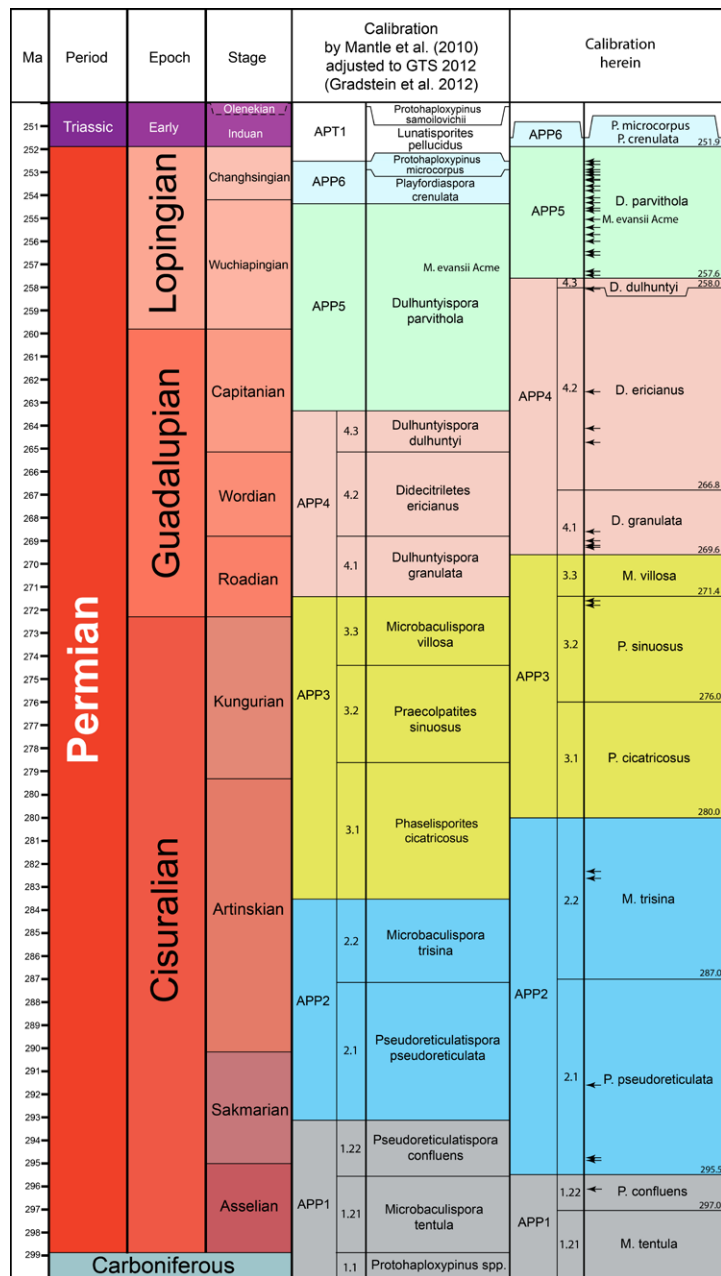
Fig. 1. Recalibration of Australian Permian palynostratigraphy. At left is the Permian timescale of Henderson et al. (2012) with the Permo-Triassic boundary age from Burgess et al. (2014). In the middle is the calibration of the eastern Australian palynostratigraphic scale of Mantle et al. (2010), updated to GTS 2012 (Gradstein et al. 2012). On the right is the calibration of the Guadalupian and Lopingian based on the new CA-IDTIMS dates of Laurie et al. (in press). The calibration of the Cisuralian is preliminary and is based on work still in progress.

Zone lies in the middle Roadian; the top of the *Dulhuntyispora granulata* (APP4.1) Zone lies in the Wordian; the top of the *Didecitrletes ericianus* (APP4.2) Zone lies in the first half of the Wuchiapingian; the entire *Dulhuntyispora dulhuntyi* (APP4.3) Zone lies within the Wuchiapingian; and the top of the *Dulhuntyispora parvithola* (APP5) Zone lies at or near the Permian−Triassic boundary.

These new calibrations involve some major changes, the most significant being the base of the *Dulhuntyispora parvithola* (APP5) Zone, which is about 6 million years younger than previously calibrated.

A preliminary assessment of the Cisuralian, in eastern Australia, suggests that the *Pseudoreticulatispora pseudoreticulata* (APP2.1) Zone and the *Microbaculispora trisina* (APP2.2) Zone (APP2.2) are both of greater duration than previously thought. Contrastingly, the *Pseudoreticulatispora confluens* (APP1.2.2) Zone is older and of shorter duration than previously suggested (Mantle et al., 2010). However, at this stage this interpretation is based on relatively few dated ash beds (Fig. 1).

Preliminary data indicates that similar miscorrelations are also a feature of the current Mesozoic palynomorph zonation, and future work will attempt to remedy this.

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Insights into the Permian/Triassic transition in Western Tethys: new stratigraphic and paleontological data from the Catalan Pyrenees (NE Iberian Peninsula)

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Introduction

The Permian and Triassic successions of the Catalan Pyrenees provide key information on the stratigraphic and paleontological
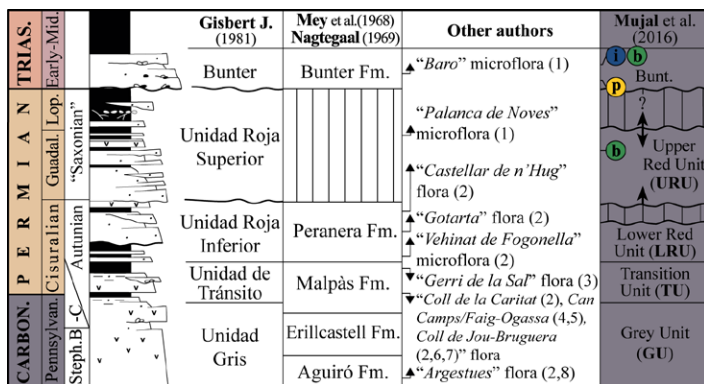

Fig. 1. Late Paleozoic–Mesozoic lithostratigraphy mostly based on Gisbert (1981), Mey et al. (1968) and Nagtegaal (1969). Other authors: See references in Mujal et al. (2016). In Mujal et al. (2016): (b) Tetrapod bone remains; (p) palynomorphs; (i) tetrapod ichnites. Carbon.: Carboniferous; Steph.: Stephanian; Guadal.: Guadalupian; Lop.: Lopingian; Trias.: Triassic; Mid.: Middle; Bunt.: Buntsandstein.

record of Southern Europe. These deposits are encompassed in a long terrestrial succession ranging from the Late Carboniferous to the Middle Triassic, having been historically studied by different disciplines (e.g., Mey et al., 1968; Nagtegaal, 1969; Hartevelt, 1970; Gisbert, 1981; Speksnijder, 1985; Saura, 2004; Saura and Teixell, 2006; Gretter et al., 2015). Nevertheless, there are few works focused on the paleontological record, especially on vertebrate remains. A detailed revision of the known Permian and Triassic vertebrate record of the Pyrenean Basin was provided by Fortuny et al. (2011). More recently, the Lower Permian has been biostratigraphically constrained by vertebrate footprints (e.g., Mujal et al., in press), and the Permian-Triassic transition was analyzed in detail in Mujal et al. (2016).

Concerning this latter work, our international and interdisciplinary team carried out new stratigraphic, sedimentological and paleontological analyses from the Permian Upper Red Unit (URU) and the Triassic Buntsandstein facies of the Catalan Pyrenees. We aimed to constrain the Permian-Triassic succession in the Western Tethys sub-basins providing new (bio-) chronologic data together with a general sedimentological revision of the fossil bearing stratigraphic units (Fig. 1).

A multidisciplinary approach

Sedimentological and stratigraphic details were represented by several complete sections, each of Stephano-Autunian to Anisian age. In this work, we concentrated on the Middle Permian to Lower Triassic part of the succession. We coupled stratigraphic/sedimentological description of fossil-bearing beds with the systematic study of the tetrapod bones and ichnites, and palynological analysis.

More than 70 in situ and ex situ ichnological specimens from the Buntsandstein facies of Palanca de Noves area were processed following Haubold's and Leonardi's procedures (i.e. Haubold, 1971a, b; Leonardi, 1987). The qualitative and quantitative parameters were analyzed together with the biometric measurements in each sample, and in combination with 3D photogrammetric models of 18 selected specimens.
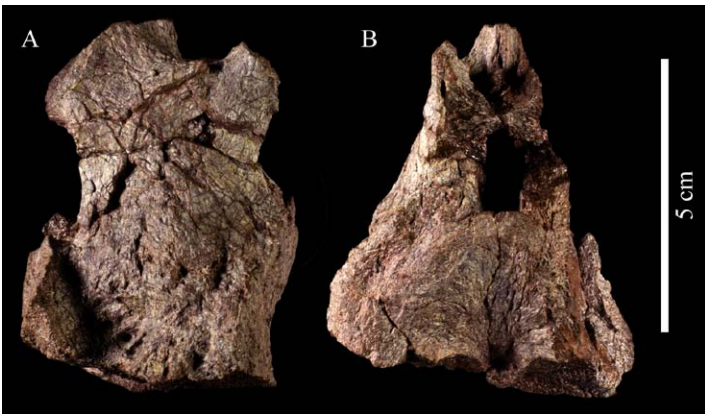
Fig. 2. Permian caseid vertebra (IPS-837365) attributed to cf. *Ennatosaurus tecton*, in right lateral (A) and anterior (B) views. Scale bar of 5 cm. Modified from Mujal et al. (2016).
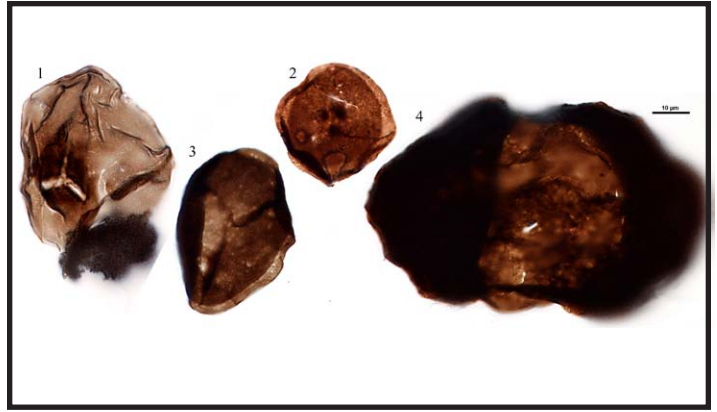
Fig. 3. Selected palynomorphs of late Early Triassic age. 1. *Calamospora tener* (Leschik) Madler 1964. 2. *Densoisporites nejburgii* (Schulz) Balme 1970. 3. *Endosporites papillatus* Jansonius 1962. 4. *Voltziaceaesporites heteromorpha* Klaus 1964.
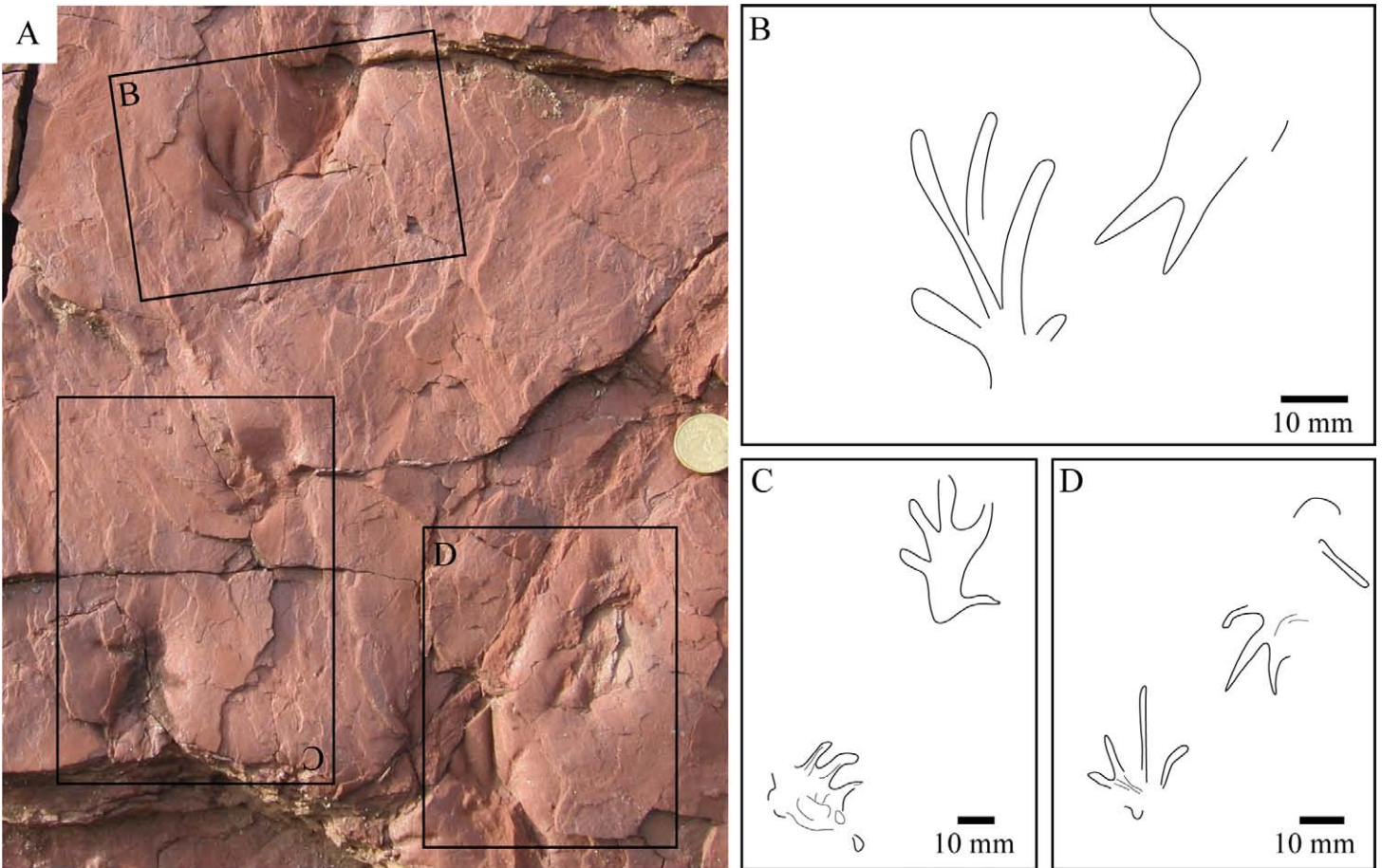
Fig. 4. A. Tetrapod footprints of late Early-early Middle Triassic age attributed to *Rhynchosauroides* cf. *schochardti* and an undetermined morphotype. B-D: Outline drawings (note C is upside-down).

The Permian-Triassic record of the Catalan Pyrenean Basin (NE Iberian Peninsula)

The studied Middle Permian-Lower Triassic stratigraphic succession consists of sedimentary units deposited in intracontinental sub-basins. The genesis of these troughs starts from the Pennsylvanian in a post-collisional strike-slip tectonic regime. The consequent Permian extensional setting leads to the deposition of fluvial and lacustrine facies, accompanied by extensive pyroclastics. The detailed outcrop-based stratigraphic analyses of the "Permian red-beds" known as Upper Red Unit (URU of Gisbert, 1981) showed a fining-upwards clastic sequence, mostly made up of conglomerates, sandstones and siltstones corresponding to braided

and meandering rivers and floodplain deposits.

For the first time, a large vertebra attributed to a caseid synapsid (poorly known in Western Europe) was reported (Fig. 2), which permitted tentative attribution to the fossil-bearing deposits of the Middle Permian. This vertebra was located in the upper portion of the Permian URU, interpreted as a playa-lake setting with a low influence of fluvial water channels,related to the distal parts of alluvial fans. In a nearby locality, with a similar setting as that of the caseid vertebra, Robles and Llompart (1987) reported large tetrapod footprints preliminarily attributed to either amphibians or reptiles.

At the beginning of the Triassic, deposition is recorded by the onset of widespread extensional sedimentation. The Buntsandstein facies of the Catalan Pyrenean Basin unconformably overlies the URU and consists of oligomictic quartz rich conglomerates at the base, followed by reddish sandstones and shales. The fine-grained levels rich in footprints are constituted by massive dark-red mudstones or siltstones. They show mud-cracks and occasionally well-developed paleosols. Fine red bioturbated sandstones with ripples constitute centimetric beds into dark-red massive siltstones. The Buntsandstein facies can be entirely attributed to the Triassic. In fact, the new palynological analysis presented in Mujal et al. (2016) (Fig. 3) gives an age of late Olenekian (late Early Triassic) to the basal portion of the Buntsandstein succession, instead of the doubtful Thuringian (Middle-Late Permian) of previous authors. Accordingly, the vertebrate ichnological record of these facies (see Fortuny et al., 2010; Mujal et al., 2016; Fig. 4) is consistent with a late Early-early Middle Triassic age.

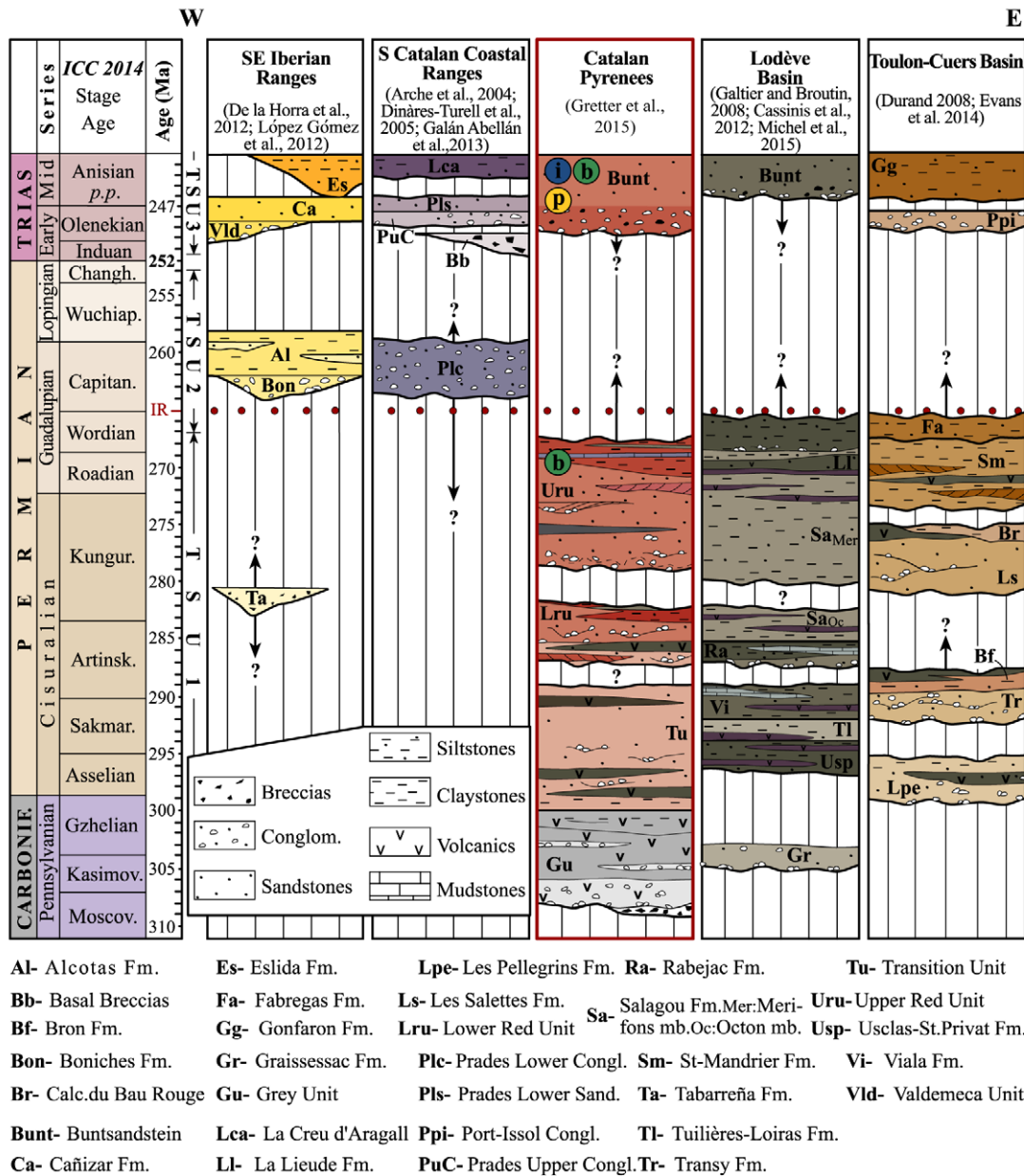Fig. 5. Correlation scheme of the Late Carboniferous-Middle Triassic stratigraphy in the Southwestern European framework modified from Gretter et al. (2015). The green "b", yellow "p" and blue "i" indicate respectively the new bones, palynomorphs and tetrapod ichnites analyzed in Mujal et al. (2016).
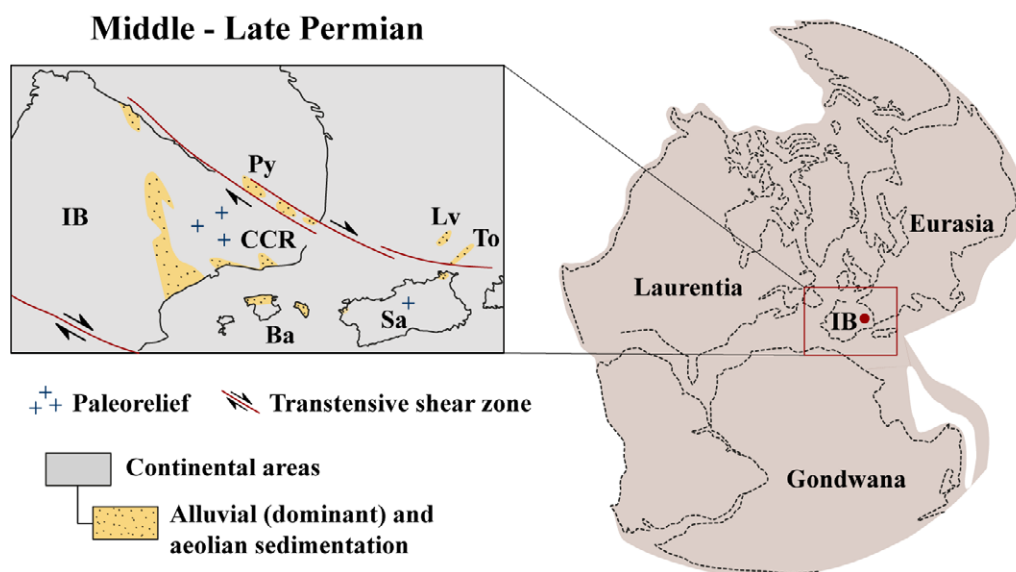
Fig. 6. Paleogeographic reconstructions for the Middle-Late Permian of the Iberian Plate. Modified from Mujal et al. (2016) and references therein. Ba: Balearic Islands. CCR: Catalan Coastal Ranges. IB: Iberian Plate. Lv: Lodève Basin. Py: Pyrenean Basin. Sa: Sardinia. To: Toulon-Cuers Basin.

Correlation with the Permian record of the Western Tethys domain

The Pyrenean biostratigraphical data show similarities with those of the nearby Western Tethys basins where large faunas similar to those of the Pyrenees are known.

The presence of a caseid vertebra in the Catalan Pyrenees (Fig. 2) indicates a minimum age of Middle Permian for the part of the succession where it was found (Fig. 5). This group of synapsids was relatively abundant during this time interval, although few specimens have been so far reported in Europe (e.g., Sigogneau-Russell and Russell, 1974; Wernerburg et al., 2007; Reisz et al., 2011; Ronchi et al., 2011; Romano and Nicosia, 2014). The Pyrenean vertebra is tentatively attributed to cf. *Ennatosaurus tecton*, a species only known from the Russian Mesen region (Ivakhnenko, 2008; Maddin et al., 2008), currently dated as Urzhumian (preceding the Illawarra Reversal; Gorsky et al., 2003), which is correlated to the Wordian (Henderson et al., 2012). This Middle Permian (Wordian) age agrees with the supposed age of the other European and North American caseids.

Robles and Llompart (1987) identified two morphotypes of tetrapod footprints that, after a reexamination, we found to be similar to the therapsid and caseid footprints of the La Lieude Member (French Lodève Basin) described by Gand et al. (2000) and by Gand and Durand (2006), and recently dated as Wordian (Michel et al., 2015). The stratigraphic succession and sedimentary environment of the Pyrenean vertebra and footprints is similar to that of La Lieude Member (Körner et al., 2003; Schneider et al., 2006; Lopez et al., 2008; Pochat and Van Den Driessche, 2011), also interpreted as a playa lake. Therefore, the Pyrenean and the nearby Lodève basins can be correlated. Other Upper Permian sites with similar large tetrapod footprints are those of the Spanish Cantabrian Basin (Demathieu et al., 2008), the Moroccan Argana Basin (e.g., Voigt et al., 2010), the Italian Southern Alps (Valentini et al., 2009), and the Cis-Urals region of European Russia (Surkov et al., 2007). These findings suggest a widespread distribution of large synapsids and parareptiles during the Middle-?Late Permian (Fig. 6).

In all, these results shed light upon the age of the Permian-Triassic continental successions and on the correlation with the nearby basins (Figs 5, 6). Additional work in progress will also contribute to an accurate definition of the Permian paleobiogeography in the Western Tethys.

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Early Permian tetrapod extinction events

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Introduction

Recognizing a substantial extinction or a mass extinction relies on timing—correlations that demonstrate numerous species disappeared "synchronously" (in geologic time terms) or within a
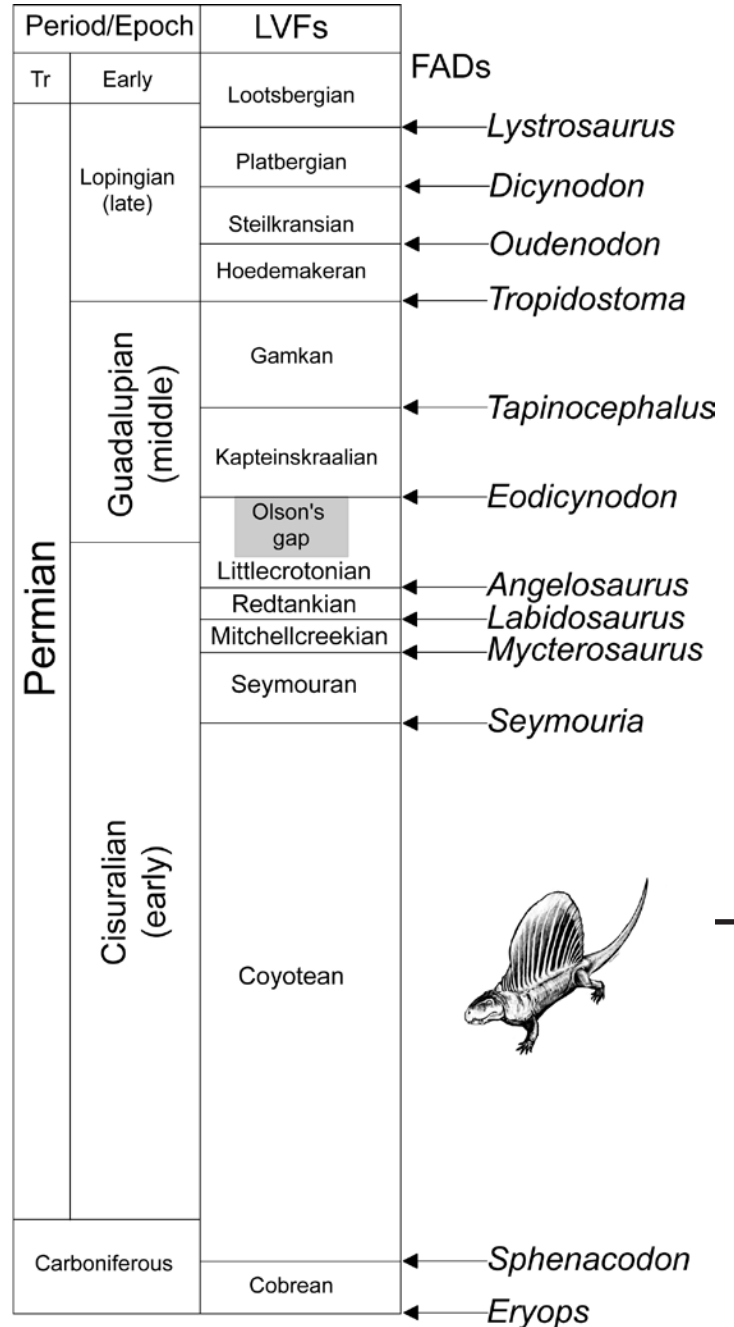

Fig. 1. The Permian timescale based on tetrapod evolution showing the land-vertebrate faunachrons (LVFs) and the FADs (first appearance datum) of the tetrapod genera that define the beginning of each LVF.

geologically short time interval (much less than one million years). Mis-correlations and poor stratigraphic resolution can produce the incorrect perception of a mass extinction. This has happened more than once in the Early Permian record of tetrapods (amphibians and reptiles) and merits correction. Here, I discuss perceived tetrapod extinctions during the Early Permian and at the Early-Middle Permian boundary using the biochronological framework of land-vertebrate faunachrons (LVFs) proposed by Lucas (2006), and its most recent correlation to the standard global chronostratigraphic scale (SGCS) for the Permian (Fig. 1).

Some History

Bakker (1977) was one of the first to discuss Permian tetrapod extinctions before the end-Permian extinction, and he did not identify an Early Permian tetrapod extinction. Instead, he stated that many of the characteristic Early Permian tetrapod families (dissorophids, captorhinids, sphenacodontids, caseids) temporally overlap the earliest therapsids of the Middle Permian and died out during the initial therapsid diversification.

Olson (1982), however, did identify a tetrapod extinction between the "Early" and "Middle" Permian. He did this by comparing three data points of pooled family- and genus-level diversity: "Early" Permian (Asselian-Artinskian), "Middle" Permian (Kungurian-early Tatarian) and "Late" Permian (late Tatarian-Dorashamian). Olson identified a high "Early" Permian diversity of amphibians that dropped in the "Middle" Permian, but the opposite among reptiles—an increase in reptile diversity from the "Early" to "Middle" Permian. The overall affect was a drop in tetrapod family-level diversity from 36 in the "Early" Permian to 28 in the "Middle" Permian. However, Olson's analysis is a classic example of the compiled correlation effect (Lucas, 1994) in which pooling diversity of long time intervals because of poor temporal resolution creates an apparent major drop in diversity across a stage boundary.

Benton (1985, 1987, 1988, 1989) presented a very different assessment of tetrapod extinction during the Early Permian than did Olson (1982). Thus, Benton showed an extinction of tetrapod families across the Sakmarian-Artinskian boundary that he identified as the loss of 15 families. He noted that reptiles were hit hardest by this extinction and, in particular "it marked the sharpest decline in the formerly dominant pelycosaurs (early synapsids)."

However, soon thereafter, Benton (1993) and Milner (1993) plotted the temporal ranges of Permian tetrapod families, and this showed a major loss of families at the Artinskian-Kungurian boundary. In one of the latest analyses along these lines, Sahney and Benton (2008, p. 760) identified a Guadalupian (Roadian-Wordian) mass extinction among tetrapods and called this "Olson's extinction." Sahney and Benton (2008) characterized this as "worldwide two-thirds of terrestrial vertebrate life was lost."

Recently, Bakker et al. (2013), in an abstract, argued that there is a substantial tetrapod extinction that they called "Olson's event," during early Redtankian (Kungurian) time (approximately at the top of the Arroyo Formation of the Clear Fork Group in the Texas section). They saw this as the extinction of large herbivorous tetrapods, the Diadectidae and Edaphosauridae. Their sampling identified this extinction as both sudden and cutting across lithofacies in the Clear Fork Group.

The Relevant Fossils

The fossil record of tetrapods of the latter part of the Early Permian (Artinskian-Kungurian) is almost totally from Texas-

	Asselian-Sakmarian	Artinskian		Kungurian	
	Wolfcampian		Leonardian		
taxa	Coyotean	Seymouran	Mitchellcreekian	Redtankian	Littlecrotonian
Acheloma				●	
Angelosaurus					●
Araeoscelis		●	●	●	
Archeria	●	●	●		
Aspidosaurus	●	●		●	
Bolosaurus	●	●	●		
Brachydectes	●		●		
Brevidorsum	●				
Broiliellus	●	●		●	
Cacops			●	●	
Captorhinus	●	●	●		
Carrolla		●			
Casea				●	
Caseoides					●
Chenoprosopus	●				
Cotylorhynchus				●	●
Crossotelos			●		
Ctenospondylus		●			
Cymatorhiza					●
Diadectes	●	●	●	●	
Dimetrodon	●	●	●	●	●
Diplocaulus	●	●	●	●	●
Ecolsonia	●				
Edaphosaurus	●	●	●	●	
Edops	●				
Eothyris		●			
Eryops	●	●	●	●	
Glaucosaurus			●		
Kahneria					●
Labidosaurikos			●	●	
Labidosaurus				●	
Lupeosaurus	●	●			
Macroleter					●
Mycterosaurus			●		
Neldasaurus	●				
Neopteroplax	●				
Ophiacodon	●	●	●		
Pantylus	●		●		
Pariotichus		●			
Parioxys	●	●			
Platyhystrix	●	●			
Protocaptorhinus		●	●		
Protorothyris	●				
Romeria	●				
Rothianiscus					●
Secodontosaurus		●		●	
Seymouria	●		●	●	
Slaughenhopia					●
Sphenacodon	●	●			
Stereophallodon	●				
Tersomius	●	●	●		
Trematopsis				●	
Trimerorhachis	●	●	●	●	
Tseajaia	●	●			
Varanodon					●
Varanosaurus		●	●	●	
Zatrachys	●	●		●	

Fig. 2. Temporal ranges of principal tetrapod genera of the Early Permian, based primarily on their stratigraphic ranges in the Texas, USA section. Modified from Lucas (2006).
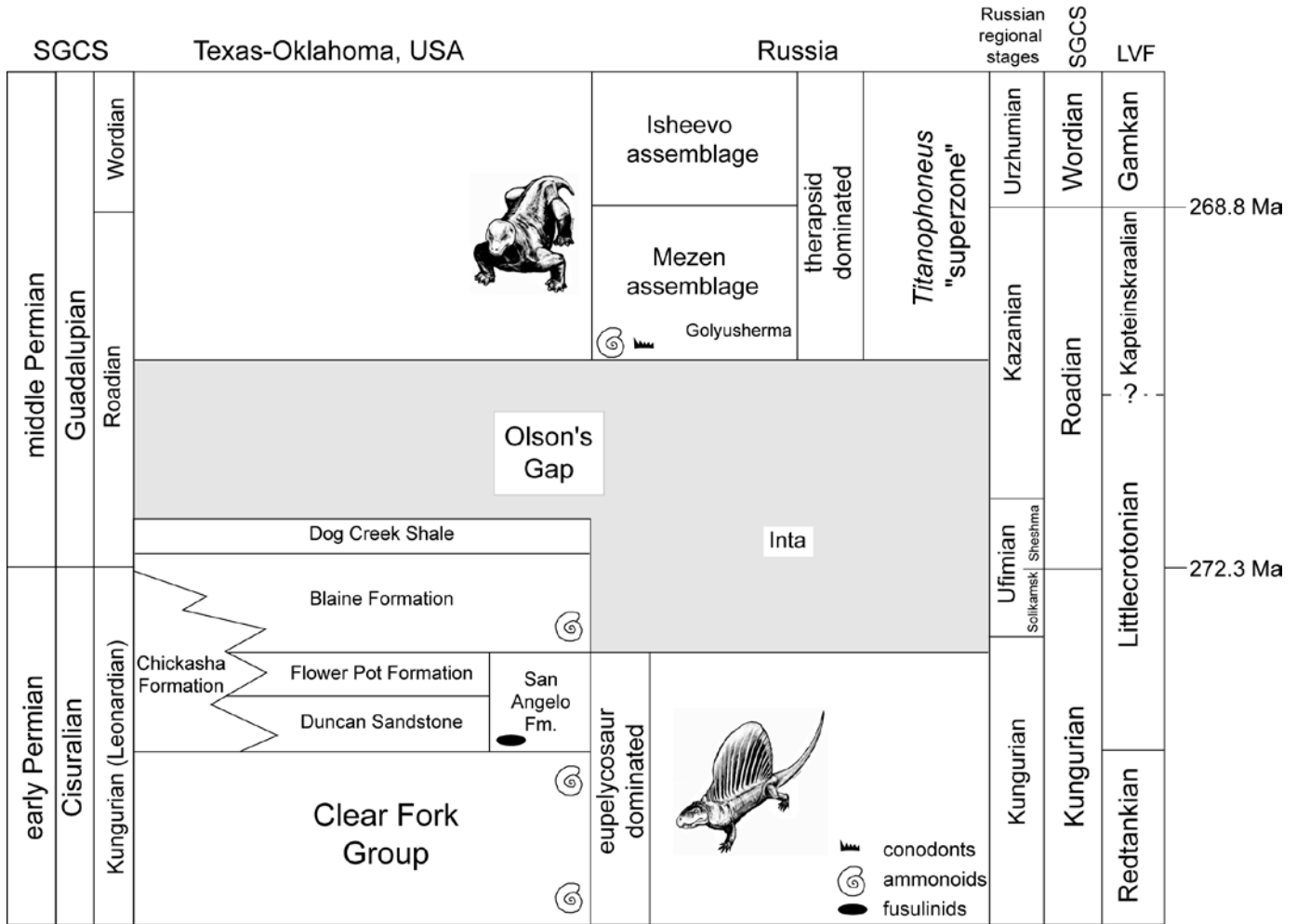
Fig. 3. Olson's gap is shown here as the hiatus between the youngest Lower Permian tetrapod assemblages of Texas-Oklahoma, USA, and the oldest Russian Permian tetrapod assemblages. Modified from Lucas (2004).

Oklahoma, USA (e.g., Olson, 1958, 1989; Simpson, 1979; Olson and Mead, 1982; Murry and Johnson, 1987; Lucas, 2006). Indeed, only the Texas-Oklahoma record is stratigraphically dense and superposed, and thus amenable to actual study of stratigraphic ranges of tetrapod taxa in the Artinskian-Kungurian interval (Fig. 2). European records of tetrapods of Artinskian-Kungurian age are very few, and are mostly scattered records of caseid pelycosaurs and a few amphibians (e.g., Ronchi et al., 2011). Other records are isolated, such as the tetrapod assemblage of possible Kungurian age recently reported from northeastern Brazil (Cisneros et al., 2015). Thus, if there was a tetrapod extinction at the Sakmarian-Artinskian boundary or at the Artinskian-Kungurian boundary, we should see it in the Texas-Oklahoma section. Or, put differently, any compelling evidence for a Sakmarian-Artinskian or an Artinskian-Kungurian tetrapod extinction would have to be based largely on the Texas-Oklahoma tetrapod record.

However, the Texas-Oklahoma record of tetrapods shows no mass extinction at either the base of the Artinskian or the base of the Kungurian (Fig. 2). Instead, it shows at least three extinction events, all within the Kungurian. Indeed, Olson (1952) and Olson and Vaughn (1970) long ago reviewed the Texas-Oklahoma tetrapod record and did not identify a substantial extinction, but instead they identified a complex and prolonged turnover in the chronofaunas due to drying of climate during part of Kungurian (Redtankian) time.

Redtankian Events
It has long been known that no substantial evolutionary turnover took place among tetrapods across the Carboniferous-Permian boundary. Thus, Coyotean tetrapod assemblages, which cross the Carboniferous-Permian boundary, are a classic chronofauna of lepospondyl and temnospondyl amphibians, diadectomorphs, primitive amniotes and eupelycosaurs. Lucas (2006) drew attention to the long duration of the Coyotean, ~ 15-20 Ma by the numerical calibration of the sgcs then available, and the current calibration still suggests a relatively long duration of ~ 10 Ma (Fig. 1). This lengthy period of community/assemblage stasis merits investigation, as does the change to the much shorter succeeding Early Permian LVFs that imply more rapid evolutionary turnover rates among tetrapods.

Much evolutionary turnover takes place late in the Early Permian (Fig. 2), associated with the Redtankian LVF. Therefore, I refer to this succession of events, which have often been viewed as a single event, as the Redtankian events. The oldest event is the extinction

of lysorophians, "microsaurs," anthracosaurs and ophiacodontid eupelycosaurs by the end of the Mitchellcreekian, and it is followed by the extinction of trematopids, some captorhinomorphs, diadectomorphs, araeoscelids and edaphosaurids in the Texas-Oklahoma section in the early Redtankian (highest occurrences are in the lower Clear Fork Group) (e.g., Lucas, 2006; Kissel, 2010; Bakker et al., 2013; Schoch and Milner, 2014). However, recent discovery of a diadectomorph in the Upper Permian of China (Liu and Bever, 2015) indicates that the "extinction" of diadectomorphs in Texas-Oklahoma is a local, not a global event.

During Littlecrotonian time, caseid eupelycosaurs diversified, and there is an evident diversification of parareptiles with the lowest occurrences of lanthanosuchoids and nyctiphruretids in the Redtankian-Littlecrotonian interval (e.g., Maddin et al., 2008; Tsuji et al., 2010, 2012; Ruta et al., 2011; MacDougall and Reisz, 2014; LeBlanc et al., 2015; Modesto et al., 2014, 2015; Romano and Nicosia, 2015). However, cladograms of the parareptiles indicate long ghost lineages before these LOs, so their records may be extended back with further collecting.

Therefore, there is no single tetrapod extinction at the Artinskian-Kungurian boundary, nor at the Sakmarian-Artinskian boundary. The stratigraphic data indicate the extinctions are spread out through Redtankian time, which is equivalent to part of the Kungurian, and perhaps as much as 2-3 million years long. Given the incomplete nature of the late Early Permian tetrapod record outside of Texas-Oklahoma, it is difficult to know whether the Redtankian events are geographically limited to the western USA or global in nature. The Late Permian diadectomorph recently reported from China certainly is a cautionary note to those who would extrapolate all of the extinctions and originations of the Redtankian events to the globe. However, there is some evidence from tetrapod footprint assemblages of a diversification of parareptiles during the late Early Permian (e.g., Marchetti et al., 2015a, b), though this footprint-based diversification occurs in the New Mexico section close to the Seymouran-Mitchellcreekian boundary, which is within the Artinskian (Voigt and Lucas, 2015).

Olson's Gap

Lucas (2004) recognized a global gap ("Olson's gap") between the youngest North American Permian tetrapods (San Angelo Formation and equivalents) and what he considered the oldest, therapsid-dominated assemblages, those of Russian Zone I and the *Eodicynodon* assemblage zone of South Africa (Fig. 3). This is a temporal gap between Lower Permian eupelycosaur-dominated tetrapod assemblages and Middle-Upper Permian therapsid-dominated tetrapod assemblages.

Lucas (2004) explained in detail why the youngest North American Permian tetrapod assemblages (from the San Angelo, Flowerpot and Chickasha formations of Texas-Oklahoma) are late Leonardian (Kungurian) in age. In brief, this is because marine strata intercalated in the San Angelo Formation yield Leonardian fusulinids, and overlying strata at the base of the Blaine Formation (and the correlative San Andres Formation) yield ammonoids of Leonardian age (Fig. 4). Thus, the youngest Permian tetrapod assemblages in North America are late Leonardian (Kungurian) in age, which is older than the oldest Permian tetrapod assemblages from Russia, which are Roadian in age (Fig. 3).

No reliable data indicate a mass extinction during Olson's gap, but Sahney and Benton (2008) show a single major crash of tetrapod diversity at the Cisuralian-Guadalupian (Kungurian-Roadian) boundary, which they call "Olson's extinction." To achieve this result, Sahney and Benton (2008) compressed all the extinctions of the Mitchellcreekian-Littlecrotonian as well as Olson's gap into one event. This is an example of what Lucas (1994) termed the compiled correlation effect, in which extinctions are artificially concentrated at stage boundaries because of poor temporal resolution, and it is also predicated on the incorrect correlations later published by Benton (2012). Indeed, perhaps the term "incorrect correlation effect" should be coined to refer to how incorrect correlations, such as those being used by Sahney and Benton (2008) and Benton (2012), can create the appearance of a single extinction.

There are three ways by which vertebrate paleontologists have attempted to bridge Olson's gap. The first is phylogenetically, by finding more primitive therapsids than are known after the gap. Nevertheless, identifying the most primitive therapsid(s) is confounded by a lack of agreement on early therapsid phylogeny (e.g., Kemp, 2006, 2009; Benson, 2012; Kammerer et al., 2013; Spindler, 2014, 2015). For example, a supposed therapsid in Lower Permian strata, *Tetraceratops* from the Redtankian of Texas (see Laurin and Reisz, 1996), is not considered a therapsid by most workers (e.g., Sidor and Hopson, 1998; Conrad and Sidor, 2001; Rubidge and Sidor, 2001; Liu et al., 2009; though see Amson and Laurin, 2011). Whether the most primitive therapsids are from South Africa, Russia or China is an interesting question for phylogeny and paleobiogeography, but the judged "primitiveness" of therapsids is not a reliable way to correlate them to the SGCS.

The second way to bridge the gap is to find tetrapod fossils from the gap, in other words, tetrapod fossil assemblages that correlate to late Kungurian-early Roadian on the SGCS. Despite claims to the contrary, that has not happened. Thus, for example, Liu et al. (2009) claimed that the Dashankou locality in the Chinese Xidagou Formation fills the gap, but that assemblage is readily correlated to the Russian Isheevo assemblage and thus is of Gamkan age (Lucas, 2006). The correlation of Liu et al. (2009) was based on the idea that *Raranimus*, the new biarmosuchian they named from Dashankou, is the most primitive therapsid, so their age assignment is based on phylogeny, or "stage of evolution," and thus is questionable. Indeed, even if the Dashankou assemblage is older than Gamkan, there are no data to indicate it is older than the South African *Eodicynodon* assemblage zone or the Russian Mezen assemblage (Abdala et al., 2008). The fact is, there must be some actual data to correlate a tetrapod assemblage to Olson's gap, not just some idea about the primitiveness of its therapsids.

The third way to bridge the gap has been simply to ignore the evidence provided by marine biostratigraphy that the youngest Permian tetrapods from Texas-Oklahoma are beneath Kungurian strata and that the oldest Permian therapsid-dominated assemblages must be younger than that (e.g., Reisz and Laurin, 2004; Lozovsky, 2005; Benton, 2012, answered by Lucas, 2005, 2013). Thus, Benton (2012, fig. 1) simply ignored the marine biostratigraphic data, assigning a Roadian age to the San Angelo, Flowerpot and Chickasha formations of Texas-Oklahoma. He also moved the Ufimian down into the Kungurian (Cisuralian), citing the

Russian Interdepartmental Stratigraphic Committee as authority, apparently not aware that they were not correlating the Ufimian to the Kungurian, but simply moving the Kungurian upward to encompass the Ufimian (Lozovsky et al., 2009). Benton (2012, fig. 1) thus mis-correlated the youngest North American Permian tetrapod assemblages upward and the oldest Russian therapsid-dominated assemblages downward, thereby "closing" Olson's gap. However, rather than ignore the marine biostratigraphic data, the search for tetrapod assemblages that fills Olson's gap should continue.

Despite claims to the contrary discussed above, Olson's gap remains a hiatus in the global record of Permian tetrapods. The hiatus is equivalent to part of Kungurian-Roadian time, approximately 2-3 Ma on the currently calibrated SGCS. The importance of the hiatus is the dramatic difference between tetrapod assemblages below and above Olson's gap. Clearly, the origin and earliest diversification of therapsids took place during the gap, and the fossils to document that remain to be found.

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GSSPs for the Permian Cisuralian Series stages

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During the XVIII ICCP at Kazan, Russia, August 11-15, 2015, significant progress was shown in the study of GSSP candidates for the Sakmarian, Artinskian, and Kungurian stages of the Permian Cisuralian Series. However, these sections have not been formally approved, and the Global Boundary Stratotype Section and Points (GSSPs) have not been formally defined. The ratification of the
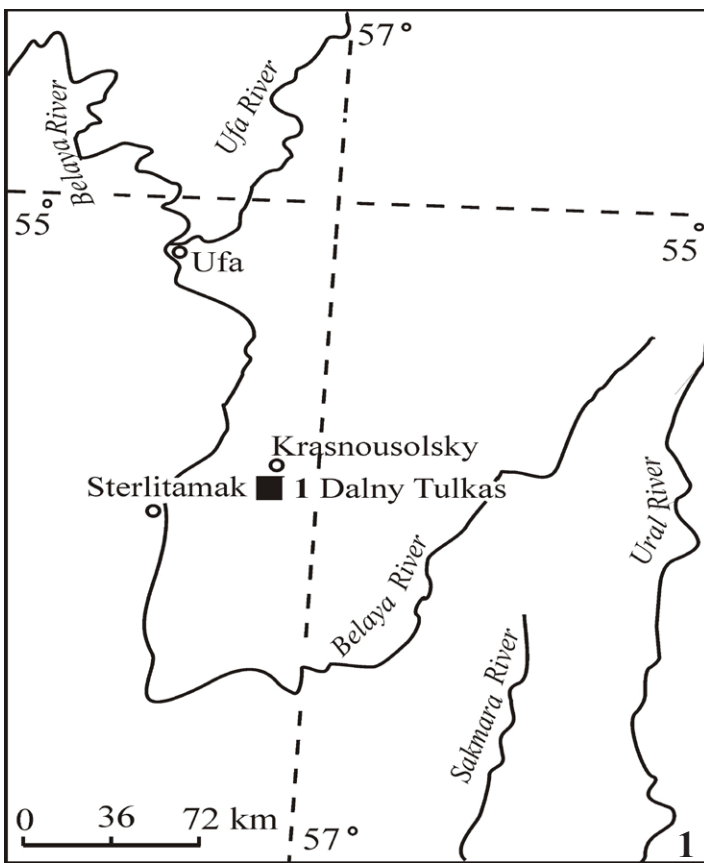
lower boundary of the Permian System and Asselian stage (GSSP) in the shallow shelf facies of the Aidaralash section in Kazakhstan (Davydov et al., 1998) may not fully satisfy the new ICS requirements for stage boundaries (Lucas, 2013). SPS members proposed the Usolka section as an Auxiliary Boundary Stratotype Section and Point (ASSP) (Miller et al, 2015).

The base of the Permian system and Asselian stage is marked by the FAD of the conodont species *Streptognathodus isolatus* in the phylogenetic line *S. wabaunsensis → S. isolatus → S. glenisteri*, and it has a radiometric age of 298.90+0.31/-0.15 Ma.

The Usolka section has been nominated as a new GSSP for the base of the Sakmarian stage. The horizon is marked by the FAD of *Mesogondolella uralensis* inside the *M. pseudostriata → M. arcuata → M. uralensis* chronomorphocline at 51.6 m from the base of the Usolka section, as well as by the FAD of the cosmopolitan conodont species *Sweetognathus merrilli* in the phylogenetic sequence *Sw. expansus → Sw. merrilli → Sw. binodosus* at 295.5 Ma. Data on conodonts, geochronology, and strontium isotopes (Schmitz and Davydov, 2012) make it possible to trace this boundary in North America (Midcontinent, Arctic Canada, British Columbia), and in China (Chernykh, 2003, 2006). Currently accepted correlations of glacio-eustatic cyclothems found in the Midwestern USA (Schimitz and Davydov, 2012) with the Asselian - Sakmarian boundary, suggest the end of the Gondwana glaciation at this level. Previously, the Kondurovka section on the right bank of the Sakmara River was chosen as a regional candidate for the Sakmarian stratotype (RSSP). The stage boundary was determined by the appearance of the species *Sweetognathus merrilli*. However, the lack of volcanic ash beds in the Kondurovka section excluded the possibility of radiometric dating of the boundary. Therefore, the Usolka section was selected as a candidate for the GSSP of the base of the Sakmarian with the marker *Mesogondolella uralensis*.

Fig. 1. Location of the Dalny Tulkas section; Fig. 2. Exposure of Sakmarian deposits of the Dalny Tulkas section; Fig. 3. Exposure of Artinskian deposits of the Dalny Tulkas section
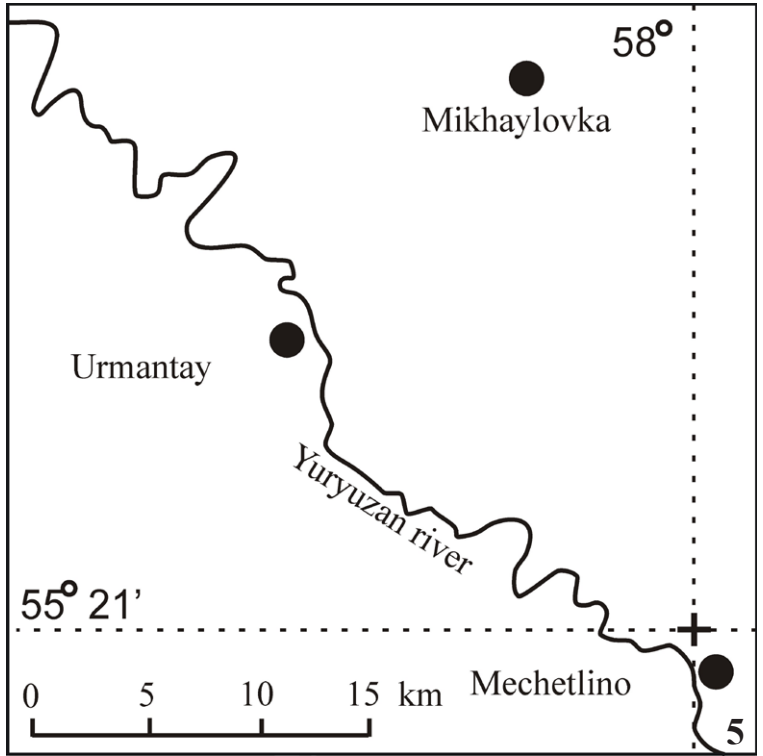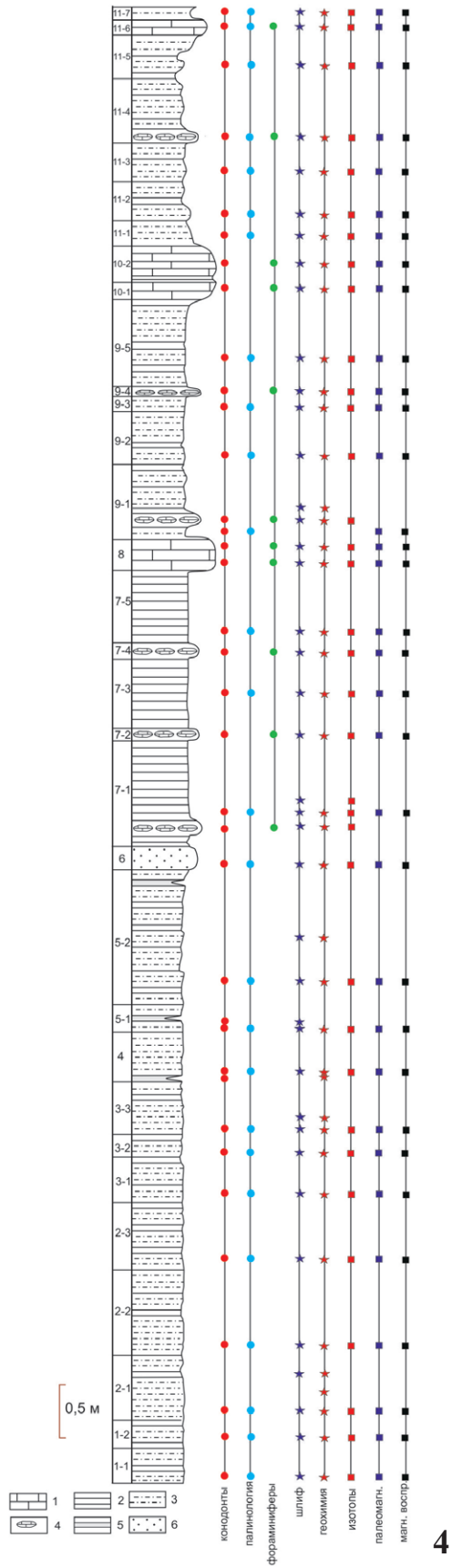
Fig. 4. Stratigraphic column of Dalny Tulkas with distribution of samples taken for conodonts, palynology, foraminifers, geochemistry, magnetic susceptibility; Fig. 5 Location of the Mechetlino Quarry section; Fig. 6. Artinskian deposits of Mechetlino Quarry.

Fig. 7. Exposure of the Artinskian-Kungurian (Gabdrashitovskaya and Mysovskaya formations) deposits of the Mechetlino Quarry section.

The Dalny Tulkas section (Figs 1-4), located 3 km from Krasnousolsk Town in the Republic of Bashkortostan, is considered as the GSSP candidate for the Artinskian.

The stage base is defined by the FAD of the conodont *Sweetognathus whitei* in the *Sweetognathus binodosus → Sw. anceps → Sw. whitei → Sw. clarki* phylogenetic line (Chernykh, 2012). The selected marker provides a global correlation of the base of the Artinskian over the entire area of its development (the Urals, North and South America, China, Pamir) (Chernykh, 2003).

Strontium isotope data for the base of the Artinskian indicate a ratio of 0.70765. The values of $\delta^{13}C$ present a dramatic depletion from -4.70‰ to -11.7‰ near the Sakmarian-Artinskian boundary in the Dalny Tulkas section. Strontium isotope and radiometric age data represent additional criteria for tracing the Artinskian lower boundary (Zeng et al., 2012).

Currently, two sections are considered as GSSP candidates for the Kungurian lower boundary: the Mechetlino section on the right bank of the Yuryuzan River in Bashkortostan Republic and the Mechetlino Quarry located 700 m from the previous one (Figs 5-8), where exhaustive conodont data were obtained. V.V. Chernykh determined an additional conodont species marker for the Kungurian boundary – in addition to the *Neostreptognathodus pnevi - N. lectulus* Chern. line, the *N. ruzhencevi-N. lectulus* line could also be used; it is recognized in the sections of the USA (Behnken, 1975; Clark et al, 1979.; Wardlaw and Collinson, 1986) and Canada (Henderson, 1999).

Outside Russia, the base of the Kungurian is identified by conodonts (Chernykh, 2003) in the Great Bear Cape Formation and Trapper Cove Formation in southwestern Ellesmere Island, of the Sverdrup Basin in the Canadian Arctic. The *Neostreptognathodus clarki-N. ruzhencevi* zone recognized in the Arctic Canada contains forms transitional to *N. pnevi*, marking the Kungurian lower boundary. Strontium isotope data obtained in the Mechetlino section increase the correlation potential of the Kungurian lower boundary (Chernykh et al., 2012). The $^{87}Sr/^{86}Sr$ ratio at the base of the

Artinskian is 0.70767. The $^{87}Sr/^{86}Sr$ ratio in conodonts from the transitional Artinskian-Kungurian interval in the Mechetlino section varies from 0.70743 to 0.70739. By projecting these ratios on the extrapolated seawater curve, it yields an apparent age for the Kungurian boundary of 283.5±0.5 Ma (Schmitz et al., 2009; Schmitz and Davydov, 2012).

The field trip to the sections during the XVIII ICCP and the discussion during the SPS meeting have shown that the candidate global stratotype sections in the southern Urals: Usolka, Dalny Tulkas and the Mechetlino require additional clearing and additional study. The SPS Chair Shu-Zhong Shen recommended the creation of a Russian Working Group for further study of the candidate global stratotype sections in the southern Urals: Usolka, Dalny Tyulkas, and Mechetlino. The Russian Working Group was created at the Russian Permian Subcommission meeting during the XVIII ICCP and comprises leading scientific experts including V.V. Chernykh, G.V. Kotlyar, G.A. Mizens, V.I. Davydov, R.Kh. Sungatullin, G.M Sungatullina., R. Kutygin and T. Filimonova. Unfortunately, B.I. Chuvashov is unable to participate in the Working Group activities for health reasons. Later G.V. Kotlyar recieved a grant to carry out all planned works.

A field workshop of the Working Group was conducted in the southern Urals this summer over two months. Work was focused on the Dalny Tulkas and Mechetlino Quarry sections (Figs 1-8), in order to determine the potential Lower Permian GSSP sections for the base-Artinskian and base-Kungurian. The main goal of the field workshop was to make a full clearing by excavator (Fig. 9) of the Sakmarian and Artinskian deposits in the Dalny Tulkas and Mechetlino sections in order to make additional sampling for conodonts (Guzel Sungatullina and V. Chernykh), foraminifera (Filimonova), brachiopods (Kotlyar), ammonoids (Kutygin), palynology, carbon and oxygen isotopes, magnetic susceptibility, TOC, and X-ray fluorescence spectral analysis. Detailed investigation and description of sedimentology were made by G. Mizens and Rafael Sungatullin. V. Davydov searched for primary volcanic ash falls. Special attention was paid to the boundary beds. We invite the SPS voting member to visit the Dalny Tulkas and Mechetlino Quarry sections and to carry out multi- and interdisciplinary studies. We will be glad to see the all voting member in the Southern Urals.

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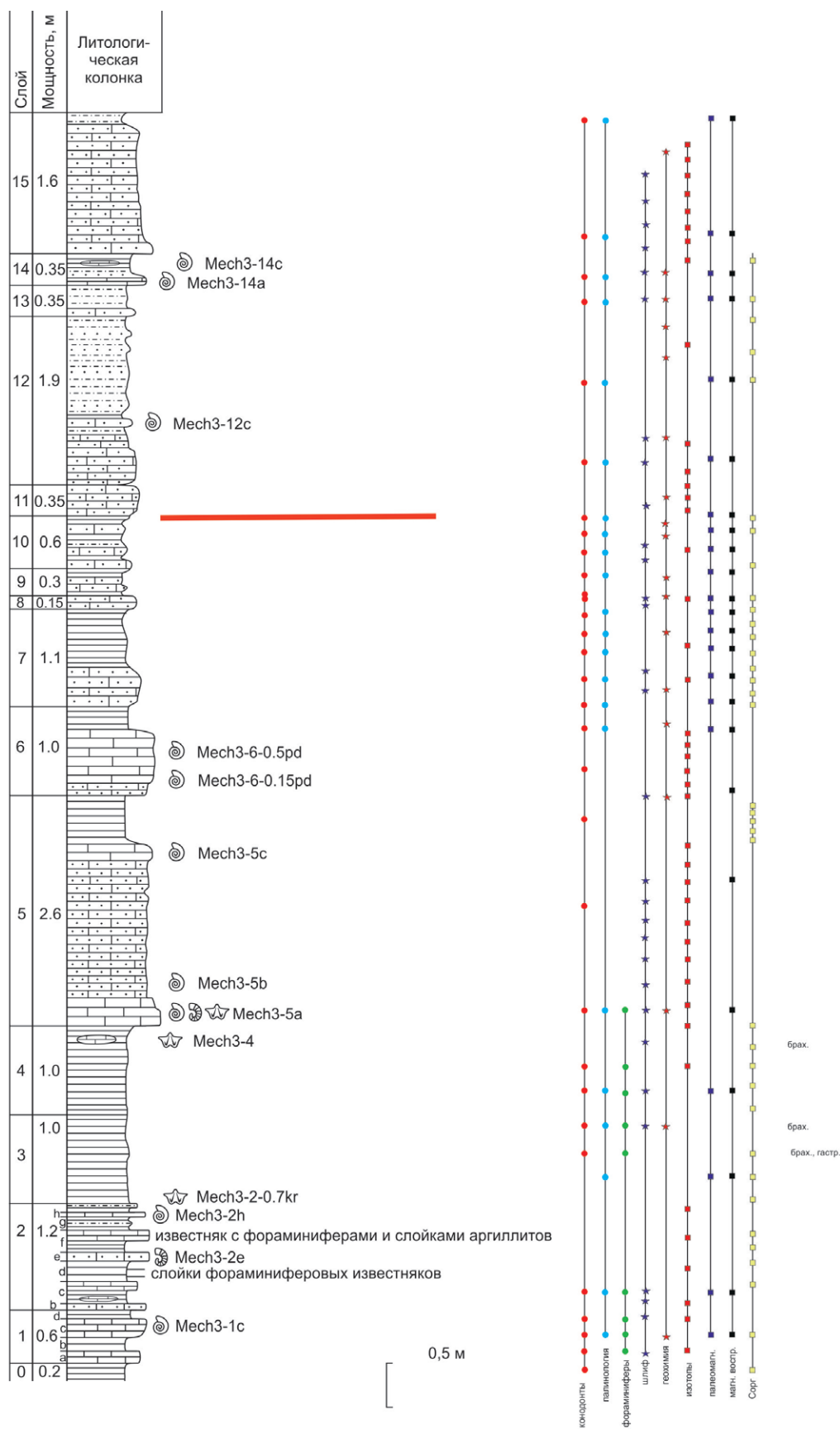
Fig. 8. Stratigraphic column of Mechetlino with distribution of samples taken for conodonts, palynology, foraminifers, ammonoids, brachiopods, geochemistry, detailed carbon isotope, geochemistry, magnetic susceptibility. The red line is the supposed Artinskian/ Kungurian boundary.

Fig. 9. Excavator on the Mechetlino Quarry section (from left Gunar Mizens, Tatiana Filimonova, Valery Chernykh, Guzel Sungatullina, her son, Rafael Sungatullin).

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A new Late Pennsylvanian to Early Triassic conchostracan biostratigraphy

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Introduction

As shown in several publications for the latest Permian and parts of the Triassic, conchostracan form a well applicable tool for local to interregional biostratigraphic subdivision and correlation of continental deposits (e.g. Tasch and Jones, 1979; Gosh et al.*,* 1987; Kozur and Seidel, 1983; Kozur and Weems, 2010; Ferreira-Oliveira and Rohn, 2010; Scholze et al., 2015, 2016).There minute eggs could be transported by air currents over large distances and they occur in almost any freshwater accumulations from lakes to ponds and puddles. Because of their specific reproduction strategy they could form mass occurrences even in extreme environments of sabkha and playa dry red beds. Additionally they have a high preservation potential because of their chitinous shells. All this properties together made them to ideal guide fossils for nonmarine biostratigraphy, especially in otherwise fossil-free sediments. Unfortunately, this potential remained nearly unused for the Late Carboniferous and Early to Middle Permian, apart from some attempts as e.g. by Novozhilov (1970), Martens (1983, 2012), Kozur et al. (1992). Our study provides an attempt for a conchostracan bio-zonation of continental and mixed continental-marine deposits from the Late Carboniferous up to the Early Triassic in Euramerica, to stimulate further research on this field (Fig. 1). It is mainly based on data from hydrocarbon exploration wells of the seventies and eighties of the last century, which remained buried so fare in confidential internal research reports with one exception only (Hoffmann et al., 1989) as well as a project of the Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e.V. (DGMK, German Society for Petroleum and Coal Science and Technology) which focused on the revision of Upper Carboniferous stratigraphy of about 45 deep exploration wells drilled in the North German part of the Variscan foredeep (Rößler 1996). As a result, a combined conchostracan-insect range chart for the Westphalian (Bashkirian/Moscovian) up to the Kungurian (late Early Permian) was proposed, based on archimylacrid and spiloblattinid blattoid (cockroach) insect-lineage zones and conchostracan-assemblage zones. Unfortunately, this DGMK research report (no. 459-3/3; Schneider and Rößler, 1996), written in German and published in a very limited edition, remains nearly unknown. Only a short report was published by Schneider et al. 1995 in Permophiles 26. With the present paper we want to draw attention to a detailed publication, which will be printed in Lucas and Sheng 2016 as Schneider and Scholze 2016.

Methods

Methodologically we use assemblage zones instead of the taxon-range zones based on single guide forms as, e.g., applied by Kozur (1993 ff.) and Martens (1983, 2012). Assemblage zones based on the co-occurrence of two or more species can provide much more reliable time limits. Stephanian and Permian conchostracan occurrences and assemblage zones, respectively, are as far as possible calibrated by cross-correlation with other biostratigraphic zonations, such as the combined insect and amphibian zonation of Schneider & Werneburg (2006, 2012). In some cases, calibration of conchostracan-bearing sections to the Standard Global Chronostratigraphic Scale is possible by isotopic ages. This relates in particular to the Westphalian and Stephanian of the West-European Regional Scale which is, for the first time, in parts very precisely linked to the Standard Global Chronostratigraphic Scale by Opluštil et al. (2016). In the best cases we could link conchostracan assemblage zones with insect lineage zones and the marine conodont zones too, mainly in North America.

For several of the zone-species we use informal names to avoid the introduction of new taxon names before an extensive revision of Upper Carboniferous and Lower Permian conchostracans is carried out. These informal names are derived from discovery localities and designated as "forms". We use, in combination with the stages of the Standard Global Chronostratigraphic Scale, the classic Heerlen West European subdivisions into Westphalian A to D, abbreviated as WA, WB, etc., and the Stephanian A to C, abbreviated as StA, etc. (see Fig. 2).

Definition of conchostracan zones

(1) ***Palaeolimnadiopsis pruvosti-Pseudestheria* cf. *striata*– assemblage zone (Figs 1 - 1 and 2):**

Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Palaeolimnadiopsis* form Pudagla – *Pseudestheria* form Ibbenbüren assemblage zone. WA to WA/WB transition (Duckmantian to Early Bolsovian; late Bashkirian to early Moscovian).

Accompanying form: *Leaia tricarinata minima* Pruvost 1919.

(2) ***Palaeolimnadiopsis* form Pudagla–*Pseudestheria* form Ibbenbüren assemblage zone (Figs 1 - 3 and 4):**

Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Megasitum* form Markenkamp–*Pseudestheria* form Hoya assemblage zone. Latest WA and WB (latest Langsettian and Duckmantian, late Bashkirian to early Moscovian).

Accompanying form: *Pseudestheria* cf. *striata* (Münster, 1840), Fig. 1 - 2.

(3) ***Megasitum* form Markenkamp-*Pseudestheria* form Hoya assemblage zone (Figs 1 - 5 and 6):**

Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Anomalonema reumauxi-Pseudestheria simoni* assemblage zone. WC without its upper part (Bolsovian, middle Moscovian).

Accompanying form: *Pseudestheria* form Hervest (Fig. 1 - 7).

(4) ***Anomalonema reumauxi-Pseudestheria simoni* assemblage zone (Figs 1 – 8 and 9):**

Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Pseudestheria limbata-Pseudestheria rimosa-Lioestheria warthi* assemblage zone. Late WC and WD late Asturian and Cantabrian; late Moscovian and early Kasimovian).

Accompanying forms: ?*Palaeolimnadiopsis freysteini* (Geinitz 1855), Fig. 1 – 10.

(5) ***Pseudestheria limbata-Pseudestheria rimosa-Lioestheria* form Köllerbach assemblage zone (Figs 1 – 11, 12 and 13):**

Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Pseudestheria minima-Lioestheria* form Frenswegen-*Palaeolimnadiopsis* form Jessen assemblage zone. StA and ?StB (Barruelian-Saberian; middle Kasimovian to early Gzhelian).

Accompanying form: *Leaia baentschiana* Beyrich, 1864.

(6) ***Pseudestheria* sp. M-*Lioestheria* form Frenswegen-*Palaeolimnadiopsis* form Jessen- assemblage zone (Figs 1 – 15,**
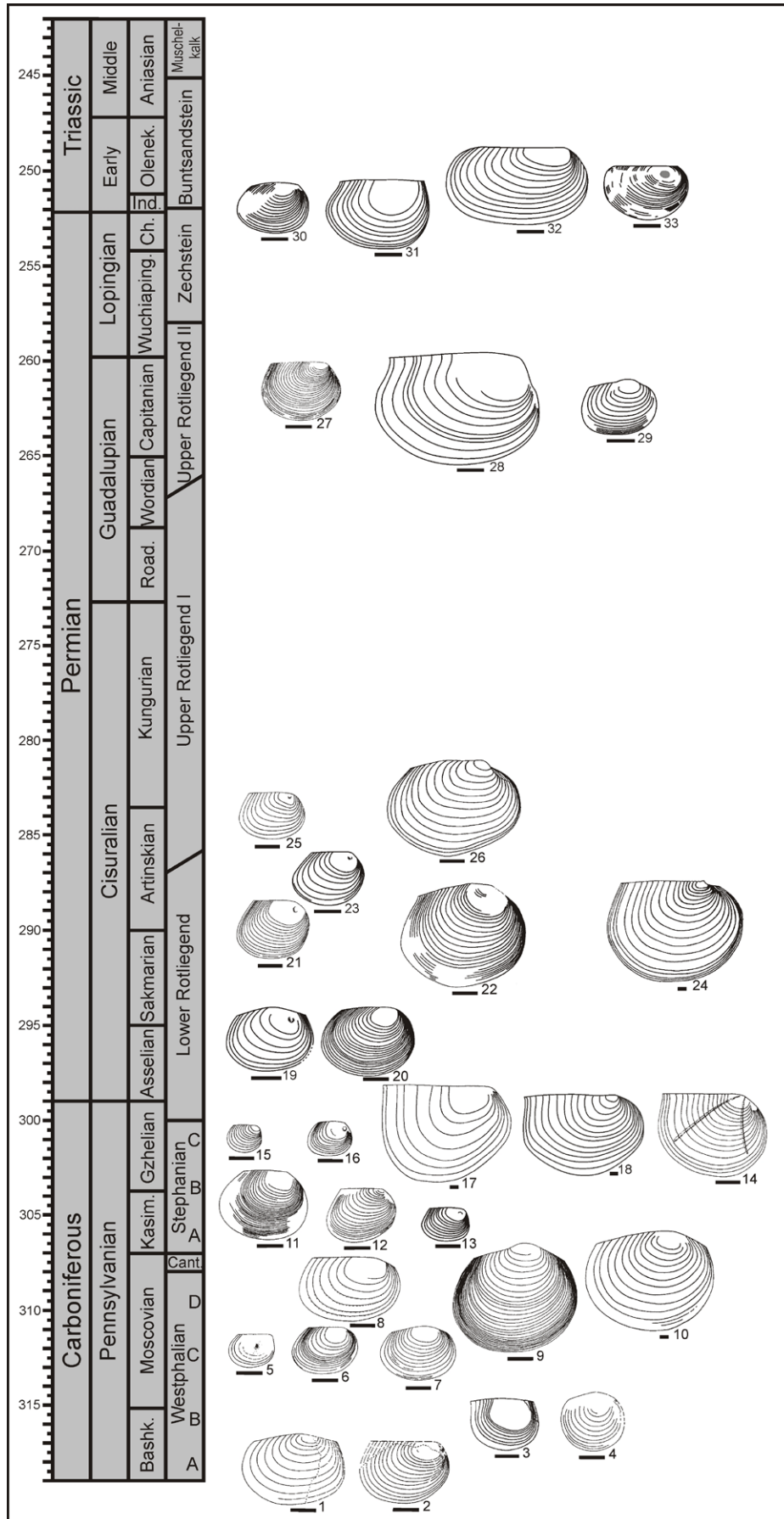
Fig. 1

Figure 1. Zone index species and accompanying forms of the conchostracan assemblage zones for the Late Pennsylvanian to Early Triassic. Scale bars 1 mm; (1) *Palaeolimnadiopsis pruvosti* - well Löhnen 1, Ruhr area, Voort Horizon, Bochum Formation, WA, Bashkirian, Variscan foredeep; (2) *Pseudestheria* cf. *striata* - well Löhnen 1, Ruhr area, Voort Horizon, Bochum Formation, WA, Bashkirian, Variscan foredeep; (3) *Palaeolimnadiopsis* form Pudagla - well Pudagla 1/68 by 5,456.00 m, ?Wieck Formation, WA/B, Late Bashkirian to Early Moscovian, NE part of the Variscan foredeep; (4) *Pseudestheria* form Ibbenbüren - LANRW Kar 2491, well UB 414 (Kar 2491), Ibbenbühren, Domina Horizon, Horst Formation, WB, Moscovian, Lower Saxony part of the Variscan foredeep; (5) *Megasitum* form Markenkamp - LANRW Mar 2, well Markenkamp 2, 986.7-986.2 m, Dorsten Formation, WC, Moscovian, Lower Saxony part of the Variscan foredeep; (6) *Pseudestheria* form Hoya - LANRW ZFH 6, well Hoya Z1, core 4580.7-4593.2 m, Dorsten Formation, WC, Moscovian, Lower Saxony part of the Variscan foredeep; (7) *Pseudestheria* form Hervest - LANRW He 2/4, well Hervest 2, 872.65 m, Dorsten Formation, WC, Moscovian, Lower Saxony part of the Variscan foredeep. (8) *Anomalonema reumauxi* - LANRW Wielen Z4/1, well Wielen Z4, 2647.7-2664.7 m, Osnabrück Formation, WD, Moscovian, Lower Saxony part of the Variscan foredeep; (9) *Pseudestheria simoni* - FG 681/PdC 3, Pas-de-Calais basin, Sallaumines, Faisceau de Du Soich and Faisceau d´Edouard, WD, Variscan foredeep, Pas-de-Calais basin, Northern France; (10) ?*Palaeolimnadiopsis freysteini* - FG 681 Zw 3/1, Oelsnitz town, Zwickau Formation, WD, Zwickau-Oelsnitz basin, Moscovian, East Germany. (11) *Pseudestheria limbata* - SaM D/545/4, Merchweiler village, lower Ottweiler Subgroup, Göttelborn Formation, StA, Kasimovian, Saar-Nahe basin. (12) *Pseudestheria rimosa* - SaM D/Mi/1, Michelsberg village, lower Ottweiler Subgroup, Göttelborn Formation, StA, Kasimovian, Saar-Nahe basin; (13) *Lioestheria* form Köllerbach - SaM D/490/2, Köllner Mühle, lower Ottweiler Subgroup, Göttelborn Formation, StA, Kasimovian, Saar-Nahe basin; (14) *Rostroleaia* form WISBAW - FG 681 W 860/79/35/42, well WISBAW 860/79, Mansfeld Subgroup, Stephanian, Gzhelian, Saale basin; (15) *Pseudestheria* sp. M - FG Sw 2/75/1, well Schadewalde 2/75, Mansfeld Subgroup, late Stephanian, Gzhelian, Saale basin. (16) *Lioestheria* form Frenswegen - LANRW Fw 5/29/1, well Frenswegen 5, at 2735.0 m, late Stephanian, Lower Saxony part of the Variscan foredeep. (17) *Palaeolimnadiopsis* form Jessen - FG 681 Js2z/61/3, well Jessen 2z/61, 637.4 m, Mansfeld Subgruppe, Siebigerode Formation, StC, Gzhelian, Saale basin; (18) *Palaeolimnadiopsis wettinensis* - after Laspeyres (1870, Pl. 16, Fig. 2), Fischer shaft, Wettin town, Mansfeld Subgroup, Siebigerode Formation, Wettin Subformation, StC, Gzhelian, Saale basin; (19) *Lioestheria paupera* - after Holub & Kozur (1981, Pl.4, Fig.1), Cesky Brod, Skalka, StC; (20) *Pseudestheria palaeoniscorum* - after Martens (1983, Fig. 22), MNG-3625-6-1, Homigtal near Breitenbach village, Goldlauter Formation, Sakmarian, Thuringian Forest basin; (21) *Lioestheria extuberata* - FG O/LO/5, Lochbrunnen near Oberhof village, Lower Oberhof Formation, Sakmarian/Artinskian, Thuringian Forest basin. (22) *Pseudestheria* form Oberhof - after Martens (1983, Fig. 25), Lochbrunnen near Oberhof village, Lower Oberhof Fomation, Sakmarian/Artinskian, Thuringian Forest basin; (23) *Palaeolimnadiopsis obenaueri* - after Martens (1984, Fig. 3), Meisenheim Formation, Humberg bank (Lebach geods), Artinskian, Saar-Nahe basin. (24) *Lioestheria oboraensis* - FG 681 Leina 2, Leinatal near Finsterbergen village, Upper Oberhof Formation, Artinskian, Thuringian Forest basin. (25) *Lioestheria andreevi* - FG 681 Ta1, Bromacker near Tambach-Dietharz town, Tambach Formation, latest Artinskian, Thuringian Forest basin. (26) *Pseudestheria* form Wilhelmsthal after Martens (1983, Fig. 30), MNG-3507-1, Wilhelmsthal near Eisenach town, Eisenach Formation, Kungurian-Rodian, Thuringian Forest basin; (27) *Pseudestheria graciliformis* - FG 681 Ho/Kon1, Konberg quarry, Rothenschirmbach village, Upper Hornburg Formation, Early Capitanian, Saale basin; (28) *Palaeolimnadiopsis* form Rhinow – FG681 118036/1b, well Rhinow 5/71, Hannover Formation, Early Wuchiapingian, Southern Permian basin; (29) *Pseudestheria* form Lieth – UH, salt dome Lieth in Schleswig-Holstein, Hannover Formation, Early Wuchiapingian, Southern Permian basin; (30) *Euestheria gutta* - after Kozur & Seidel (1983, Pl. 5, Fig. 2), Caaschwitz quarry at the Läuseberg hill, Fulda Formation ("brittle shale"), Induan, Central European basin; (31) *Palaeolimnadiopsis vilujensis* - after Scholze *et al.* (2015, Fig.14A), FG 618/7b, Caaschwitz quarry at the Galgenberg, basal Calvörde Formation, Induan, Central European basin; (32) *Magniestheria mangaliensis* - after Scholze *et al.* (2016, Fig. 7B), FG 618/4, Nelben clay pit, Calvörde Formation, Induan, Central European basin: (33) *Cornia germari* - after Scholze *et al.* (2016, Fig. 7B), NHMS-WT1436, Kraftsdorf, Bernburg Formation, Induan, Central European basin.

16 and 17):
Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Lioestheria paupera-Pseudestheria palaeoniscorum* assemblage zone. StB and StC, late Gzhelian to ?earliest Asselian.
Accompanying forms: *Palaeolimnadiopsis wettinensis* (Laspeyres 1870), Fig. 1-18; *Pseudestheria* cf. *limbata*, and *Rostroleaia* form WISBAW (Fig. 1 – 14).

(7) ***Lioestheria paupera-Pseudestheria palaeoniscorum* assemblage zone (Figs 1 – 19 and 20):**
Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Lioestheria extuberata-Lioestheria oboraensis-Pseudestheria* form Oberhof assemblage zone. Lower Rotliegend, Asselian – Sakmarian.

(8) ***Lioestheria extuberata-Lioestheria oboraensis-Pseudestheria* form Oberhof assemblage zone (Figs 1 - 21, 22 and 23; Fig. 3E):**
Definition and range: FOD of the zone species up to the FOD of the

zone species of the following *Lioestheria andreevi-Pseudestheria* form Wilhelmsthal assemblage zone. Higher Lower Rotliegend (late Sakmarian to late Artinskian).
Accompanying form: *Palaeolimnadiopsis obenaueri* (Guthörl 1931), here Fig. 1 – 24, is in the Saar-Nahe basin in places common in the uppermost Meisenheim Formation, Humberg bank ("Lebach geodes").

(9) ***Lioestheria andreevi-Pseudestheria* form Wilhelmsthal assemblage zone (Figs 1 – 25 and 26):**

Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Pseudestheria graciliformis-Palaeolimnadiopsis* form Rhinow - *Pseudestheria* form Lieth assemblage zone. Higher Lower Rotliegend and Upper Rotliegend I (late Artinskian to Rodian/Wordian).

(10) ***Pseudestheria graciliformis-Palaeolimnadiopsis* form Rhinow- *Pseudestheria* form Lieth assemblage zone (Figs 1 – 27, 28 and 29):**
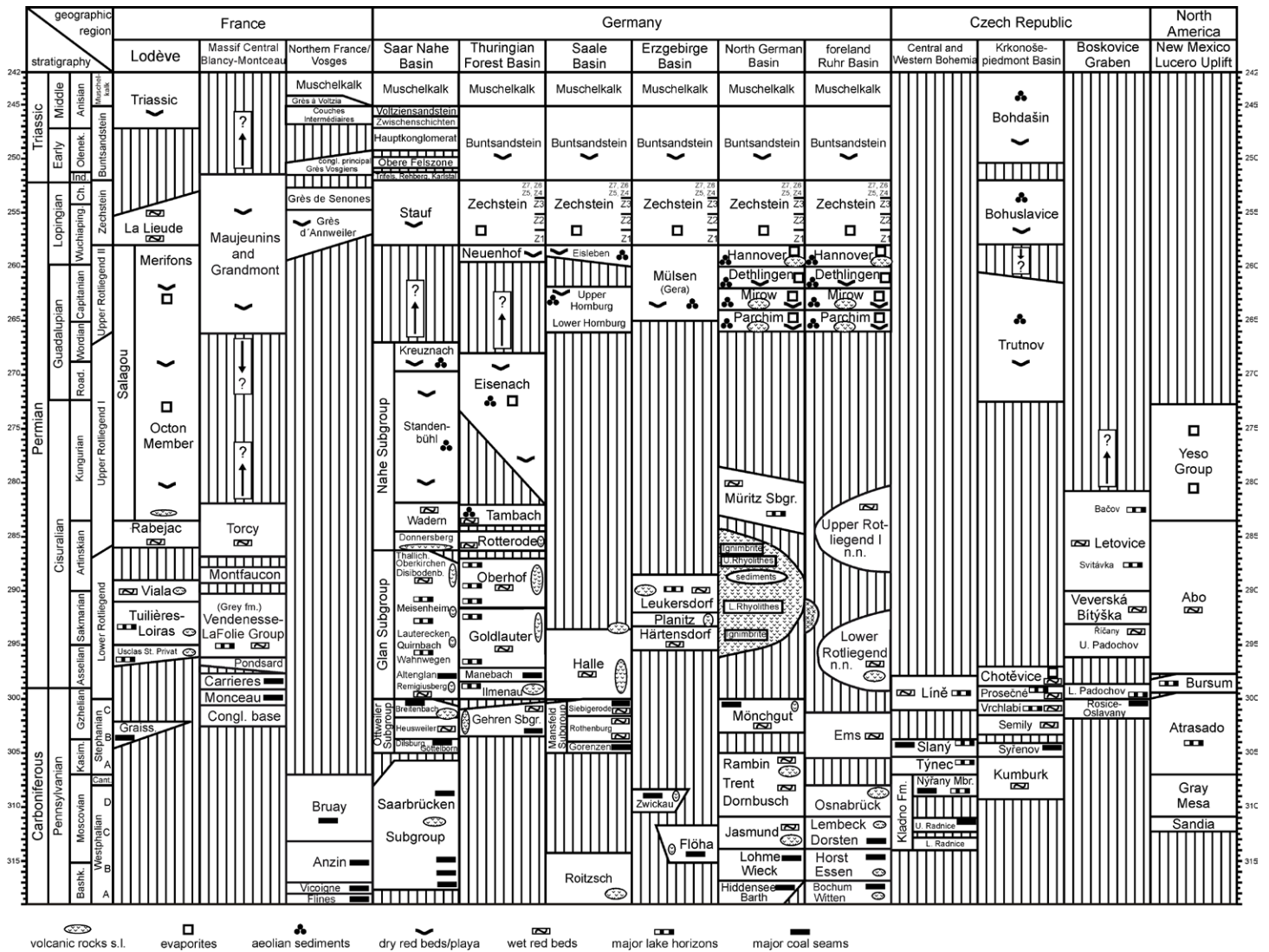

Fig. 2. Correlation chart of the basins with their respective formations in the European Variscides and New Mexico mentioned in the text. Correlations are based on data from Schneider et al. (2006), Roscher & Schneider (2006), Schneider & Werneburg (2006, 2012), Schneider & Romer (2010), Lucas et al. (2013), Oplustil *et al.* (2015), and International Chronostratigraphic Chart 2016/4.

Definition and range: FOD of the zone species up to the FOD of the zone species of the following *Euestheria gutta-Palaeolimnadiopsis vilujensis* fauna. Upper Rotliegend II (Capitanian to early Wuchiapingian).

(11) *Euestheria gutta* interval (Fig. 1 – 30):
Definition and range: FOD of *Euestheria gutta* (Lutkevich, 1937) up to the FOD of the following *Cornia germari* (Beyrich 1857) interval. Early Triassic (early Induan).
Accompanying forms: *Palaeolimnadiopsis vilujensis* Varentsov, 1955 (here Fig. 1 – 31), *Magniestheria mangaliensis* (Jones, 1862), here Fig. 1 - 32, *Cornia germari*, Fig. 1 – 33, and *Rossolimnadiopsis* sp. (Scholze et al., 2015).

(12) *Cornia germari* interval (Fig. 1 – 33):
Definition and range: FOD of *Cornia germari*. The upper stratigraphic range of this interval is currently in revision and therefore preliminarily confined here by the LOD of *Cornia germari*. Early Triassic (Induan).
Accompanying form: *Magniestheria mangaliensis* (Jones, 1862), here Fig. 1 – 32).

Conclusions
As shown above, the here used assemblage zones cover larger time-intervals than the seemingly high-resolution conchostracan species-range zones of Holub & Kozur (1981), Kozur (1993) and Martens (1982, 2012). But, they are far more applicable because not only one zone species characterizes a particular time interval. The mean time resolution of our 12 zones is roughly 5 Ma, which corresponds more or less to the mean duration of Pennsylvanian and Permian stages. Unfortunately, due to increasing aridization, which caused an increasingly discontinuous fossil record during the late Early Permian and especially during the Middle Permian in Central and Western Europe, the time resolution deteriorates to 15 Ma in late Early to Middle Permian time. Middle to Late Permian conchostracan biostratigraphy, however, will be considerably improved by ongoing investigations based on the continuous Middle Permian to Early Triassic fossiliferous continental sections of the East European Platform (Golubev, 2000; Golubev et al., 2012; Scholze et al., 2015, 2016). Both non-marine and marine workers are asked for support to improve the conchostracan biostratigraphy and its link to the marine Standard Global Chronostratigraphic Scale.

Acknowledgements

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Gondwanaland or Gondwana How a Useful Geological Concept is Becoming Almost Meaningless

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Abstract
The name Gondwana belonged to an ancient Indian kingdom. During the 19th Century, geologists from the Geological Survey of India examined a geological succession containing significant Permian coal measures that they designated as the Gondwana Series as it occurred within the boundaries of Gondwana. Subsequently similar series were found beyond Gondwana and named the Gondwana Series. Later workers discovered the Gondwana Series to occur over a significant part of the Earth's land surface all located on a massive continent named Gondwanaland by the
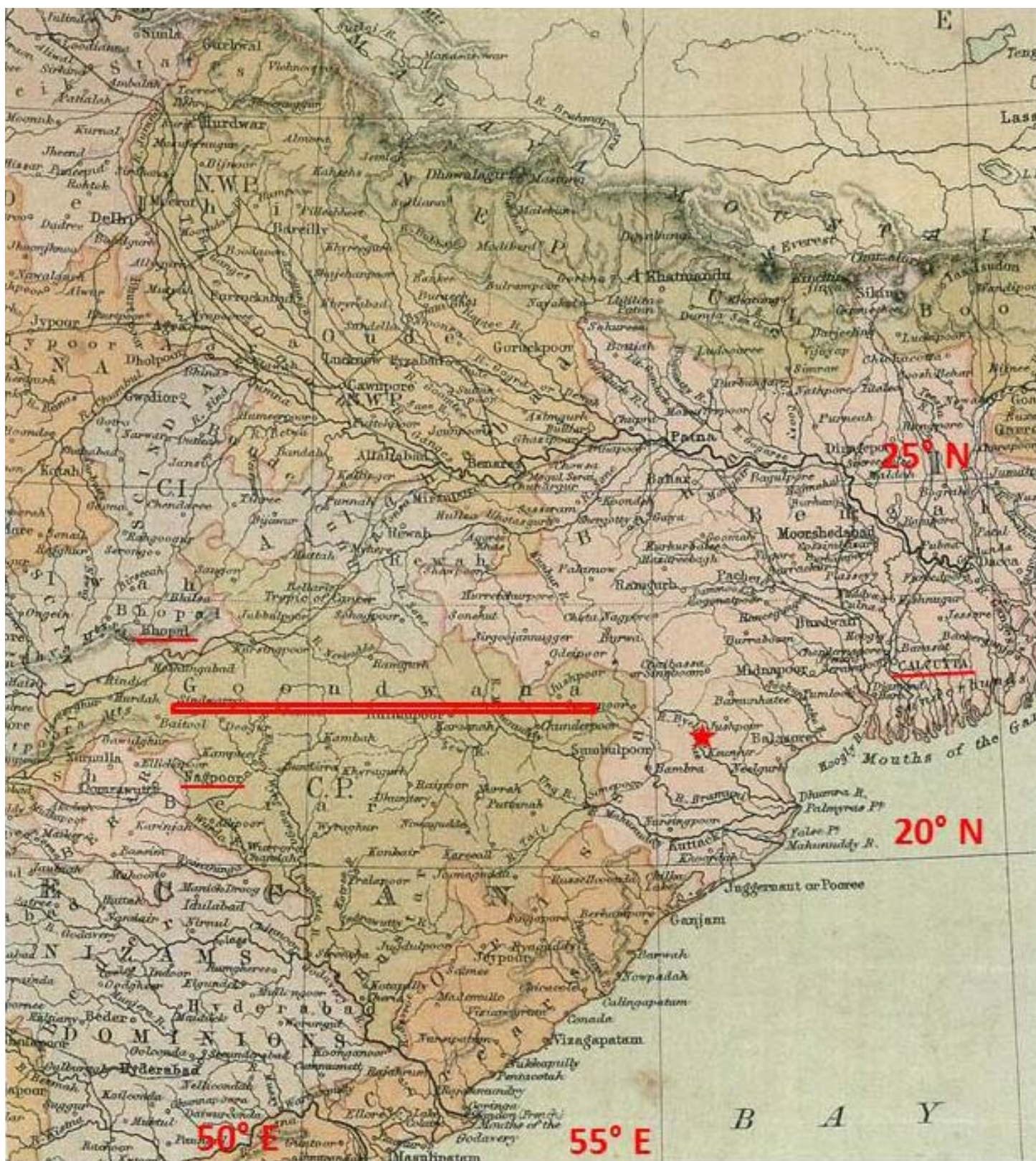
Fig. 1. Copy of part of map of central and eastern India (The Academic Atlas, 1880, map 21), the only map I have been able to find indicating the presence of Gondwana (Goondwana on the map, double underlined in red). Names of some cities have been single underlined to aid in locating the approximate whereabouts of Gondwana, with some geographical coordinates also inserted in red. The red star is the city of Talcher, not identified on the map. All red labels have been inserted by the author. The map was published before the spelling in English for names in Hindi/Sanscrit had become standardised.

Austrian academic, E. Suess. Principally during the second half of the 20th Century this became abbreviated to the preoccupied name Gondwana, justified by the mistaken impression that 'land' was a tautonym of 'wana', which it is not. In doing so the meaning became blurred.

Introduction

The author is solely responsible for the views and interpretations herein.

The eminent Indian palaeontiologist, S. C. Shah, formerly GSI [Geological Survey of India], now deceased, and I had discussed the use of the name Gondwana to describe a Late Palaeozoic – Mesozoic continent. We were not happy. Palaeontologists are most particular to respect priority. The name Gondwana has priority, meaning first defined usage, for a feudal Dravidian kingdom that more or less covered the same area as the modern Indian states of Madhya Pradesh and Jharkhand, along with the northern parts of Chhattisgarh and Odisha. It was first mentioned in 14th Century Muslim chronicles (Gondanaland, 2015). Its demise began when in the 18th Century the Gonds were conquered by the Marathas, until the final remnants disappeared when India became independent in 1947. The only archival map of 18th Century India available to me post-dates the Maratha Conquest so I am unable to figure the region covered by Gondwana. An atlas published about 1880 (The Academic Atlas, 1880) has the word 'Gondwana' across the map of India covering the modern states listed above but without any boundary. As such it refers to an historical region of India, it does not include all the terrestrial areas of the most of the present day Southern Hemisphere along with India as for some modern usage within geology. The original definition of the name Gondwána-Land in German was by the Austrian academic Suess (1885, 1904) in a geological context. I consider the change in spelling to Gondwana land then later omitting the space, to be an orthographic correction during translation from its original German into present day English. Suess gave a precise definition of his concept, discussed further, below. Since then, the name has been used or misused. There have been many significant reviews of the Gondwanaland concept, including by Teichert (1952), Sastry et al. (1977) and Thenius (1981).

What is the meaning of the word Gondwana?

Herein words from Sanskrit or Hindi are written using the Devanagari alphabet.

गोंड = Gond, the name of a people.

वाना (or वना) = wana, meaning forest.

Together these two words became Gondwana meaning forest of the Gond as the name of a kingdom (Gondwanaland, 2015).

This has been combined with the word थूमि = thumi, meaning land, country, nation, territory. I have only seen this used in text written in or translated into Hindi. Incidentally, the pronunciation of thumi is t-humi but not as if it were spelt using the Greek θ as θumi. This was the reason my Indian colleagues used both wana (= forest) and thumi (= land as in country/nation) in translating Gondwanaland as they knew these two words had different meanings.

When all these are combined, using the preferred spelling, they become, गोंडवानाथूमि (=Gondwanathumi) meaning Gond-forest-land, or the Land/Nation of the Gond-Forest.

Talcheer, then Talchir, now Talcher have been used as alternative transliterations using the Latin alphabet for a princely state in one area where the Gond people lived. Talcher is located in the central part of Odisha (=Orissa) state. More recently, Talchir has been retained as the spelling for the name in stratigraphy in Indian literature, and Talcher is the correct transliteration of the name from the Hindi तलचेर, for all other purposes including geographical.

Why was the name Gondwana used?

Below, I have retained the spelling of localities used by cited authors in their publications. The Blanford brothers H. F. and W. T. have their initials added in citations to make the text easier to follow.

Blanford, W. T., Blanford, H. F., et al. (1859), geologists from GSI, described the geology of the Talcheer Coal Field for the first time. They described a boulder bed as the lower part of the Talcheer Group in detail, noting its glacial aspect but they were in my supposition apparently confused by its presence in a non-mountainous region within the tropics.

Later Blanford W. T. (1872) redescribed the geology of the Nágpúr area of the Talcheer Coal Field including an extended description of the "boulder beds" giving reasons why they were unlikely to be of glacial origin. Oldham (GSI), in his editorial capacity, inserted a footnote (p. 324 of Blanford's text), reporting the discovery (by Fedden) of a striated pavement and polished surfaces on boulders in an outcrop of the 'boulder bed', at the same time apologising he had not been able to hand the data to Blanford who had by then departed to a remote area on an urgent field program. Fedden later (1875) published the first scientific description of his observations thereby formalising his observations.

Medlicott (1872), also from GSI, published comments on his mapping of the geology of the Satpura Basin, a sub-basin of the Talchir Coalfield. Sometime about that year he had submitted a manuscript report, never published, apparently now lost (Sastry et al.. 1977), in which the name Gondwana Series was used in the description of the Late Palaeozoic strata he had mapped as it lay within the boundaries of the historical nation of Gondwana.

Feistmantel (1876), in a discussion of some fossil floras of India said that tha the name 'Gondwana Series' had been used unofficially within GSI, but the first time it had been used in print was by Blanford, H. F. (1876, or earlier).

W. T. Blanford (1876) discussed the terrestrial floras and marine invertebrate faunas of the 'Gondwána Series with formations ranging from the Upper Palæozoic to the Lower Jurassic' in both India and eastern Australia based on generic identity of fossils, thus recognising a biological connection. He did not mention the ?glacial beds of the Talchir Coal Field as evidence for a Late Palaeozoic glaciation that was unknown at that time beyond Talcher including in Australia where Permian coal measures were known. Furthermore at that time any evidence for the Gondwana Series in Africa, South America and Antarctica was unknown.

The first volume of Suess (sometimes spelt Süß) 'Das Antlitz der Erde' (1885) began a sinthesis of all known worldwide aspects of stratigraphy both sedimentary and igneous. In the chapter 'Das gebrochene indische Festland' he discusses certain sedimentary basins from India as the 'Serie der Gondwána' comprising the Late

Palaeozoic 'Unter-Gondwána' and the Jurassic 'Ober-Gondwána' differentiated on the basis of their fossil terrestrial floras. In part 2, chapter 12, p. 768 'Die Continente' he defines the regions where the ancient Gondwána-Flora occurred in Gondwána-Land as defined by him. In later volumes of 'Das Antlitz der Erde' he redefined Gondwána-Land based on subsequent geological discoveries, eg. in South America. Vols 2 and 3 appeared later wherein the definition of Gondwanaland had been broadened in keeping with later geological discoveries. These were not significant to the present discussion, so are not listed as references.

Suggestions towards its use in geology

The use of the name Gondwana in Indian history and archaeology is to be continued without alteration as it has priority, or in any redefinition when referring to the territorial extent of the Dravidian kingdom which predates the beginning of geology as a science. This does not preclude the usage, eg. as in Gondwanan fossil flora when referring to the flora found within Gondwana, or in correlating an obviously related flora from elsewhere. Priority of naming in all cases must be applied similarly as in taxonomy and stratigraphy. Gondwanaland has priority for usage in palaeogeography and similar geological applications. The change of á to a, and closing the space before 'land' are orthographic corrections in translation into modern English.

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13th International Field Workshop on the Triassic, Xingyi/Guizhou, Southwestern China, August 1–5, 2016

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The 13th International Field Workshop was held in Xingyi/ Guizhou, Southwestern China. This was in stark contrast to last year's workshop on Svalbard/Norway, both geographically and geologically. Whereas the former workshop was well north of the Polar Circle at some 78° northern latitude in the arctic realm, the latter was at some 25° N in a subtropical and humid climate close to the Tropic of Cancer. The workshop was organized by Professors JIANG Da-Yong and SUN Zuo-yu of Peking University. Their invitation was accepted by around 50 Chinese and international participants. Xingyi is a modern city of some 800,000 inhabitants, the bustling capital and commercial center of the Autonomous Qianxinan District of the Bouyei and Miao minorities. Guizhou was once one of the poorest provinces in China and is now experiencing rapid infrastructural and economic development. Large parts of Guizhou Province consist of mountainous areas that are predominantly formed by thick limestones of Permian and Triassic ages. The carbonates are often karstified and frequently show kegelkarst (cockpit karst) with typical conical peaks that may rise to more than 1500 m above sea level forming beautiful landscapes (Fig. 1). In recent years, the region has become internationally famous because of its spectacular Middle and Upper Triassic fossil lagerstätten with outstandingly preserved marine reptiles, fish, crinoids and other faunal elements. The lagerstätten occur in several relatively thin intervals of euxinic

Fig. 1: Xingyi National Geological Park, kegelkarst in Triassic carbonates; fig. 2: Guanling Formation (Anisian) near Yongning village with distinct cyclicity.

Fig. 3: Guanling National Geopark. Xiaowa (Falang) Formation (Carnian) with *Traumatocrinus* attached to driftwood.

black shales and limestones within the more than 2000 m thick Triassic succession, deposited in depressions on the extensive Yangtze carbonate platform.

The **Maling Gorge**, which is just a few kilometers from the city, was visited during a pre-workshop trip. There, the Maling River is steeply entrenched into Triassic limestones and many picturesque waterfalls occur along the 150 m high cliffs.

The workshop was formally opened in the Fukang Hotel and chaired by Province Vice-Governor ZHOU Zhou, City Mayor YUAN Jinlin and other political leaders. The first field trip went to the **Xingyi National Geological Park.** In the Zhuganpo Formation of late Ladinian age are found abundant well preserved marine reptiles, including small *Keichousaurus hui*, fish as well as crinoids. A museum and a research center are under construction at the fossil site. A second museum is closer to the city to attract more visitors later. Other parts of the geological park are already fully developed for tourism with a new road leading along a karst valley, where visitors, sitting in special cars, are driven along and can overlook the beautiful "polje" and kegelkarst landscape, dotted

with small villages (Fig. 1). From Wangfenglin ("Emperor's tree"), the highest peak in the area, there was an amazing view of the bizarre cones of the kegelkarst spread out from horizon to horizon. On the new highway, leading over the high Maling and Beipan suspension bridges, it takes about 90 minutes to reach Yongning village near Guanling City. The improvement and widening of the old road between Yongning and Wayao villages has created excellent new outcrops of the Yangluijing, Guanling, Yongningzhen and Zhuganpo and Xiaowa (Falang) formations (Middle to Upper Triassic; Fig. 2). The **Guanling National Geopark** exists since 2004. In several buildings the Guanling fauna from the black shales of the Xiaowa (Falang) Formation (Carnian) is shown, consisting of well preserved marine reptiles including ichthyosaurs, thalattosaurs, placodonts and fish, some in their original positions. Extraordinary are the large colonies of the pseudoplanctonic crinoid *Traumatocrinus* with up to 10 meter long stems attached to driftwood (Fig. 3). Two new buildings are under construction including a multi-media center. The day closed in Guanling City with a dinner by local authorities. Dr.

Fig. 4: Luoping National Geopark; fig. 5: Luoping National Geopark, excavation site in upper Guanling Formation (Anisian).

HANS HAGDORN conveyed warm greetings of Hohenlohe County in Germany. Following earlier Chinese-German geological research, there has been a successful coorporation with Guanling County for the last few years.

In the **Wumengshan National Geopark** near Yangjuan village/ Panxian County the Guanling Formation (Anisian) has yielded numerous marine reptiles and fish. Yet unfinished buildings protect the fossil sites. Several bentonite beds indicate ages of around 245 Ma.

Luoping National Geopark in Yunnan Province is some 70 km west of Xingyi and can be reached readily by a new highway. The entrance to the park is adorned by a huge bronze monument showing crawling reptiles and, further up the mountains, there is an impressive stone column (Fig. 4). Wisely, the Guanling Formation was kept open along the road cut. The large excavation site in the upper Guanling Formation can be examined bed by bed (Fig. 5). Explanations were given by Professor HU Shixue, Chengdu University, Head of the excavations. Many of the marine reptiles and other fossils found are shown in a museum in nearby Dawazi town. Afterwards participants accepted the kind invitation for lunch by the mayor of Luoping town.

Back in the Xingyi Conference Center, the late afternoon was dedicated to a discussion of potential UNESCO Geoparks or Word Heritage Sites. The excavations and scientific work of the last decades have shown that an exceptionally broad variety of well preserved Triassic marine reptiles and other faunal elements exists here, important to understand the world some 240 Ma ago and the evolution of marine life in general. These fossil lagerstätten are embedded in a fascinatingly beautiful karst landscape with thousands of hills and deeply incised valleys inhabited by friendly people belonging to various ethnic groups.

The outstanding social highlight was certainly the festive dinner in the large hall of the Conference Center on the kind invitation of Xingyi Mayor YUAN Jinlin. Cordial words of thanks to the generous hosts and to the organizers with many "*gan bei*" closed this very successful workshop.

The next workshop is planned in Jordan in early March 2017, organized by Abdalla Abu Hamad of the University of Jordan, Amman. The main topic will be the famous epicontinental Permian and Triassic on the eastern side of the Dead Sea. For contact: abdalla80@hotmail.com or gerhard.bachmann@geo.uni-halle.de.

62. (available on open access via: http://www.sciencedirect.com/ science/journal/20953836)
This paper explores the controversy between anoxia vs oxygenated shallow oceans in the immediate aftermath of the end-Permian extinction, using information on the oceanography of the modern Black Sea. The paper proposes the possibility that upwelling events (known to occur in the Black Sea) have the potential to sweep anoxic indicators, especially pyrite framboids, into the upper mixed water mass where it can be transported to the shelf and deposited.

Kershaw, S., Collin, P-Y. and Crasquin, S. 2016. Comment to Lehrmann et al. New Sections and observations from the Nanpanjiang Basin, South China. *Palaios*, **31**, 111-117, doi:10.2110/palo.2015.093.
This comment addresses a few points in Lehrmann et al.'s 2015 comprehensive paper, and recommends a few reconsiderations. Note that Lehrmann et al. replied (see Palaios 2016, v.31, pages 118-121, dx.doi.org/10.2110/palo.2016.016)

Kershaw, S. and Guo, L. 2016. Beef and cone-in-cone calcite fibrous cements associated with the end-Permian and end-Triassic mass extinctions: Reassessment of processes of formation. *Journal of Palaeogeography*, **5**, 28-42. (available on open access via: http://www.sciencedirect.com/science/journal/20953836)
This paper explores the processes of formation of beef and cone-in-cone (B-CIC) calcite in relation to the two extinctions, which has been suggested in recent publications to relate to ocean acidification and formation of sub-seafloor precipitates. We present evidence that supports a later diagenetic formation of the B-CIC calcite found in these deposits; thus we view B-CIC as NOT being related to environmental processes associated with both extinction events. Fig. 1 shows some features, from this paper, of the B-CIC deposits from southern England, and the caption indicates the later diagenetic aspects of these deposits.

Reports on outputs recently produced on the end-Permian events

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The following outputs have been produced in the last year:
Kershaw, S. 2015. Modern Black Sea oceanography applied to the end-Permian extinction event. *Journal of Palaeogeography*, **4**, 52-

Fig. 1. A. Field photo showing layered Cone-in-Cone (CIC) calcite in Upper Purbeck non-marine limestones (Lower Cretaceous) on the east side of Lulworth Cove, southern England. B. Vertical section of loose block of limestone from the marine Shales-with-Beef beds of Lower Jurassic at Lyme Regis, Dorset, south England. Although the way up of this bed cannot be determined, it is of great importance that the CIC calcite layers at the upper and lower margins of this block are orientated outwards, and therefore opposite each other. Note numerous compacted ammonites in cross section scattered through this bed, crushed by compaction of sediment. C. Enlargement of area of blue box in B showing a small angular patch of clay, interpreted here as the insoluble fraction remaining after reorganisation (by displacement and/or replacement) of the original sedimentary carbonate that the rock comprised. Also visible is a crushed ammonite in cross section. D. shows the ammonite in thin section, demonstrating it was encased in CIC calcite after compaction, thus the CIC calcite formed later in diagenesis. E. Detail of a different sample from the Lower Jurassic at Lyme Regis, showing downward (red arrow) and upward (blue arrow) growth of small CIC calcite crystals pervade the sediment, which may have replaced the limestone with CIC calcite crystals and compressing the insoluble clay component into small lens-shaped areas. Note that the crystals develop in the direction opposite to the taper direction, so they are relatively flat-topped crystal masses composed of small needle-shaped crystals. Growth of small masses of CIC crystals in opposite directions is the normal situation, and easily explained by recrystallisation of the carbonate fraction of the sediment.

OBITUARY

IN MEMORIAM

Dr. Bruce R. Wardlaw passed away on Wed. March 23, 2016 from injuries due to a fall.

From his obituary:
On March 23, 2016 Bruce Richardson Wardlaw (Age 68) at INOVA Fairfax Hospital; Beloved husband of Jeanne E. Wardlaw of Herndon, VA; Loving and devoted father of Kristen Deanne Frankforter of Beaumont, CA, Andrea Jean Radics of Budapest, Hungary, Jane Wardlaw and Erin Michelle Wardlaw; both of San Diego CA. He is also survived by his brother Kirk Wardlaw of Marysville, CA and four grandchildren.

Dr. Wardlaw was the Chief Paleontologist of the US Geological Survey, which allowed him to travel to remote places around the world to investigate important sedimentary deposits. He was an internationally known expert in Paleozoic fossils and stratigraphy authoring many research papers in scientific journals and serving as editor of newsletters and proceedings volumes. During his 40-year research career Dr. Wardlaw was recognized for his exceptional service to the USGS in helping to understand various complex geological problems and managing teams of research scientists. He also served as liaison between the USGS and the Smithsonian's Museum of Natural History helping to curate unique collections of fossils from across the world.

Dr. Wardlaw was also active in coaching youth basketball.

The Permian is somehow just a bit quieter now
Bruce received his B.S. in Geology from the University of California-Riverside in 1969 and his Ph.D. from Case Western Reserve University in 1975 with his dissertation on *The biostratigraphy and paleoecology of the Gerster Formation (Upper Permian) in Nevada and Utah*. Bruce started his career with the USGS as a post doctoral fellow in 1975 and became a full-time research geologist in 1976. Over his career, he contributed to USGS science in stratigraphy, carbonate petrology, upper Paleozoic and Triassic conodont and brachiopod biostratigraphy and paleoecology, thermal maturation, coal geology, and nuclear bomb test craters. Although much of his research was in the western U.S., he reached out internationally in the Middle East, Pakistan, the Pacific atoll of Enewetak, and South China. More recently, Bruce was an integral part of a proposal to map the geology of Qatar for his expertise in carbonate petrology and paleontology. Also, Bruce was a prolific writer with well over 200 publications on his broad knowledge of geology. His legacy will include editorship of volumes of Micropaleontology and Stratigraphy, which will be published in 2016 and he was honoured at the Pander Session at GSA in Denver, September 25, 2016.

Randy Orndorff (USGS) says "I will miss him greatly. I have had many interactions with Bruce from my early career starting at the National Museum of Natural History (NMNH), and have relied on his knowledge and expertise in my current position as center director. Bruce would never hesitate to offer his help and never complained about any assignment he was given. Over the last several years, he has stepped up to work with the Smithsonian on inventorying, compacting, and evaluating over 120 years of USGS paleontological collections at NMNH. In doing so, he has worked with many student interns sharing his knowledge and mentoring them. As Chief Paleontologist and the last chief of the USGS Branch of Paleontology and Stratigraphy, he was the man for the job."

Charles Henderson adds "Bruce contributed enormously to the Subcommission on Permian Stratigraphy as the Secretary and later two terms as Chair of SPS. His work on Permian conodonts forms a lasting legacy including papers with Shilong Mei and me based on sections in China. The Smithsonian Contribution related to the Guadalupian Symposium will be cited for a long time to come. Bruce and I really got to know each other when I served as his Secretary for SPS. He visited Calgary in the summer and I visited Washington DC in the winter (much more sensible then the other way around) so that we could prepare *Permophiles*. This work was usually fueled with a few drinks and especially some fine scotch. It may surprise some, but as conodont workers we didn't always agree. We had many heated scientific debates that occasionally resulted in a compromise. Our conversations went well into the night, much to the consternation of our respective wives. Thanks to Elizabeth and Jeanne for putting up with us! I will always remember one trip to DC in which I joined him as one of his daughters played basketball and he had to referee. He asked me to be the timekeeper, but was uncertain of his request when I asked how long was a game? It is apparently shorter than the three 20 minute periods of hockey. I did learn during that visit, how much he loved coaching basketball, especially his girls, and how much he loved his family. I miss him."

He will be missed by so many people. One of my former students, Tyler Beatty, remarked "I have some good memories of Bruce - in particular the BBQ you and Elizabeth hosted in the fall of 2006, where Bruce turned me green with envy with his stories of seeing all of my favorite rock bands (Zeppelin, Stones, Deep Purple) back in the 70s. It seems to be a tough couple of years for both pioneering conodont workers and 70s rock legends. Perhaps they get to share a special place upstairs." Nancy Stamm added "You guys had some fabulous adventures together, and the best scientific discussions over refreshing beverages! It was a real treat for me just to hang out and listen to a few of them." Shilong Mei remembers his time in DC and hosting Bruce in China – quite a few papers resulted from their collaboration. He also conducted collaborative research with Merlynd Nestell at UT Arlington, which is described below.

Bruce Wardlaw and the Nestell's research connection

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Bruce Wardlaw and Merlynd Nestell first met in the spring of 1976 in the Paleobiology Department of the Smithsonian Institution and

began what was to be a 40 year collaboration resulting in over 45 joint publications of papers or abstracts on various aspects of Pennsylvanian/Permian conodonts and biostratigraphy from such diverse places as Greece (Nestell and Wardlaw, 1987), Vietnam (Wardlaw et al., 2015; Nestell et al., 2015), Mexico, Oregon, Kansas, Iowa (Nestell et al., 2016), and Texas. In that spring, they discussed their common interest in the Permian and decided to collaborate on a field trip the following summer to visit the well-known Permian section at Las Delicias in the state of Coahuila in Mexico. William Furnish of the University of Iowa was also invited to be a participant on this trip. The section is very remote and requires camping, and Nestell's four wheel drive vehicle was used to gain access. This trip was the first of three that Wardlaw and Nestell took to this section and eventually results were presented in two publications (Wardlaw et al., 1979, 2000). In their next field trip together in the summer of 1978 they met in Los Angeles with their two 12 year old daughters for a memorable joint camping and field work trip to central Oregon to examine the Permian rocks of the Grindstone terrane. Thomas Dutro of the USGS met them in central Oregon and a resulting paper was later published (Wardlaw et al., 1982).

Serious collaboration began after Wardlaw and Nestell participated in the Symposium of the Permian Guadalupian held in Alpine, Texas in 1996. One of the field trips was to the Apache Mountains northeast of Van Horn in West Texas and at one of the stops, Wardlaw, Nestell, Garner Wilde, and Lance Lambert recognized that there was a very substantial and unstudied section of the uppermost part of the Bell Canyon Formation and lowermost part of the Castile Formation exposed on a public road in the Apaches. On the day after the trip, Nestell returned to the field trip site to examine this section and accidently met one of ranch landowners in the area who, after some discussion, graciously agreed to allow future geological field work by Nestell and his students on his very large ranch. That summer, on a field trip to the look at the Permian of the Crimea, Nestell met and soon after married Galina Pronina, a Russian Permian foraminifer worker and also at that time the Secretary of the Committee on the Permian System of Russia. Subsequently, both of the Nestells, Wardlaw, Gordon Bell, geologist for Guadalupe Mountains National Park, and Lance Lambert agreed to cooperate on several projects on the study of Permian microfaunas of the Guadalupe and Apache mountains areas because three sites in the Guadalupe Mountains area were being proposed as Guadalupian stratotypes. Since that time these stratotypes have been established. A number of joint publications and meeting presentations have resulted from this collaboration (Lambert et al., 2002; Nestell et al., 2006; Nestell and Wardlaw, 2010; Wardlaw and Nestell, 2010; Ellwood et al., 2012; Nestell et al., 2015; Wardlaw and Nestell, 2015; Nestell and Wardlaw, 2015). Work still continues at the present time to finish several papers on which Wardlaw is an author or coauthor.

In the 1990's Darwin Boardman and Nestell initiated a study of the latest Pennsylvanian and Early Permian conodont faunas of Kansas and northern Oklahoma as well as north-central Texas and later invited Wardlaw to participate in the project (Boardman et al., 1998). The Kansas study resulted in a Kansas Geological Survey publication (Boardman et al., 2009). Although much material was collected, processed and photographed for the Texas study, it has not yet completed. One paper on two occurrences of *Streptognathodus*

isolatus in Pennsylvanian/Permian boundary strata in Texas was published in Permophiles (Wardlaw and Nestell, 2014).

Soon after the work in the Apache Mountains was initiated, Wardlaw was included on several UT Arlington student thesis committees as an adjunct professor. He began to come regularly to Arlington for week visits, staying with the Nestells and working on papers, meeting with students, or going to do field work in West Texas or Nevada. At the time of his death he was serving on the committees of four graduate students.

Wardlaw and the Nestells worked very well together as a team and had many lively discussions on the various aspects of Permian faunas and their use in biostratigraphy. The establishment of the Guadalupian GSSP's in the Guadalupe Mountains area also stimulated more investigations into the documentation of Middle Permian microfaunas from the West Texas area. Bruce's insightful input into past publications is gratefully acknowledged and his careful and thoughtful work will be greatly missed.

Bruce Wardlaw and his Chinese colleagues

Bruce Wardlaw has long been one of the most intensive collaborators in the Late Paleozoic Research Group of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences. He began to work with Prof. Yugan Jin and Shilong Mei in the early 1990s. In addition to his leadership in establishing the Guadalupian GSSPs, Bruce Wardlaw also made significant contributions to the establishment of the Lopingian-base GSSP at Penglaitan, Laibin, Guangxi Province and the Changhsingian-base GSSP at the Meishan section D, Zhejiang Province (Jin et al., 2001, 2006). The conodont zonation of the Guadalupian and Lopingian in South China established by Mei co-authored with Wardlaw (Mei et al., 1994a, b) is still widely applied as the standard for global correlation. The sample population approach advocated by Bruce Wardlaw still has a deep impact on the identification of Permian gondolellid conodonts (Mei et al., 2004; Shen and Mei, 2010; Yuan et al., 2014). He, together with Shu-Zhong Shen, guided the International Lopingian Working Group to visit the Laibin area. This field excursion became a marker to persuade international colleagues to agree with the Lopingian-base GSSP in Penglaitan, Guangxi Province.

Bruce Wardlaw was a trusted colleague, an outstanding scientist, and a good friend to the Nanjing Group. In 2004, Bruce provided the Chinese Group with a guided tour of the Permian sequences in western USA and the Guadalupe and Apache Mountains in west Texas. During that trip we also had a flat tire in the desert in the Hugup Mountains near Salt Lake City and only managed to make it out by Bruce's ingenuity.

We enjoyed numerous field collaborations in South China with Bruce where he had the chance to experience some of the spicy local cuisine. Bruce was such a big fan that he once guided a chef of the hotel we were staying at on how to make the dished even more spicy and numbing. Bruce was also an easy going character. It has become a well-known custom for Bruce to give his SPS business meetings with a beer in his hand and a smile on his face. This "tradition" has since been succeeded by the successive SPS Chair Charles Henderson and current Chair Shu-Zhong Shen. Bruce will be missed as an inspiration, an intellectual leader, and most of all as a friend in times of need.

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Fig. 1A) B. Wardlaw and C. Henderson. Permophiles 43; December 2003. B) J. Yugan, C. Henderson and B. Wardlaw. Permophiles 45; June 2005. C) B. Wardlaw, Sweatt and G. Nestell standing on top of Bell Canyon Formation Limestone at AVN section in Apache Mountains; 2010. D) B. Wardlaw and H. Kozur sitting on the Roadian base; 2007. E) B. Wardlaw and M. Nestell sitting in Cherry Canyon Sandstone equivalent below massive Permian debris flow in canyon at Square Mesa, Apache Mountains, Texas; 2012.

Fig. 2. A) B. Wardlaw was interviewed at the Meishan D GSSP section in Changxing, South China by the journalists from the Changxing TV Station. October 2003. B) B. Wardlaw introduced the Guadalupian/Lopingian boundary at the Apache E section in Texas. (From left to right: Bruce Wardlaw, Shu-Zhong Shen, Yue Wang, Xiangdong Wang). May 2004.

SUBMISSION GUIDELINES
FOR ISSUE 64

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

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Permian Timescale

AGE (Ma)	Epoch/Stage	Polarity Chron	Conodonts	Fusulinaceans	Ammonoids	Vertebrates	Main Seq. T R
250	Triassic 251.902 +/-0 .024		Isarcicella isarcica / Hindeodus parvus		Ophiceras / Otoceras		
252	Changhsingian		H. praeparvus-H. changxingensis / Clarkina yini C. meishanensis / C. changxingensis / C. subcarinata / Clarkina wangi	Palaeofusulina sinensis / Palaeofusulina minima	Rotodiscoceras/Paratirolites / Pseudotirolites / Pseudostephanites	Lystrosaurus	
254	Lopingian —254.14+/-0.07—		C. orientalis/C. longicuspidata				
256	Wuchiapingian		C. transcaucasica/C. liangshanensis		Sangyangites / Araxoceras / Anderssonoceras		
258	259.1 +/-0.5		C. guangyuanensis / Clarkina leveni / C. asymmetrica / C. dukouensis / Clarkina postbitteri postbitteri / C. postbitteri hongshuiensis	Codonofusiella / Lepidolina	Roadoceras / Doulingoceras	Dicynodon	
260	Capitanian		Jinogondolella granti / J. xuanhanensis / Jinogondolella altudaensis				
262			Jinogondolella shannoni		Timorites	Oudenodon / Tropidostoma / Tapinocephalus	
264	— 265.1 +/-0.4 —		Jinogondolella postserrata	Yabeina			
266	Guadalupian Wordian		Illawarra	Neoschwagerina margaritae			
268	— 268.8 +/-0.5 —		Jinogondolella aserrata	Afghanella schencki / Neoschwagerina craticulifera	Waagenoceras / Paraceltites	Eodicynodon	
270	Roadian						
272	272.3 +/-0.5		Jinogondolella nankingensis	Neoschwagerina simplex	Demarezites		
274			Mesogondolella lamberti / Neostreptognathodus sulcoplicatus			Angelosaurus	
276			Mesogondolella idahoensis	Cancellina	Pseudovidrioceras		
278	Kungurian		Sweetognathus guizhouensis	Armenina		Labidosaurus	
280			Neostreptognathodus prayi	Misellina	Propinacoceras		
282			Neostreptognathodus pseudoclinei / Neostreptognathodus pnevi	Brevaxina		Mycterosaurus	
284	Cisuralian — 283.5 +/- 0.6 —		Neostreptognathodus pequopensis	Pamirina / Chalaroschwagerina	Uraloceras / Aktubinskia / Artinskia	Seymouria	
286	Artinskian		Sweetognathus clarki	Pseudofusulina solidissima / Pseudofusulina juresanensis	Popanoceras		
288				Pseudofusulina pedissequa			
290	— 290.1 +/- 0.26 —		Sweetognathus whitei / Sweetognathus anceps / Mesogondolella bisselli	Leeina urdalensis	Uraloceras / Metalegocers / Properrinites		
292	Sakmarian		M. visibilis / Mesogondolella lata	Leeina vernuelli			
294	— 295.0 +/-0.18 —		Sweetognathus binodosus / Sw. merrilli M. uralensis	Sakmarella moelleri	Sakmarites		
296			Streptognathus postfusus / Mesogondolella striata / Streptognathus fusus / Streptognathus constrictus	Sphaeroschwagerina sphaerica / Pseudoschwagerina uddeni / Sphaeroschwagerina moelleri	Juresanites		
298	Asselian		Streptognathus sigmoidalis / Streptognathus cristellaris / S. glenisteri / Streptognathus isolatus	Globifusulina nux / Sphaeroschwagerina fusiformis	Svetlanoceras		
300	298.9 +/- 0.15 Carboniferous		Streptognathus wabaunsensis		Shumardites / Emilites	Sphenacodon	

Note: This is the latest version of the Permian timescale which SPS recommends (Shen et al., 2013, New Mexico Museum of Natural History and Science, Bulletin 60, p. 411-416). We welcome any comments to improve it. All the information will be updated from time to time here. Geochronologic ages are combined from Burgess et al. (2014, PNAS 111, 9, p. 3316–3321); Shen et al. (2011, Science 334, p. 1367-1372) for the Lopingian; Zhong et al. (2014) for the Guadalupian-Lopingian boundary; Schmitz and Davydov, (2012, GSA Bulletin 124, p. 549-577.) for the Cisuralian, Henderson et al. (2012, The Geologic Time Scale 2012 (vol. 2), p. 653-679) for the base of Kungurian and the Guadalupian. Tetrapod biochronology is after Lucas (2006, Geological Society London Special Publications 265, p. 65-93).