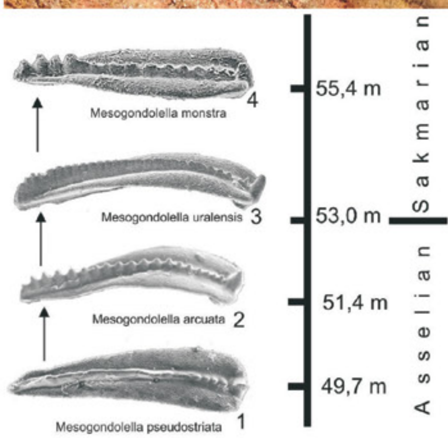
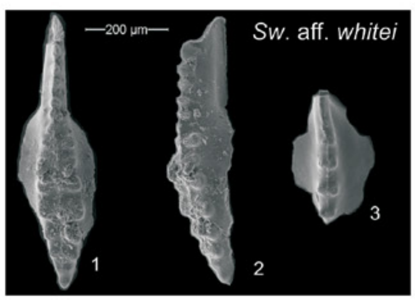
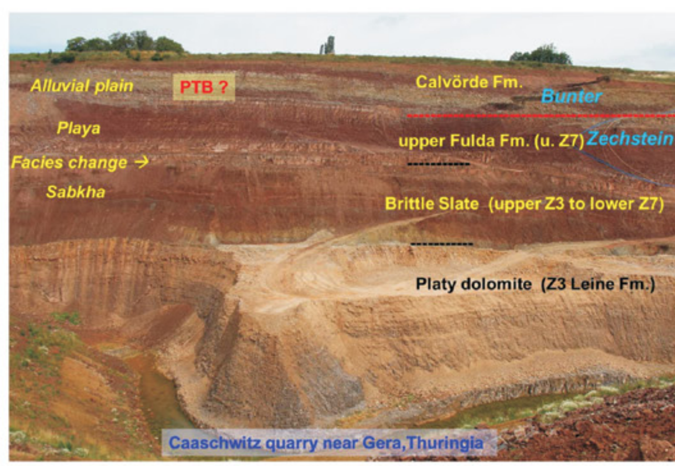
Permophiles

International Commission on Stratigraphy
International Union of Geological Sciences







Newsletter of the
Subcommission on
Permian Stratigraphy
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EXECUTIVE NOTES

Notes from the SPS Secretary

Lucia Angiolini

Introduction and thanks

This issue was planned by Shuzhong and I in the beautiful landscape of the Ali Bashi Mountains, near Julfa, NW Iran, during a successful Chinese-Iranian-Italian fieldtrip focused on detailed brachiopod and conodont sampling in the Permian-Triassic boundary beds in September 2013 (see report in this issue). The issue, which is the second of the new executive committee of Subcommission on Permian Stratigraphy, was then finalized and edited by Shuzhong in Nanjing and myself in Milano through email communication.

I would like to draw again your attention to the new SPS webpage that Shuzhong Shen has provided at http://www.stratigraphy.org/permian/, 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 an updated Permian timescale. Please check carefully if your details are reported correctly in the list of SPS corresponding members and write to me and the chair if anything is not correct.

In this foreword, I would like to thank very much Maryam Bahrammanesh, Syrus Abbasi, Mina Birjandi and the two drivers Mr. Takhtchin (GSI of Tehran) and Mr. Eshghi (GSI of Tabriz) for the excellent organization of the field trip in the famous Ali Bashi sections (Iran) that we led a few weeks ago (September 25-October 5, 2013).

As the secretary, I would like to thank the protagonists of the heated debate on the Kungurian base GSSP candidates from the Mechetlino section in southern Ural and Rockland section in Pequop Mountains, Nevada. This discussion was very fruitful to move Kungurian studies forward and culminated with the contribution of Stanley Finney, Chair of the International Commission on Stratigraphy, who clarified the voting procedures and with the final and wise decision of the SPS chair Shuzhong Shen to postpone the vote until further data on both sections are provided.

We received several contributions from our Permian colleagues recently, that make this issue rich and interesting. Contributions and comments from Permian workers (and not only from them) are very important to move Permian studies forward and to improve correlation and the resolution of the Permian Timescale. In the same way, these contributions will be important to keep going for future issues of *Permophiles*. So I want to warmly thanks Stanley Finney, Vladimir Davydov, Charles Henderson, Spencer Lucas, Valery Chernykh and co-authors, Boris Chuvashov and co-authors, Abbas Ghaderi and co-authors and the Chinese-Iranian-Italian working group and the Sino-German Group for their contributions to this issue.

Previous and forthcoming SPS Meetings

Two SPS meetings have been recently held. A joint business meeting with the Carboniferous Subcommission was held in Albuquerque, during the International meeting on Carboniferous and Permian Transition, which was hosted by the New Mexico Museum of Natural History and Science, Albuquerque, New Mexico, USA, May 20-22, 2013. The SCS chair Barry Richards and Shuzhong Shen chaired the meeting. Both chairs reported the progresses of the subcommissions and agreed to organize a joint working group on the global correlation of the Carboniferous and Permian transition between marine and non-marine sequences. Joerg W. Schneider will lead this working group and he is publishing a note in this issue to call your participation to the working group. The Carboniferous/Permian boundary GSSP at the Aidaradash and its problems of correlation was also intensively discussed during the business meeting (see reports in this issue by Spencer Lucas and Vladimir Davydov). The following colleagues attended the bussiness meeting: Alexander Biakov, Jim Barrick, Ausonio Ronchi, Barry Richards, Vladimir Davydov, Alexaner Ivanov, Shuzhong Shen, Spencer Lucas, Wenkun Qie, Dongxun, Yuan, Karl Krainer, Steve Rosscoe, Phil Fedreick, Yuping Qi, Lance Lambert.

Two forthcoming SPS meetings are scheduled. One will take place during the XVIII International Congress on Carboniferous and Permian to be held in the Kazan Federal University, Kazan, Russia, August 7-15, 2015.

A business meeting will be organized during an international field meeting on continental Carboniferous and Permian in the second half of July 2014 in Freiberg, Germany. Both this meetings will serve as the kick off for the cooperation of colleagues interested in Carboniferous and Permian marine - non-marine correlation.

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Besides the report of the Kungurian GSSP ballot, this issue contains the following reports:

Stanley Finney's paper, here reported from "Finney, S.C., 2013, The reality of GSSPs: Ciências da Terra (UNL), 18: 9-12", is very important to stimulate the ongoing discussion among the SPS members. It outlines the problem that, unfortunately, the GSSP for a specific boundary is too often presented only as the single stratigraphic signal at which the boundary is placed in the stratotype section. In reality it only has significance for chronostratigraphic correlation when it has high potential for correlation across a range of paleogeographic and paleoenvironmental settings.

We have also included Stanley Finney's abstract for the Annual Meeting of Geological Society of America, October 2013, because it says that if an already approved GSSP is shown to be inadequate for reliable, high-resolution correlation it should be reconsidered.

Spencer Lucas comments on the primary criterion used to correlate the base of the Permian, the FO of the conodont *Streptognathodus isolatus*, showing that it is now problematic. The evolution and taxonomy of *S. isolatus* are not agreed on, and *S. isolatus* is a very rare taxon, of little use to global correlation. The GSSP section at Aidaralash Creek is also far from ideal and leads him to conclude that we should reconsider the position of the base of the Permian and its current GSSP.

Valdimir Davydov answers to Spencer Lucas underlying that, at Aidaralash Creek, the C-P boundary position is characterized by bioevents of the three major fossil groups - fusulinids, conodonts and ammonoids - and also by palynomorphs. Besides, it has paleomagnetic proxies with high potential for global correlations. He provides other cases of multi-variant interpretation of phylogeny concerning primary criteria for GSSP and he shows that the distribution of *S. isolatus* is quite wide.

Valery Chernykh and co-authors provide a GSSP Proposal for base-Sakmarian stage to be defined by the FAD of *Mesogondolella uralensis* in Bed 25 at the Usolka section; the boundary can be correlated by an extrapolated geochronologic age, strontium isotope values, a negative shift in δ13Ccarb value, and by fusulines.

Boris Chuvashov and co-authors provide a GSSP Proposal for base-Artinksian to be established on conodonts, fusulinaceans and ammonoids in the Dal'ny Tulkas section. Once read by the Permian community, the chair should be able to consider a vote in the new year on these two proposals.

The Chinese-Iranian-Italian working group presents a short report on a field trip they led in the Ali Bashi Mountains and at Zal in NW Iran with some preliminary considerations, some of which in agreement with the following report by Ghaderi et al.

Abbas Ghaderi and co-authors comment on the debated correlation of two famous sections in the Ali Bashi Mountains, Julfa, NW Iran, namely the famous section 1 and 4 firstly described by Teichert et al. (1973). They suggest a solution for the long-standing debate which is in agreement with previous reports on the subject published in several issues of *Permophiles* (*Permophiles* 50, 51, 52).

Finally, the Sino-German Cooperation Group presents a report of their field excursion focused on the Carboniferous and Permian successions of Europe (Austria, Germany and Italy).

Future issues of Permophiles

The next issue of *Permophiles* will be the 59th issue.

I kindly invite our colleagues in the Permian community to contribute papers, reports, comments and communications.

REMEMBER, your contributions are very important to move Permian studies forward. Do not miss this opportunity!

The deadline for submission to Issue 59 is February 28, 2013. 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 and advices to improve the webpage as we move forward.

Errata to issue 57

Figure 6, page 12, reported by Maryam Bahrammanesh, shows a photo of a thrombolite in the field, which does not come from Iran, but from the Dongwan site in Sichuan Province in China. The same has been figured by Ezaki et al 2003, Palaios, v. 18, p. 388-402 and Kershaw et al. 2007, Facies, v. 53, p. 414.

Report on the Kungurian GSSP ballot (SUSPENDED)

Between 12th March 2013 and 12th April 2013, the voting members of SPS have been called to vote for the Global Stratotype Section and Point (GSSP) for the base of the KUNGURIAN STAGE of the Lower Permian, which is defined at two possible sites including the Rockland section in the Pequop Mountains of NE Nevada, USA and at the Mechetlino Quarry section in Russia.

Received Ballots: 13
Yes to Rockland: 6
Yes to Mechetlino: 7

Abstained: 2
Not voted: 2

On April 8th, 2013, the SPS Chair decided to suspend the vote on the Kungurian GSSP on the basis that all discussions must be completed before ballots are distributed and a vote is taken. In fact a hot debate accompanied the voting procedure, indicating that the open discussion period that proceeded the vote was not enough to elucidate all problems and present and challenge all the positions. The discussion period for the Kungurian GSSP was thus opened again.

Notes from the SPS Chair

Shuzhong Shen

How to understand and use a GSSP for correlation based on its definition is really a complicated topic. In this issue, we particularly invited the paper by ICS Chair Stanley Finney published in the proceedings of the 1st International Congress held in Lisbon in July, 2103. In his paper, Stan emphasized that a GSSP in reality is only significant for chronostratigraphic correlation when compared to the distribution of other stratigraphic signals in the boundary interval. Some colleagues still think that a GSSP is the unique standard when defined. However, in many cases such kind of unique standard is commonly biased by incompleteness of fossil records, facies changes and collecting intensity. Some recent high-precision geochronologic ages and chemostratigraphical signals are already beyond the resolution of fossil zonation. I would thank Stan for his agreement to publish his paper here for the Permian community.

The Kungurian-base GSSP is one of the most difficult one to be defined because multiple signals are not available, in particular, the chemostratigraphical, geochronological and magnetostratigraphical records are still not available. The two proposals of the Rockland section and Mechetlino Quarry section were submitted to SPS for voting this year. We failed to get a consensus based on the voting process. Both sections have obvious pitfalls which suggest more work is needed before the SPS voting members get a clear idea of which section is better. For the time being, the definition is based on a single standard, that is, the FAD of the conodont Neostreptognathodus pnevi. Therefore, SPS, decided to postpone the voting for the Kungurian-base GSSP candidates after discussion in the executive committee and with ICS officials until we get sufficient data to indicate better correlation potential of either sections. We also encourage our colleagues to propose new sections for the Kungurian-base GSSP.

I would thank Valery Chernyk and Charles Henderson for their time to work on the proposals for the Sakmarian-base and Artinskian-base GSSPs. Both are included in this issue. We will set up one-month fixed term for discussion on these two proposals among the SPS voting members shortly, then, send the comments back to the leaders of the working group for revision. We hope we can submit the proposals to ICS for voting if the SPS committee pass these two proposals. This is the priority work to do for the SPS recently.

I would thank Charles Henderson and Lance Lambert for their kind guidance and joint work in the Guadalupe National Park on the Guadalupian Series. Three GSSP markers were placed on the GSSP sections (see cover photo). I would also thank Drs. Jonena Hearst and Pierce Karl of the Guadalupe National Park for their kind support and permission in the field work. We collected more than 1000 kg samples for various studies.

I would thank Jörg Schneider, Hans Kerp, Werner, Buggisch, Michael Joachimski, Karl Krainer, Evelyn Kustatscher, Frank Scholze, Ronny Rößler, Ralf Werneburg, Sebastian Voigt for their wonderful organization and kind guidance of the Sino-German joint field excursion in Europe and Alps for the Chinese team. During this field trip, we have investigated the Pennsylvanian, Permian, Triassic sequences and various marine and terrestrial fossils in Germany and Alps (see a brief report by Wang, Shen and Schneider in this issue).

I would also thank Lucia Angiolini, Maryam Bahrammanesh, Syrus Abbasi for their kind guidance for the field work in the Kuh-e-Alibashi sections. Now it is quite clear that the section at Locality 4 measured by Teichert et al. (1973) represents the Dzhulfian Stage only and the section at Locality 1 represents the Dorashamian Stage and extends to the lowest Triassic (see reports by Angiolini et al. and Ghaderi et al. in this issue).

An SPS and SCS joint business meeting was held during the international meeting on the Carboniferous-Permian transition held between May 20-22, 2013 in the New Mexico Museum of Natural History and Science, Albuquerque, New Mexico, USA. Both subcommissions and about twenty participants agreed that a joint working group on the correlation between marine and nonmarine sequences of the Carboniferous-Permian transition should be organized. SCS chair Barry Richards came to Nanjing in October, 2013 and we met again. We emphasized that it is important to organize this working group. We welcome your suggestions and participation of the working group.

The SPS Annual Report 2013, which will be submitted by the end of December, is also included in this issue. The latest Permian timescale is available at http://permian.stratigraphy.org/per/per.asp, which was published by Shen et al. (2013, pdf is available at http://permian.stratigraphy.org/files/20130721210111619.pdf). Lucia Angiolini also updated the corresponding members of the Permian Subcommission. We look forward to your comments, suggestions and contributions.

REPORTS

Subcommission on Permian Stratigraphy

Annual Report 2013

1.TITLE OF CONSTITUENT BODY and NAME OF REPORTER

International Subcommission on Permian Stratigraphy (SPS)

Submitted by:
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2.OVERALL OBJECTIVES, AND FIT WITHIN IUGS SCIENCE POLICY

Subcommission Objectives: The Subcommission's primary objective is to define the series and stages of the Permian, by means of internationally agreed GSSP's, and to provide the international forum for scientific discussion and interchange on all aspects of the Permian, but specifically on refined regional correlations.

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

3a.CHIEF ACCOMPLISHMENTS AND PRODUCTS IN 2013

Progress was made on the three remaining Lower Permian (Cisuralian) stage GSSPs including Sakmarian-base, Artinskian-base, and Kungurian-base, two proposals for the Kungurian-base GSSP were voted within SPS voting members, but the voting was suspended because one of the voting members circulated his vote with his favorite opinion during the last stage of voting. Although the voting continued until the deadline, no consensus was reached. Thus, SPS suggested more work to do for both candidates and will open a new voting process for those two proposals in the next future. An SPS business meeting was held on the 21st of May, 2013 at Albuquerque, New Mexico, USA during the Carboniferous-Permian Transition Meeting. Two executives and four voting members attended the workshop.

In addition, the proposals of the Sakmarian-base and Artinskian-base GSSPs are are ready prepared by a working group led by Valery Chernykh and Charles Henderson. These two proposals are published in this issue of *Permophiles*. After the proposals are published, a one-month term for discussion will be set up, followed by a voting process within SPS voting members in 2014.

In addition, we have organized an international group to do a joint field excursion on the Guadalupian Series in West Texas in May, 2013. During this field excursion more than 800 kg samples were collected for conodonts and high-resolution geochemistry. Three GSSP markers were placed at the GSSP sections.

3b List of major publications of subcommission work (books, special volumes, key scientific paper)

One issue of *Permophiles* (Issue 57) has been published in March 2013. Another issue is nearly ready to be finished. We will publish Issue 58 before the end of this year.

Two volumes of special issues on the Carboniferous-Permian Transition have been published in 2013. These two special issues have been edited by Spencer Lucas (Bulletin 59 and 60 of New Mexico Museum of Natural History & Science). More than 100 papers/abstracts including a latest Permian timescale (Shen et al., 2013) have been published in these two special issues.

3c. Problems encountered, if appropriate

We have encountered a problem when we voted for the two proposals of the Kungurian-base GSSP candidates. One of the voting member circulated his vote with his favorite opinion during the last voting stage, thus the voting was suspended.

4a. OBJECTIVES AND WORK PLAN FOR NEXT YEAR (2014)

The primary objectives are to complete the last three GSSPs (Sakmarian, Artinskian, and Kungurian stages). We will publish the two proposals of the Sakmarian-base and Artinskian-base GSSPs in the forthcoming issue of *Permophiles* in 2013.

4b. Specific GSSP Focus for 2014

The priority of 2014 for GSSP is voting for the proposals of the Artinskian-base and Sakmarian-base GSSPs which are available.

5. SUMMARY OF EXPENDITURES IN 2013

A completely new website for SPS was established (http://permian.stratigraphy.org/index.asp). This website costs US$1290. Both SPS Secretary Lucia Angiolini and the former SPS Chair Charles Henderson visited Nanjing in in February, 2013 for *Permophiles* and field work in Laibin, Guangxi Province. The fund from ICS has been partly spent on paying their stay in Nanjing (US$1320). As invited by ICS, SPS chair Shuzhong Shen attended the 1st International Congress on Stratigraphy which was held in Lisbon (US$3174.6). Originally, a part of the cost to attend the congress in Lisbon should have been paid by the funds from ICS according to the Budget established in 2013, however, the expenditure has been much beyond the funds given by ICS ($2000), thus all the costs for the congress have been paid by Shuzhong Shen's project money. In addition, four bronze markers for three Guadalupian GSSPs have been made in China, and they costed $200.

6. BUDGET REQUESTS AND ICS COMPONENT FOR 2014

1)An international symposium on the Permian issues in early 2014 has been proposed by SPS Vice-Chair Joerg Schneider. We will organize a SPS business meeting to solve the last GSSP (Kungurian-base GSSP) problem and future directions for SPS ($2500). The money will be used to support the participation of some colleagues who lack funding.

2)Supporting Lucia Angiolini (SPS secretary) to come to Nanjing in March, 2014 for *Permophiles* and discussion on the plan for completion of the Sakmarian-base and Artinskian-base GSSPs within 2014: US$1500.0

3)Supporting Charles Henderson who is in charge of the two proposals to come to Nanjing in March, 2014 to 1) revise proposals, prepare voting process for the Sakmarian-base and Artinskian-base GSSPs; 2) consider and discuss a possible replacement of the Lopingian-base GSSP nearby the Penglaitan GSSP section, because the current GSSP section will be flooded within about 5-8 years, and consult local officials regarding the protection of the GSSP ($1000).

In total: US$5000.00

APPENDICES

7.CHIEF ACCOMPLISHMENTS OVER PAST FIVE YEARS (2009-2014)

1)Three GSSP bronze markers have been placed on the GSSPs in the Guadalupe National Park in USA.

2)A new executive committee of SPS has been elected and nominated. Shuzhong Shen has been elected as the new chair, Jörg Schneider has been elected as the new vice-chair and Lucia Angiolini has been nominated as the new secretary of SPS. Four voting members have been replaced by new members.

3)A high-resolution timescale of the Permian system has been significantly refined (see SPS webpage Permian Timescale).

4)SPS decided to search new GSSP candidate for the Kungurian Stage after an investigation on the previous candidates. Now two candidates for the Kungurian-base GSSP are available, but further work is necessary before a voting process is conducted.

5)Significant progress on the Sakmarian-base and Artinskian-base GSSP candidates has been made. Proposals for voting will be published soon.

6)Two monuments have been built and a protected area has been established at Penglaitan, Laibin, Guangxi Province, China for the Wuchiapingian-base GSSP.

7)Five formal issues and two supplementary issues of *Permophiles* have been published since 2009.

8. OBJECTIVES AND WORK PLAN FOR NEXT 4 YEARS (2014-2018)

1)Establishing the three GSSPs for the Cisuralian.

2)Establishing a working group on the Guadalupian and global correlation for chemostratigraphy and geochronologic calibration.

3)Developing a large working group on the correlation between marine and continental sequences. This has already been initiated.

9. ORGANIZATION AND SUBCOMMISSION MEMBERSHIP

9a Names and Addresses of Current Officers and Voting Members

See new officers and voting members since August, 2012 in this issue.

9b List of Working (Task) Groups and their officers

1)Kungurian-base GSSP Working Group; Chair-Bruce Wardlaw.

2)Sakmarian-base and Artinskian-base GSSPs Working Group; Chair-Valery Chernykh and Boris Chuvashov respectively.

3)Guadalupian Series and global correlation; Chair-Charles Henderson.

4)Correlation between marine and continental Permian System; Chair-Joerg Schneider.

5)Neotethys, Paleotethys, and South China correlations; Chairs Lucia Angiolini and Yue Wang.

9c Interfaces with other international project

SPS interacts with many international projects on formal and informal levels. SPS has taken an active role in the development of a project on the correlation between marine and continental Permian sequences bilaterally supported under the foundation of the Sino-German Centre for Research Promotion (SGCRP) by NSFC and DFG. SPS is also involved in a NSFC supported key study of major biological events in the Palaeozoic. Shuzhong Shen and Yue Wang are focused on establishing a section-based Permian database in Geobiodiversity Database which has been basically completed.

Officers and Voting Members since August, 2012

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The Reality of GSSPs

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Summary

The proposal that chronostratigraphic and geochronologic units are un-necessary and confusing is based on a mistaken concept of GSSPs. Each GSSP does represent a specific point in time, and two successive GSSPs do mark the beginning and end of an interval of time that is a geochronologic unit. But the supposition that this unit in time then serves to define a corresponding chronostratigraphic unit is mistaken. First, there were chronostratigraphic units and geochronologic units more than 100 years before there were GSSPs. The historical chronostratigraphic units that are the basis for much of the Geological Time Scale were defined on distinctive stratigraphic successions, and the time during which it was deposited is the corresponding geochronologic unit. GSSPs were established to identify specific stratigraphic levels that define the bases of the chronostratigraphic units and to resolve the problems when gaps and overlaps between successive units were later discovered. Unfortunately, the GSSP for a specific boundary is too often presented only as the single stratigraphic signal at which the boundary is placed in the stratotype section. Yet, in reality it only has significance for chronostratigraphic correlation when compared to the distribution of other stratigraphic signals in the boundary interval.

Keywords: GSSP, chronostratigraphy, geochronology,

The International Commission on Stratigraphy (ICS) was founded with its primary objective being the establishment of a single, hierarchal set of global chronostratigraphic units (stages, series, and systems) with lower boundaries defined by GSSPs (Global Standard Stratotype Section and Point). With 63 of the 100 stages boundaries of the Phanerozoic now defined by GSSPs and with a single set of standard global units mostly identified, considerable progress has been made in developing the ICS Chronostratigraphic Chart. With the addition of well-calibrated numerical ages for many stage, as well as series and system, boundaries, the ICS Chart is now widely recognized as the global standard Geologic Time Scale. The ICS concept of GSSPs was first explained in the 1st edition of the International Stratigraphic Guide (Hedberg, 1976) and further elaborated in the 2nd edition (Salvador, 1994). However, GSSPs have come to mean something different to some stratigraphers and the correlation of GSSPs is too often misrepresented.

Zalasiewicz et al. (2004) proposed that the distinction between time-rock units and time units is no longer necessary because of the widespread adoption of GSSPs “in defining intervals of geologic time within rock strata.” Because GSSPs are placed at stratigraphic horizons that also represent specific points in time, two successive GSSPs define an interval of time that is a geochronologic unit (period, epoch, age), and all strata interpreted as deposited during that interval of time would comprise the corresponding chronostratigraphic unit (system, series, stage). For this reason, Zalasiewicz et al. (2004) argue that the dual classification of chronostratigraphic and geochronologic units is not necessary and leads to confusion, and for these reasons proposed the exclusive use of geochronologic units. After a decade of discussions on the issue, Zalasiewicz et al. (2013) accepted and further clarified the nature and use of the dual classification. Nevertheless, the concept that GSSPs define geochronologic units and that a chronostratigraphic unit is the strata deposited during the time defined by the geochronologic unit is still widely held (e.g., Gradstein et al., 2004). The difference between this concept and that of the International Stratigraphic Guide (Hedberg, 1976; Salvador 1994) - that chronostratigraphic units and their boundaries serve to define corresponding geochronologic units - is subtle, yet important.

Chronostratigraphic units and parallel geochronologic units were established long before the concept of GSSPs. Rocks and their spatial relationships (superposition, cross-cutting relations, unconformities) are the record of Earth's history and the passage of time. The character of stratigraphic successions, the varied stratigraphic signals within them, and superposition are the basis for characterizing distinctive stratigraphic intervals and for evaluating temporal relationships with stratigraphic intervals elsewhere. These stratigraphic intervals, being material units that can be sampled and mapped today, are chronostratigraphic units; the time in the past during which each one was deposited is the parallel geochronologic unit. It is important to note that the International Stratigraphic Guide provides specific guidelines for establishing chronostratigraphic units, but none what-so-ever for defining geochronologic units other than that each geochronologic unit represents the time during which the interval of strata comprising the chronostratigraphic unit was deposited. According to Gradstein et al. (2004) "A geologic time unit (geochronologic unit) is an abstract concept measured from the rock record by radioactive decay, Milankovitch cycles, or other means." Further, they define a chronostratigraphic unit as follows: "A "rock-time" or chronostratigraphic unit consists of the total rocks formed globally during a specified interval of geologic time". Nowhere do Gradstein et al. (2004) elucidate how the points in time are measured, and they ignore the fact that the time measured is subject to regular refinement or considerable revision. Some GSSPs have indeed been placed at a specific sedimentary cycle that has been astronomically tuned, but such boundary levels can only be recognized in stratigraphic successions elsewhere that preserve complete sets of astronomically tuned cycles that first must be temporally correlated with considerable precision by biostratigraphic and magnetostratigraphic correlations. The numerical ages of some GSSPs are constrained by high precision radiometric ages from ash beds within the stratotype section, but without other stratigraphic signals in the boundary interval the GSSP cannot be recognized in stratigraphic sections elsewhere that lack datable ash beds. Furthermore, temporal correlation is most often required for stratigraphic intervals within chronostratigraphic units, and effective correlation of these intervals requires application of chronostratigraphic methods (i.e., biostratigraphy, chemostratigraphy, paleomagnetostratigraphy, etc.).

Most of the systems, series and stages of the ICS Chart were first defined from type-sections or type areas in Europe, the historical home of stratigraphy. They served as the basis for temporally correlating stratified Phanerozoic rocks worldwide primarily on their paleontological content. But, rarely were boundaries between succession units precisely defined. With the study of stratigraphic successions away from the type sections (or areas), overlaps of and gaps between many successive chronostratigraphic units were discovered. Because of natural limits to the palaeoecological and palaeogeographical distributions of paleontological content on which the units were recognized and because of the lack of specific boundaries, there were different interpretations of the stratigraphic extent accorded to the same unit from one region to another, and for many systems myriad sets of regional series and stages were established. It was in order to resolve these deficiencies and complexities that the concept of GSSPs was developed, and the goal of single set of global units with precisely defined boundaries that could be correlated as widely as possible was established.

Candidate GSSPs are evaluated by the ICS and its constituent working groups based on a long list of criteria (Hedberg, 1976; Cowie et al., 1986; Salvador, 1994; Remané et al., 1996). The most important of these is that the boundary at the candidate stratotype is defined at the level of a single stratigraphic signal within an interval of multiple, varied stratigraphic signals, that should allow for reliable, high-resolution correlation across the greatest possible palaeogeographical range of palaeoenvironmental settings. Chronostratigraphic correlation (chronocorrelation), i.e., evaluating temporal relationships between geographically widely separated stratigraphic successions, is an interpretative process whether it involves correlation of a GSSP, its boundary interval, or an interval within a chronostratigraphic unit. Accurate chronocorrelation requires the evaluation of multiple, varied stratigraphic signals rather than relying solely on a single signal, such as that on which the level of the GSSP was placed, e.g., the lowest occurrence of a specific taxon, a paleomagnetic reversal, an isotopic excursion, or a eustatically induced vertical facies change. Without a GSSP being chosen at horizon that not only is the level of a distinct stratigraphic signal and within a boundary level of many varied stratigraphic signals, the point in time at the GSSP is of little use for accurate, high-resolution correlation. Furthermore, the ICS Chart is composed of units that were originally defined on distinctive stratigraphic successions of variable duration, much like characteristic intervals of human history, such as the Renaissance. Defining the beginning or end of the Renaissance requires identifying human products (architecture, art, literature) on which that period of human history was identified as important and distinctive, and only then are numerical ages assigned. The same applies to chronostratigraphic units and geochronologic units. First, stratigraphic signals are selected to define a chronostratigraphic unit; they then, in turn, define a geochronologic unit. Numerical ages can be calibrated only after stratigraphic signals have been selected. It is the rock record, especially the multitude of varied stratigraphic signals within stratigraphic successions, on which the Geologic Time Scale is based and geochronologic units can only be defined once these stratigraphic signals are evaluated for correlation potential. The fallacy of the proposal that the distinction between time-rock units and time units is no longer necessary is illustrated by the GSSPs for several Silurian stages and series. Some were some at the bases of graptolite zones, yet graptolites do not occur in the sections. There the GSSPs do represent points in time, but because they were placed without regard to adequate stratigraphic signals for correlation, they have proved to be deficient and in need of re-definition.

It is unfortunate that too often the GSSP concept is illustrated only by reference to the single stratigraphic signal at which the boundary is defined (Ogg et al., 2008). Whether it is the FAD of a single taxon, a paleomagnetic reversal, or an isotopic excursion, interpretation of accurate chronocorrelation of that signal into other stratigraphic successions requires that that signal maintains the same stratigraphic level relative to other stratigraphic signals in the boundary interval as it has in the stratotype section. A true characterization of a GSSP includes not only the stratigraphic level of the single signal on which it is placed but also on the levels of other stratigraphic signals through the boundary interval. Several GSSPs have been defined on single stratigraphic signals without adequate consideration of other signals to characterize the boundary interval, and some of these GSSPs have been found subsequently to be seriously deficient.

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GSSPs (Global Stratotype Section and Point) and Correlation

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Time correlation of stratigraphic successions - chronostratigraphy - is essential for recognizing and interpreting geologic events recorded within them, for reconstructing the history of the Earth System, as well as for exploration of sediment hosted mineral and energy resources. Chrono-correlation is an interpretive process that involves evaluation of varied stratigraphic signals (or proxies) from lithostratigraphy, biostratigraphy, chemostratigraphy, magnetostratigraphy, and sequence stratigraphy as well as of numerical ages. It is expressed in the units of the ICS International Chronostratigraphic Chart, the basis for the Geologic Time Scale. The chronostratigraphic units (Systems, Series, Stages) are defined by GSSPs. Accordingly, the essential criterion for approving a GSSP must be demonstration of high potential for correlation across a range of paleogeographic and paleoenvironmental settings. Otherwise, the units will not be adequate to express unambiguous global correlations that are reliable and of high resolution. Having been shown to be inadequate for reliable, high-resolution correlation is the only reason that some of approved GSSPs must now be reconsidered.

We Need a New GSSP for the Base of the Permian

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Introduction

In 1998, the base of the Permian was defined at the GSSP located at Aidaralash Creek in western Kazakstan (Davydov et al., 1998). The primary criterion (signal) for correlation of the GSSP is the FO (first occurrence) of the conodont *Streptognathodus isolatus*, about 6 meters below the secondary signal, which is the FO of the fusulinid *Sphaeroschwagerina fusiformis.* The FO of *S. isolatus* at Aidaralash Creek was posited to be "an arbitrarily-chosen point within a single conodont chronocline" (Davydov et al., 1998, p. 15). This chronocline supposedly represented the evolution of an "isolated nodular" morphotype of *Streptognathodus* (*S. isolatus*) from a non-isolated nodular morphotype as part of the " *S. wabaunensis* chronocline" (Chernykh and Ritter, 1997; Chernykh et al., 1997). At the time of definition, it was claimed that this point could also be recognized in sections in Russia (Usolka) and North America (Kansas).

However, since ratification of this GSSP, it has become clear that: (1) the taxonomy and evolution of *S. isolatus* is not agreed on; (2) *S. isolatus* is a rare taxon, with only three well-documented records worldwide and a handful of other possible records; and (3) with respect to longstanding fusulinid biostratigraphy, the FO of *S. isolatus* is diachronous, with the GSSP being among the youngest known FOs of the species. Furthermore, the Aidaralash section is a poorly exposed outcrop of turbiditic facies for which no chemostratigraphy has been determined and from which virtually no data have been published since the GSSP was established. These observations indicate that the GSSP that defines the base of the Permian needs to be reconsidered.

Taxonomy and Evolution of *Streptognathodus isolatus*

As noted above, during the 1990s the FO of *Streptognathodus isolatus* at the Aidaralash Creek section was posited to represent a globally synchronous evolutionary event in a single chronocline.

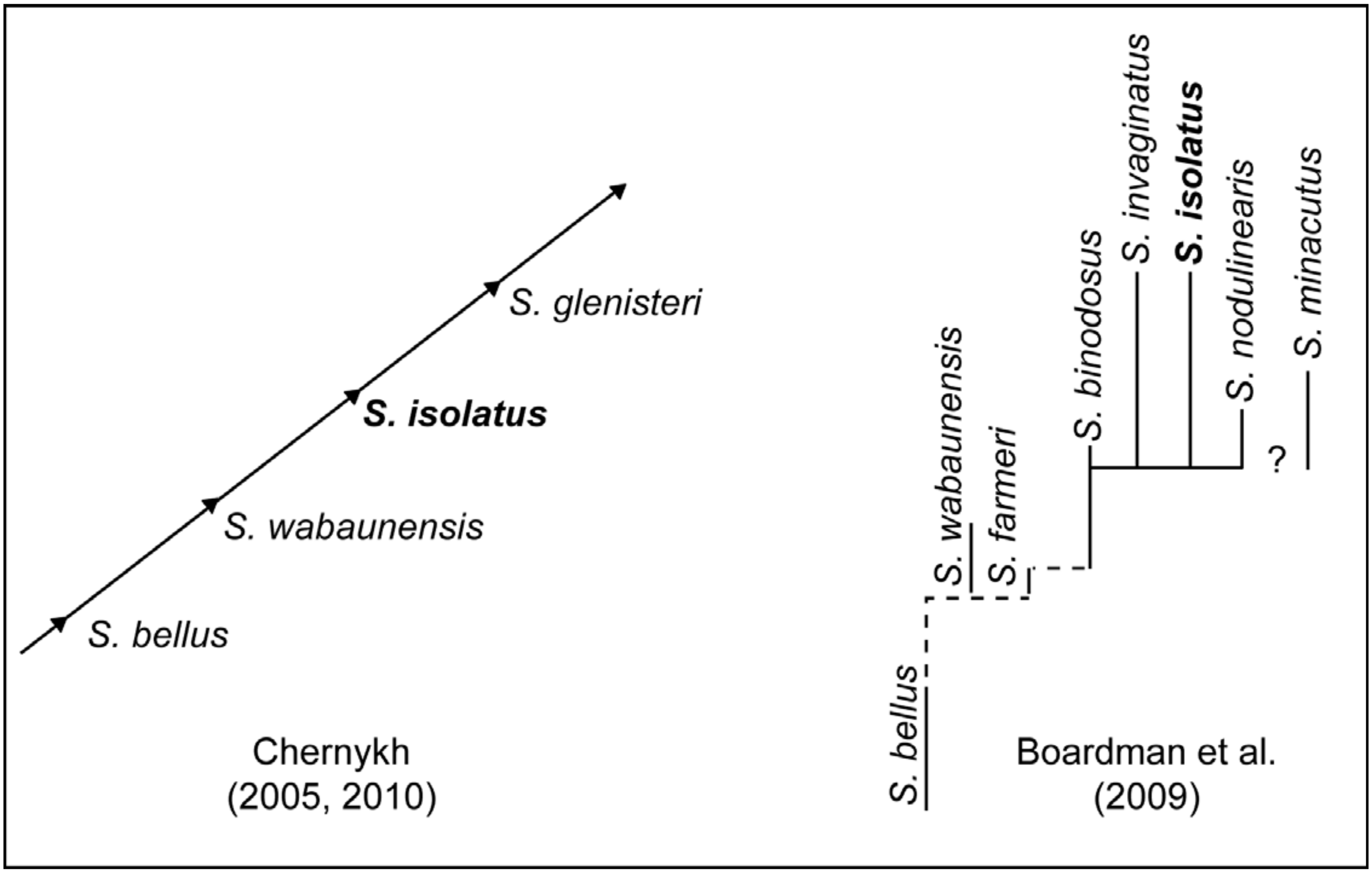

Fig. 1. Two contrasting views of the evolution of *Streptognathodus isolatus*, from Chernykh (2005, 2010) and from Boardman et al. (2009).

The first explicit effort to document this chronocline appeared seven years after the definition of the boundary, and not at the Aidaralash section, where the supposed chronocline has never been documented. Chernykh (2005, 2010) outlined the qualitative proposal of a single, anagenetic lineage *S. bellus*-*S. wabaunensis*-*S. isolatus*-*S. glenisteri* based on material from sections in the Urals, particularly the Usolka section in Russia (Fig. 1).

In contrast, Boardman et al. (2009) later posited, again qualitatively, a very different evolution of *Streptognathodus isolatus*. They proposed a polytomy of descendants of *S. wabaunensis*, in part through *S. binodosus*, based on material from successive cyclothems in Midcontinent North America (Kansas and Oklahoma) (Fig. 1). Indeed, Boardman et al. (2009) concluded that the original definition of *S. isolatus* included specimens that were assignable to the previously named *S. invaginatus* and S. minacutus. Their model shows a polytomy of similar species arising from *S. binodosus* (*S. isolatus*, *S. invaginatus* and *S. minacutus*) that possess the same FO in the Midcontinent region (Fig. 1). To preserve the name *S. isolatus* from older potential synonyms, Boardman et al. (2009) narrowly restricted its species concept to a range of morphology that excluded the types of *S. invaginatus* and *S. minacutus*.

Thus, there are now two schemes of the phylogeny of *S. isolatus* (Fig. 1) and two taxonomic definitions of *S. isolatus*--a polymorphic original definition and a revised definition that restricts the species to a single morphotype. These have been presented in a qualitative way, without apparent rigorous analysis. This calls into question both the originally proposed chronocline leading to *S. isolatus* and the ability to unambiguously recognize *S. isolatus*.

Rarity of *Streptognathodus isolatus*

Well documented and published records of *Streptognathodus isolatus* are few, and there are several records (or inferred records) mentioned but not documented in the literature. The well documented records are from (1) the Aidaralash section in Kazakstan (Chernykh and Ritter, 1997; Chernykh et al., 1997); (2) the Usolka section in Russia (Chernykh, 2005, 2010); and (3) the Kansas, USA, section, where the FO of *S. isolatus* is at the base of the Bennett Shale Member of the Red Eagle Limestone (Sawin et al., 2006; Boardman et al., 2009).

Several other reports of *S. isolatus* are in the literature but have not been documented. And, some of these reports are not of actual occurrences of *S. isolatus*, but inferences of the stratigraphic level at which it should be present based on the stratigraphic ranges of other conodont species. These are:

1. In the classic Permian section of the Glass Mountains, West Texas, USA (gray limestone member of Gaptank Formation),

the FO of *Streptognathodus isolatus* is associated with early Wolfcampian fusulinids (Ross and Ross, 2003). This is not an actual FO of *S. isolatus*, but an inferred FO because other conodonts from the gray limestone member indicate it correlates to the Foraker and Grenola formations, which in Kansas bracket the Red Eagle Shale, which has the FO of *S. isolatus* in the Kansas section (Wardlaw and Davydov, 2000).

2. Another apparently inferred record of *Streptognathodus isolatus* in north-central Texas, in the Stockwether Limestone Member of the Pueblo Formation, is associated with early Wolfcampian fusulinids (Thompson, 1954). Wardlaw (2005, p. 21) stated that "the Stockwether Limestone contains *Streptognathodus isolatus*," but M. Nestell (personal commun., 2013) tells me that the species is not present in the Stockwether and that this is inferred to be the level of its FO based on the stratigraphic ranges of other conodonts

3. A record from the Horquilla Formation of New Mexico, USA, associated with the FO of inflated schwagerinids (*Pseudoschwagerina*), has been reported in an abstract (Barrick et al., 2012).

4. There are four supposed reports from China, all based on the re-identification (as *Streptognathodus isolatus*) of illustrated specimens previously assigned to other *Streptognathodus* species (Wang, 2000). The first, from the lower part of the Zisong Zhen Formation in Guizhou, is a single specimen that Kang et al. (1987, pl. 2, fig. 8) illustrated and identified as *S. gracilis*. Chernykh et al. (1997) considered that specimen to be *S. isolatus* (also see Wang, 2000), but Boardman et al. (2009) did not refer it to that species. This *Streptognathodus* record is from the base of the Zisongian regional stage and is associated with the FO of inflated schwagerinids (*Pseudoschwagerina*) (Shi et al., 2000).

5. Wang and Zhang (1985, pl. 1, fig. 10a-b) illustrated one specimen from the upper part of the Taiyuan Formation in Shanxi that they assigned to *Streptognathodus wabaunensis*. Wang (2000) re-identified this specimen as *S. isolatus*.

6. Wang and Li (1984, pl. 1, figs. 15-18) illustrated two specimens from the Taiyuan Formation in Shanxi that they identified as *Streptognathodus gracilis*, but that Wang (2000) re-identified as *S. isolatus*. According to Wang (2000), these specimens are directly associated with inflated schwagerinids (*Pseudoschwagerina*). Similarly, from the Taiyuan Formation in Shanxi, Wang and Wen (1987, pl. 4, figs. 1, 3?, 4) identified three specimens as *S. wabaunensis* that Wang (2000) re-identified as *S. isolatus*.

Given that none of the actual Chinese specimens has been restudied, I regard all of these re-identifications of *Streptognathodus isolatus* as tentative. Indeed, as an example, consider the two specimens illustrated by Wang and Li (1984, pl. 1, figs. 15-18) that they identified as *S. gracilis* and that Wang (2000) assigned to *S.*

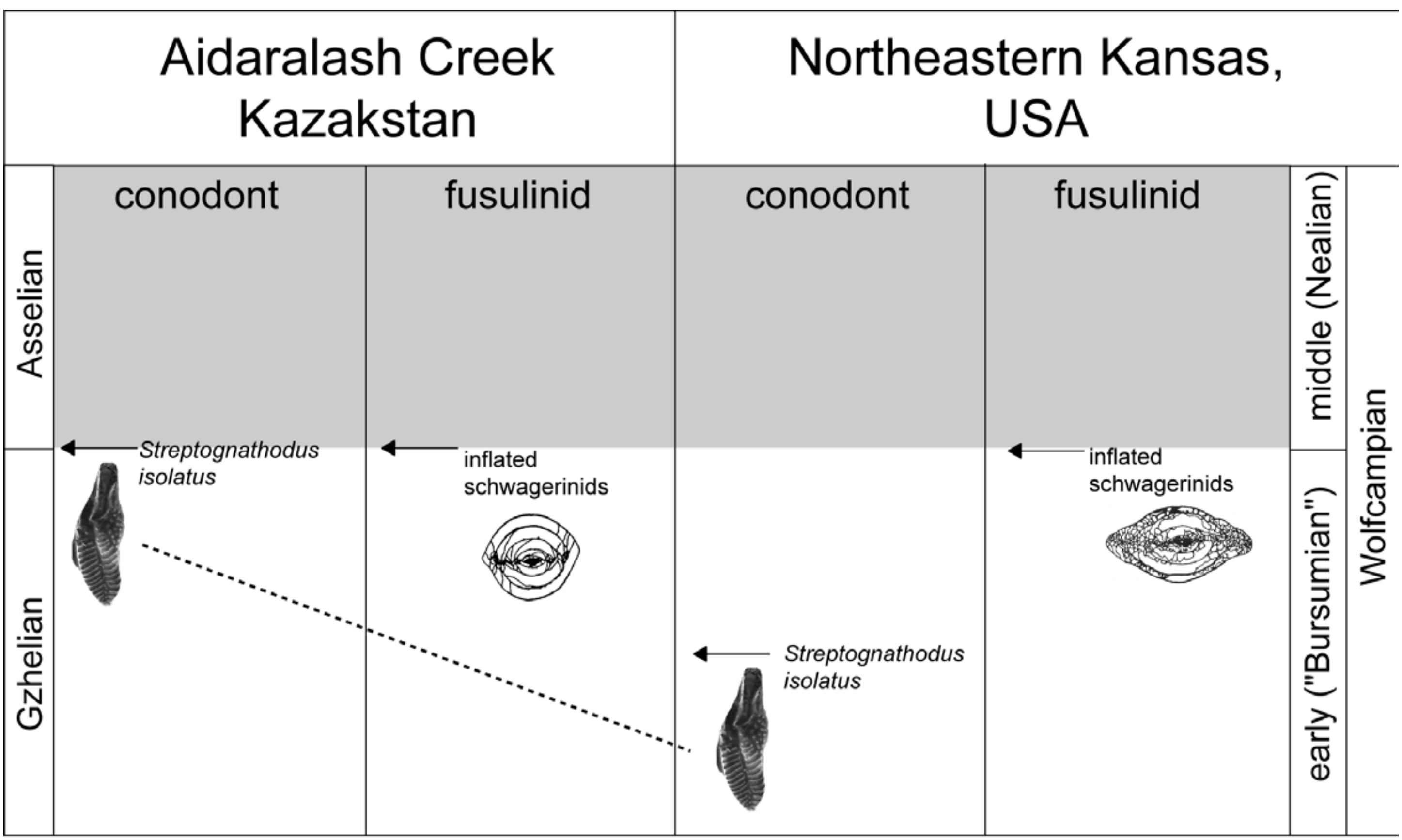

Fig. 2. Fusulinid-based correlation of the records of *Streptognathodus isolatus* suggests that the FO of the conodont species is diachronous. Thus, in the Kansas section the FO of *S. isolatus* is associated with early Wolfcampian fusulinids and thus is older than the FO of inflated schwagerinids. If the FO of inflated schwagerinids at Aidaralash Creek is used as a proxy to correlate the FO of *S. isolatus* in that section, as has been done by many workers, then it is younger than the FO of *S. isolatus* in Kansas.

isolatus. To my eye, the specimen in figures 17-18 resembles *S. isolatus*, but that in figures 15-16 looks more like *S. wabaunensis*, so from the photographs alone it is not clear to me to which species of *Streptognathodus* they should be assigned. A restudy of original material is needed to confirm the presence of *S. isolatus* at the Chinese localities just discussed.

Thus, 16 years after its description, *Streptognathodus isolatus* has proven to be a very rare taxon. Given its rarity, it is very difficult to correlate the base of the Permian using *S. isolatus*. This is why for many a more useful correlation tool has been the FO of the inflated schwagerinid fusulinds, which is stratigraphically close to the FO of *S. isolatus* at the Aidaralash Creek section. Indeed, this was the only secondary signal (or proxy) available by which to correlate the base of the Permian when the Aidaralash GSSP was defined. Correlation by the FO of inflated schwagerinids, however, indicates that the FO of *S. isolatus* is diachronous.

Diachroneity of *Streptognathodus isolatus*

The Aidaralash Creek FO of *Streptognathodus isolatus* is close to the FO of inflated schwagerinids (in this case the FO of Sphaeroschwagerina) in that section. Correlating the fusulind FO, most workers concluded that the FO of *S. isolatus* thus corresponds closely to the early-middle Wolfcampian boundary (base of the Nealian substage) in the North American section, which is the FO of inflated schwagerinids (e. g., Wahlman, 1998; Wahlman and King, 2002; Ross and Ross, 2003; Henderson et al., 2012).

However, the Kansas record of *Streptognathodus isolatus* is in strata that yield early Wolfcampian fusulinids (e.g., small species of *Leptotriticites*, large *Triticites* and small *Schwagerina*), which are stratigraphically below the FO of inflated schwagerinids (Thompson, 1954; Douglass in Mudge and Yochelson, 1962; Baars et al., 1992, 1994; Wahlman and West, 2010). These early Wolfcampian fusulinids have long been considered older than the fusulinids associated with the FO of *S. isolatus* at Aidaralash Creek (Fig. 2). This is also true of the inferred FOs of *S. isolatus* in Texas---they are in strata with early Wolfcampian fusulinids stratigraphically below the FOs of inflated schwagerinids in those sections.

It could be argued that the fusulinid records are diachronous, but this seems unlikely given that this same succession of early-middle Wolfcampian fusulinids has been documented for nearly a century from numerous sections across Permian Pangea, and within resolution indicates synchrony of the appearance of the inflated schwagerinids (e. g., *Pseudoschwagerina* sensu lato) that mark the beginning of the middle Wolfcampian (e. g., Beede and Kniker, 1924; Kahler, 1939; Thompson, 1954; Ross, 1963; Wahlman and King, 2002; Forke, 2002; Wilde, 1990, 2002, 2006; Stevens and Stone, 2007). What seems more likely is that the FO of *S. isolatus* is diachronous; it was based on a hypothetical conodont chronocline, only posited since the 1990s, that is little documented and now disputed. The oldest known *S. isolatus* thus appear to be in the USA (Fig. 2) so the species may have originated in North America and immigrated to Eurasia, with a detectable diachroneity.

Drawbacks of the Aidaralash Creek Section

There are three obvious drawbacks to the Aidaralash Creek section as a GSSP: (1) limited outcrop; (2) turbiditic facies; and (3) knowledge of the Aidaralash GSSP has advanced little since the 1990s. The Aidaralash GSSP is in the classic "steppes of Central Asia" and is very poorly exposed (see photograph in Henderson et al., 2012, fig. 24.2C). Indeed, a bulldozer had to be used to create outcrop during the GSSP studies of the 1990s. More extensive outcrops—better exposed sections—yield many more data than do human-made trenches in poor outcrops. Thus, the poor outcrop situation at Aidaralash Creek reduces the data that the section can yield and diminishes its value as a standard for correlation.

The facies of the Aidaralash section are deltaic, shallow marine and turbiditic. All coarse-grained beds in the section (sandstones and conglomerates) have been interpreted as sediment gravity flow deposits (Davydov et al., 1998). Because of this, Davydov et al. (1998) raised the possibility of some reworking and redeposition of fusulinids in the Aidaralash section. The possibility of conodont reworking and redeposition (see Macke and Nichols, 2007) at Aidaralash Creek thus also merits consideration.

Knowledge of the Aidaralash section has not advanced since the 1990s. Thus, no significant new data have appeared in print since the GSSP was ratified. Notably absent are any chemostratigraphic data (C, O and/or Sr isotopes), which are playing an increasingly important role in global correlations. Also, the taxonomy and stratigraphic ranges of the fossils from the Aidaralash section have been "frozen in time," with no new analyses of them since the 1990s.

Finally, something should be said here about priority, because Davydov et al. (1998, p. 16) claimed that the GSSP defined at Aidaralash Creek "enjoys historic priority." This is not the case. There was no basis in priority for defining a GSSP for the Permian base at Aidaralash Creek or, indeed, anywhere in the former Soviet Union. Murchison's type Permian only included rocks of Kungurian age and younger. Soviet extension of the Permian downward (to the base of the Asselian) was based largely on the work of Ruzhentsev on ammonoids. Aidaralash Creek is not the stratotype of the Asselian Stage, and the conodont-based definition redefined the Asselian to include older strata than did the original definition of Ruzhentsev.

Summary

The primariy criterion (signal) used to correlate the base of the Permian as defined by its GSSP at Aidaralash Creek---the FO of the conodont *Streptognathodus isolatus*—is now problematic. The evolution and taxonomy of *S. isolatus* are not agreed on, with two very different views in the published literature. Also, *S. isolatus* is a very rare taxon, of little use to global correlation. Ironically, correlation by the only secondary signal that definition of the Aidaralash GSSP identified---the FO of inflated schwagerinid fusulinids---suggests that the FO of *S. isolatus* is diachronous. *S. isolatus* is thus a highly problematic species with which to correlate a chronostratigraphic boundary.

The GSSP section at Aidaralash Creek is also far from ideal. Poorly exposed, it includes turbiditic facies that have a clear potential for the reworking of microfossils. Nothing new has been published on the Aidaralash Creek section since the 1990s, and there was no basis in priority for using it to define the base of the Permian System.

Based on the above considerations, I conclude that we should reconsider the position of the base of the Permian and its current GSSP. We need a GSSP for the base of the Permian that is correlateable, has the advantage of respecting longstanding usage and produces a correlateable Permian base that is synchronous within current levels of biostratigraphic resolution. Correlation needs to precede definition.

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The GSSP at the Aidaralash section is solid and has no alternative

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First of all, I'd like to thank the chair of the subcommission Dr. Shen for the opportunity to have my reply in this issue of the Permophiles. Second, at certain point I need to thank Dr. Lucas for challenging the existed Carboniferous-Permian boundary GSSP as it is always the way to push the science further. We have had discussion with Dr. Lucas on the topic few month ago at the meeting in New Mexico as his paper was published in the NMMB No 60 (Lucas, 2013), but it seems that many important arguments were not heard. So, here are few comments for the larger Permian community.

The GSSP at Aidaralash is not ideal, as pointed by Dr. Lucas in his paper, but I do not think any GSSP can be considered the ideal. They all have certain problems. The important thing is that the GSSP has to provide a solid base for the global correlation using varieties of methods and tools. I believe that the GSSP at Aidaralash provides such a base and still is the best section where the GSSP for the Carboniferous-Permian boundary is established.

Biostratigraphy considered being most reliable method of correlation and at Aidaralash the C-P boundary position characterized with three major fossil groups, such as fusulinids, conodonts and ammonoids and has additional characteristic in palynomorphs. Besides, it has paleomagnetic proxies (reversal even near the boundary) that correlated in both marine and continental sequences throughout the globe. It possesses a very careful sedimentological documentation. Most of this information summarized in our papers (Chernykh and Ritter, 1997; Bogoslovskaya et al., 1995; Dunn, 2001; Davydov and Khramov, 1991; Davydov et al., 1992; 1993; 1998; 2003). No geochemistry has been studied at Aidaralash section as these methods were not available to us back to over 20 years ago.

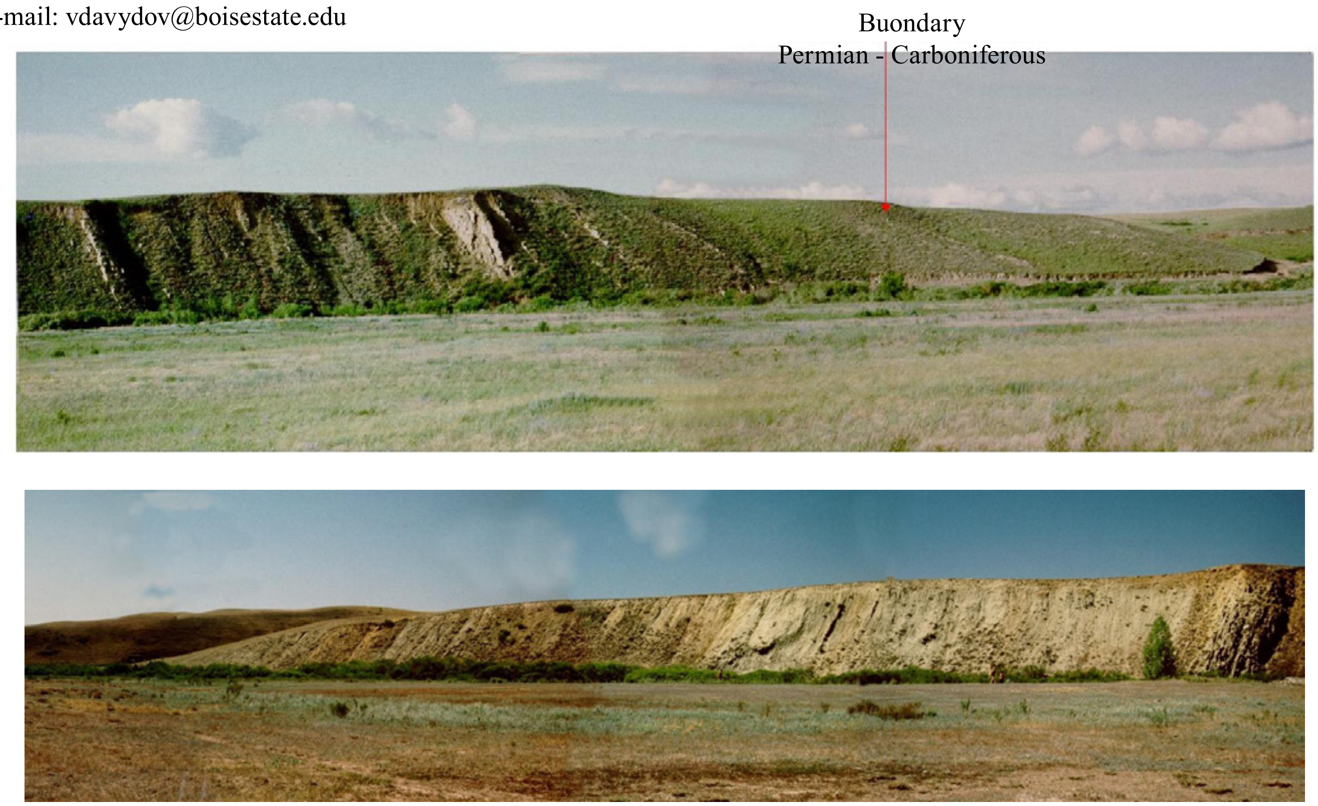

Fig. 1. The natural exposure of the Upper Carboniferous and lower Permian deposits at Aidaralash Creek.

The GSSP selection went through the long procedure and many investigations were accomplished and evaluated thought this process. It took nearly 20 years since the initial study of the section. The section was visited by the members of the Carboniferous-Permian Working Group in 1991 and all drawbacks were noted, raised and discussed at that time (see Permophiles No 19-26 for these discussions). However, still Aidaralash section has been chosen as the best to fix the Carboniferous-Permian boundary in the global Time Scale.

I see two major problems with Dr. Lucas paper. The first one is that it has only negative criticism, but does not propose any positive alternatives. The criterion to use inflated fusulinids to establish the boundary that is proposed in the paper (Lucas, this issue) does not work. Inflated fusulinid means morphology, whereas we have to use taxonomy to establish GSSP. The term "Inflated fusulinid" means very little for foraminiferal specialists and this term has been used seriously only where taxonomy was poorly known (over 100 years ago). Nowadays, we know for sure that inflated fusulinids appear independently in different regions at different time. For example, some Bashkirian-Moscovian Bedeeina (*B. gritty* Dunbar and Condra, 1927; *B. inflate* Wilde, 2006 etc.), *Staffellaeformis, Grovesella, Pseudostaffella, Plectofusulina*, etc are inflated fusulinids. *Kasimovian Kushanella* and *Tumifactus, Gzhelian Leptotriticites, Ultradaixina, Darvasoschwagerina* and *Carbonoschwagerina* are inflated fusulinids and so since 100 years the criteria of the appearance of inflated fusulinids are not used to evaluate synchronicity or diachroneity of the fossils and beds. Thus, the case of diachroneity of Streprognathodus isolatus because of correlation of inflated fusulinids cannot be considered as reliable and valid.

The second problem with Lucas manuscript is that some of the original data are misrepresented and/or misinterpreted in his paper. Considering taxonomy and evolution of *St. isolatus* Lucas concluded that that two schemes of phylogeny of the species precludes the usage of the species in the GSSP definition. Unfortunately, it is common case where evolution confused with GSSP definition. Evolution is our interpretation of the process of biological changes in the past that is often based on limited material. As we all know a phylogeny is the most questionable topics among paleontologists. The evolution is interpretation, but the GSSP definition is not. It is the solid and specific position of defined boundary within the rock record. It is not interpretive and in case with the discussed GSSP it is located 27 m above the base of the bed 19 in Aidaralash section. The FAD of *isolatus* is coincident with this level and is used to provide the correlation (not definition) as all other fossils and proxies supposed to do.

There are several other cases where interpretation of phylogeny within the GSSP's transitional beds is multi-variant but the GSSP is stable. For example, the base of Bashkirian Stage at Arrow Canyon in Nevada established 82.90 m above the top of the Battleship Wash Formation in the lower Bird Spring Formation at the first evolutionary appearance of the conodont *Declinognathodus noduliferus* s. l. It is coincident with the evolutionary event within the chronocline of Gnathodus girtyi simplex to *Declinognathodus noduliferus*. (Lane et al., 2001). An alternative model of evolution of *Declinognathodus noduliferus* s.l., in the eastern Hemisphere has been proposed within the chronocline *Gnathodus postbilineatus-Declinognathodus praenoduliferus-Declinognathodus noduliferus* (Nemyrovska, 1999). Several subspecies are recognized within the *Declinognathodus noduliferus* s.l. The GSSP in Arrow Canyon is defined at the FAD of *D. noduliferus* inaequalis, whereas in Spain *D. noduliferus* bernesgae appears in the strata that are dated with ammonoids and conodonts as Serpukhovian (Sanz-Lopez et al., 2006). Nevertheless, no suggestions about replacement of the GSSP have been proposed and the definition is valid until now. It is clear, that biostratigraphic method is not ideal and possesses some problems. The fortunate thing is that we are recognizing these problems and may resolve them further. At the same time, biostratigraphy is still most reliable tool to provide the correlation at the global scale.

As for rarity of *Streptognathodus isolatus*, I believe it is distributed wider, than Dr. Lucas think. For example it is documented within the Hare Fiord Formation in the Canadian Arctic (Mei and Henderson, 2001; Henderson, 1999). There are several publications in China that document the species (Wang and Qi, 2002 and other) but were not found by Dr. Lucas. The species was recently recognized in Central Iran (Sohrabi, 2010) and in Uzbekistan, Central Asia (Iskandarov and Bensh, 2000). So it is not as rare as suggested by Dr. Lucas.

Drawbacks of the Aidaralash Section

Limited outcrop – the section is the natural outcrop along the Creek and the C-P boundary transitional beds are well exposed (Figure 1). The section was bulldozed to study section at centimeter scale after it was visited by the members of the Carboniferous-Permian WG in 1991 and no one considered it as poor outcrop at that time.

Facies in Aidaralash definitely shallow marine, but no turbiditic beds are exist in the section. Instead, these are tempestites, the nature of which is consistent with bathymetry of the basin. It is true, that no new data were published since 2003 and no chemostratigraphy is accomplished in the section. The updates and chemostratigraphy are definitely necessary and hopefully will follow sometimes soon. Dr. Lucas is invited to visit Aidaralash section in person and he might reconsider his opinion afterwards.

At last, I would like to remind to Dr. Lucas, that the major goal of the global Time scale and the GSSP approach is the stability of the definitions and divisions within the scale. So, unless very serious problems arise and/or the definition will be proven to provide miscorrelation, we have to keep and use this historical boundary at 27 m above the base of the bed 19 in Aidaralash section. Suggestion to consider as historical the base of the Permian the Kungurian Stage looks archaic to me and cannot be taken seriously.

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The Aidaralash GSSP—Reply to Davydov

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In response to Vladimir Davydov's comments on my article critiquing the Aidaralash GSSP that defines the base of the Permian, let me reply briefly:

1. V. Davydov and I agree that Aidaralash is not an ideal GSSP, and I also agree with him when he notes that all GSSPs have "certain problems." However, the Aidaralash GSSP has a very big problem that I regard as a fatal flaw---the primary signal by which it is correlated—the FO of the conodont *Streptognathodus isolatus*—is problematic for correlation because there is no agreed on taxonomy or phylogeny of *S. isolatus*; *S. isolatus* is a rare taxon; and the FO of *S. isolatus* is arguably diachronous. A GSSP that cannot be correlated is not a good GSSP.

2. I also agree with V. Davydov that the strength of the Aidaralash section is that it is very fossiliferous (indeed, I would say this is its only strength). Unfortunately, the problems with correlation of the Aidaralash GSSP are not apparently compensated by the diversity and abundance of fossils at Aidaralash Creek.

3. V. Davydov stresses that many years of study and discussion went into choice of the Aidaralash GSSP. However, 15 years after its ratification, it is clear that the GSSP cannot be correlated. How much longer should the timescale community continue to accept such a GSSP?

4. V. Davydov says my article is only negative criticism, "but does not propose positive alternatives." However, he later states that I propose to use "the criterion of inflated fusulinids [sic] to establish the boundary" and that I "consider as historical the base of the Permian the Kungurian Stage." These are mis-statements of my article and its purpose. My article intends to encourage the Subcommission on Permian Stratigraphy to discuss and reconsider the Aidaralash GSSP and to study whether better alternatives exist---they do, contrary to the title of V. Davydov's comment. For a brief discussion of alternatives, see Lucas (2013).

5. V. Davydov discusses what he calls "inflated fusulinids", but in so doing misconstrues what I am discussing, which is the inflated *schwagerinid* fusulinids, called by some pseudoschwagerinids---schwagerinids with a tightly coiled juvenarium and an inflated (loosely coiled) adult stage, such as *Pseudoschwagerina*, *Sphaeroschwagerina*, *Paraschwagerina*, etc. This group has been well known to all students of fusulinids since at least Dunbar and Skinner (1936), and has a global distribution that made its FO a standard for correlation of the Permian base at least as early as the

work of Beede and Kniker (1924).

6. V. Davydov's discussion of the taxonomy and phylogeny of *Streptognathodus isolatus* begins by stating that I have "misinterpreted and/or misrepresented the original data." Instead, what I have pointed out is the problems associated with *S. isolatus* that make it a very poor primary signal for correlation of the Aidaralash GSSP. V. Davydov seems unable to admit that disagreement about its taxonomy and phylogeny call into question not only what is *S. isolatus,* but how and when it evolved, issues that undermine its use in correlation.

7. I am grateful to V. Davydov for pointing out other reports of *Streptognathodus isolatus* in the literature that I did not list. However, these are not documented records of the taxon in which fossils are described and illustrated and the taxonomy is justified by discussion. Furthermore, are these records of *S. isolatus sensu lato* (the original sense of Chernykh et al., 1997) or are they records of *S. isolatus sensu stricto* (the revised sense of Boardman et al., 2009)? As my original article indicated, there remain only three well documented records of *S. isolatus* on the entire planet. How can so rare a taxon be used to correlate the base of a geological system?

8. The photograph of the cutbank section at Aidaralash indicates there is more outcrop than there is where the GSSP is located. But, a creek bank in rolling prairie is, without doubt, a limited outcrop, and this is one of the drawbacks of the Aidaralash section.

9. Despite what V. Davydov says, no real sedimentological analysis of the Aidaralash section has ever been published. Instead, declarative statements and brief descriptions of lithotypes are what has been published (e. g., Davydov et al., 1998). These indicate the facies is basically turbiditic, though V. Davydov now wants to call tempestites what he previously called "gravity flows" in the Aidaralash section. Under either interpretation, reworking of microfossils should be a concern at Aidaralash, a concern originally raised by Davydov et al. (1998).

10. V. Davydov ends by stating that "stability of the definition and divisions" is a goal of timescale development, and I wholeheartedly agree. Unfortunately, Aidaralash destabilized what had been a nearly 75-year-long placement of the base of the Permian, especially in the North American section (cf. Lucas, 2013). And, what stability do we gain from the Aidaralash GSSP if it cannot be correlated?

Let me conclude by emphasizing a point not fully made in my original article. As former ICS Chairman Remane (e.g., 2003) and other have stressed, in GSSP selection, correlation needs to proceed definition. Otherwise, we may choose GSSPs that cannot be correlated. Current ICS Chairman Finney (2013) has recently pointed out that many GSSPs were chosen for which only one signal exists by which to correlate them, and many of these are now being reconsidered. I think Aidaralash is a case in point. Correlation of its primary signal is problematic, and the Aidaralash GSSP looks very much to me like a GSSP in which, unfortunately, definition preceded correlation.

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

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Introduction

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 (Fig. 1) section. Concerning the comparative characteristic of these sections, it is possible to note that Usolka section was formed under the

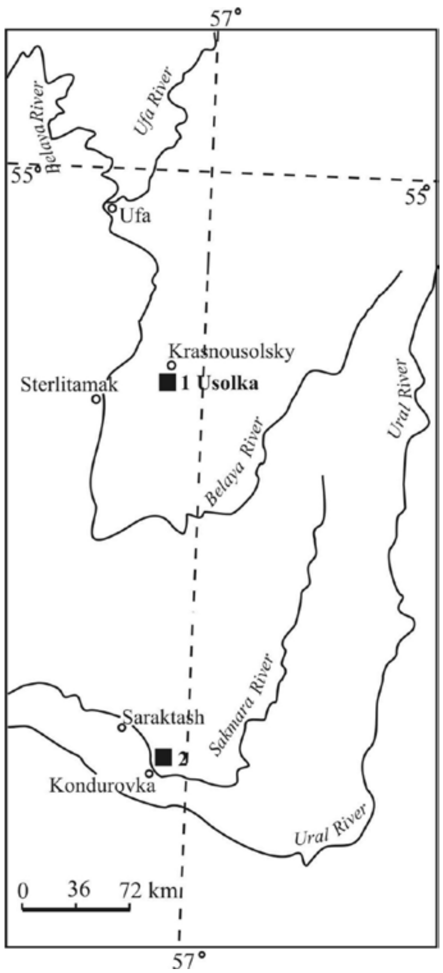

Fig. 1. Location of the Usolka (1) and Kondurovsky (2) sections.

conditions of deep shelf or slope whereas the Kondurovsky section is undoubtedly a shallower water succession. The Kondurovsky section 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 proves to be too significant.

A section of carbonate mudstone deposits on the right bank of the Usolka River, 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 proposed by us as the Global Stratotype Section and Point (GSSP) for the lower boundary of the Sakmarian Stage for the International Time Scale.

The detailed description of the Usolka and Kondurovsky sections was given before (Chuvashov et al., 1991a; Chuvashov et al., 1991b). We give here 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. 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. The nature of change of sedimentation cycles and the absence of significant tectonic 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. 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. 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 can lead 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 (Fig. 4) was studied.

The Usolka section made it possible to build the zonal scale on

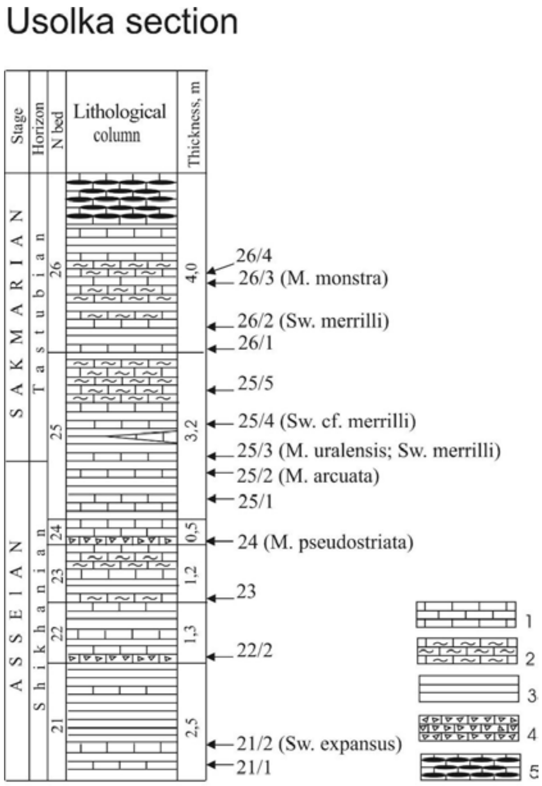

Fig. 2. Stratigraphic column with distribution of samples taken for conodonts in Usolka section; 1- limestone, 2- mudstone, 3- shale, 4- laminated limestone breccia, 5- nodules and interbeds of chert; pointers indicate the places of selection and number of informative samples taken for conodonts.

conodonts in the stratigraphic range of Upper Carboniferous to the Irginian horizon of the Artinskian Stage. To validate this zonal scale we also studied in detail the distribution of conodonts in the Kondurovsky section, where thick flysch deposits crop out.

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. 4). The description of the transitional Asselian-Sakmarian deposits of the Usolka section (Fig. 2); indication of productive levels and the determinations of fossil remains is given below.

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)

Note: Section metreage levels vary by up to a metre in two versions of the Usolka section (base of bed 26 in Fig 9 is at 52 metres; slightly lower than depicted: base of bed 26 in Fig 2 and description below is at 53 metres).

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* Chern., *S.* aff. *anaequalis* Chern., *S. lanceatus* Chern., *Sweetognathus* aff. *expansus* (Perlmutter), *Mesogondolella dentiseparata* (Reshetkova and Chern.).

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

Bed 22. A 5-7 cm thick breccias occurs at the base of the bed

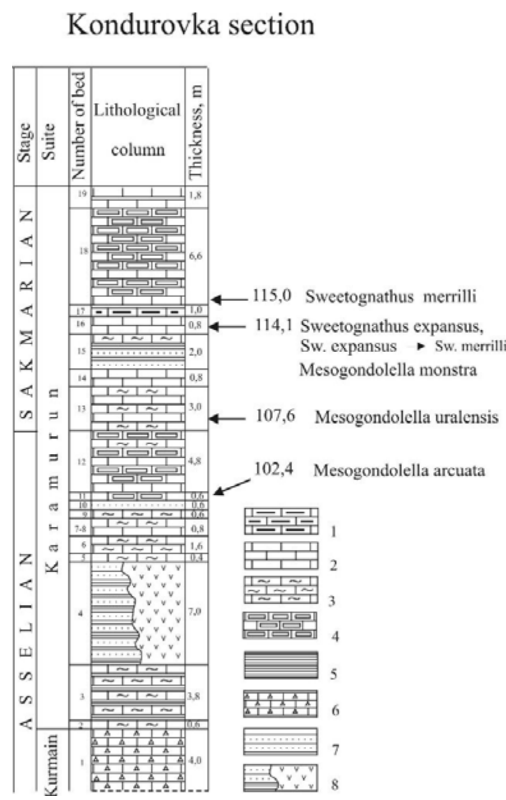

Fig. 3. Stratigraphic column with distribution of samples taken for conodonts in Kondurovsky section: 1 – chert, 2 – fine grained limestone, 3 – muddy limestone, 4- carbonate mudstone, 5 – shale; 6- calcareous conglomerate-breccia, 7- siltstone, 8 – the closed parts of section; pointers indicate the places of findings of the most important species of conodonts and distance from the beginning of section in the metres.

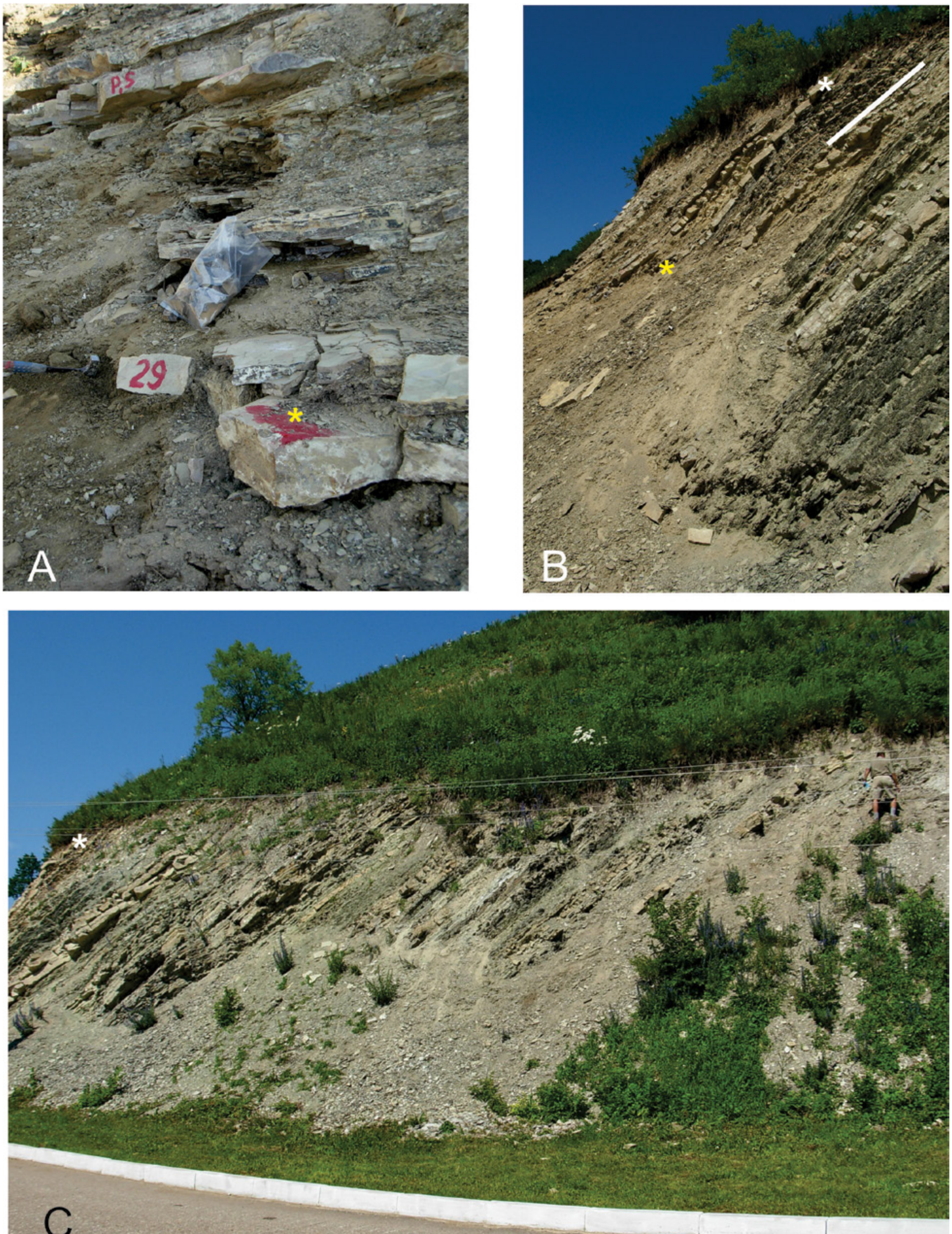

Fig. 4. A. Yellow asterisk (53 m) is on top of bed 25 and bed 26 occurs above (shown here as 29); the FAD of *M. uralensis* occurs 1.4 metres lower. B. Yellow asterisk is at same point as in 4A. Approximate GSSP level is shown by white line near the base of the mostly monofacial succession of bed 25. White asterisk provides a link to 4C. C. Asselian exposure at Usolka section (person for scale on right).

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* Chern. and Reshetkova, *S. constrictus* Reshetkova and Chern., *Mesogondolella dentiseparata* (Reshetkova and Chern.), *M. striata* (Chern.), 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 Chern.).

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: *Rugosofusulina serratashikhanensis* Suleim., *R. intermedia* Suleim., *Pseudofusulina sulcata* Korzh., *P. decurta* Korzh., *P. idelbajevica* Korzh., *P. ishimbajevi* Korzh., *P. rauserae* Korzh., *P. baschkirica* Korzh., *P. sphaerica* (Bel.), *P. sphaerica timanica* Grozd., *P. exuberate* Sham., *P. exuberate luxuriosa* Sham., *P. firma* Sham., *P. differta* Sham., *P. parva* Bel.

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* Chern., *M. simulata* (Chern.), *M. pseudostriata* (Chern.), and *M. striata* (Chern.).

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* (Sham. and Scherb.), *Schubertella paramelonica* Suleim., *Rugosofusulina shaktauensis* Suleim., *R. pulchrella firma* Suleim., *P. ishimbajevi* Korzh., *Sphaeroschwagerina* cf. *sphaerica* Scherb. 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 Chern., *Mesogondolella arcuata* Chern., *M. pseudostriata* (Chern.), *Mesogondolella arcuata* transitional with *M. uralensis*.

Sakmarian
Tastubian horizon
Zone *Mesogondolella uralensis*

Sample 25/3 (51.6 m): *Mesogondolella arcuata* Chern., *M. pseudostriata* (Chern.), *M. uralensis* (Chern.) FAD.

Sample 1250-9 (52.05 m): *Mesogondolella uralensis* (Chern.), *S. 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*), *Mesogondolella uralensis* (Chern.), *S.* cf. *postfusus*.

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

Bed 26 (Fig 4A; the new bedding number 29 for field excursion is actually 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, *Mesogon-*

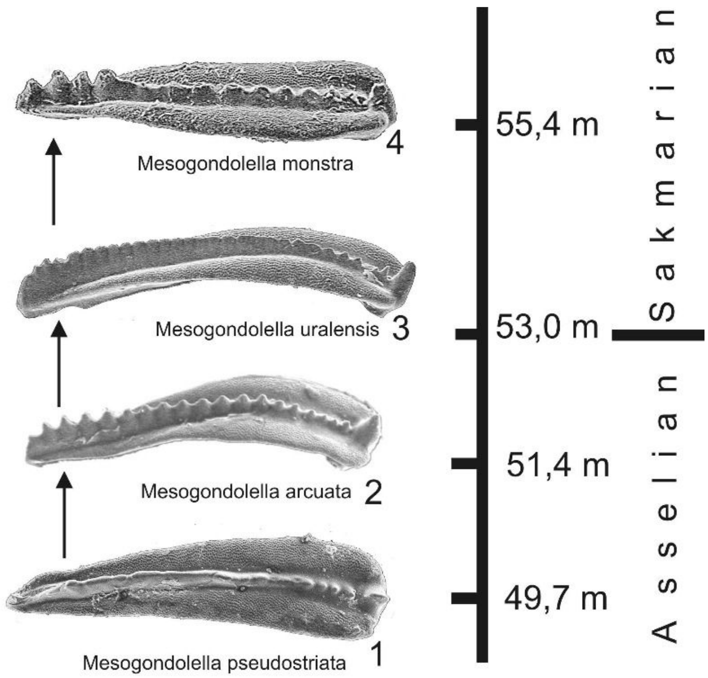

Fig. 5. The evolutionary lineage of the Asselian-Sakmarian species of the genus *Mesogondolella*. Explanation in the text.

dolella uralensis (Chern.), *Mesogondolella* aff. *uralensis* (Chern.).

Zone *Sw.* 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* Chern., *M.* cf. *monstra*, and *M.* aff. *uralensis* (Chern.).

Zone *Sw. binodosus* (=*Mesogondolella monstra*)

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

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

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* Suleim., *R.* ex gr. *shakhtauensis* Suleim., *Pseudofusulina ischimbajevi* Korzh., *P. baschkirica acuminata* Kir., *P. verneuili* (Moell.), *P. conspiqua* Raus., *P.* cf. *fixa* Kir., and *P. angusta* Kir.

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* Chern.

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 metres 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. The characteristic form *Mesogondolella uralensis* Chern., which is considered by us as the member of evolutionary lineage (Fig. 5) *M. pseudostriata* - *M. arcuata* - *M. uralensis* - *M. monstra* (Chernykh, 2006), first appears near and somewhat below the

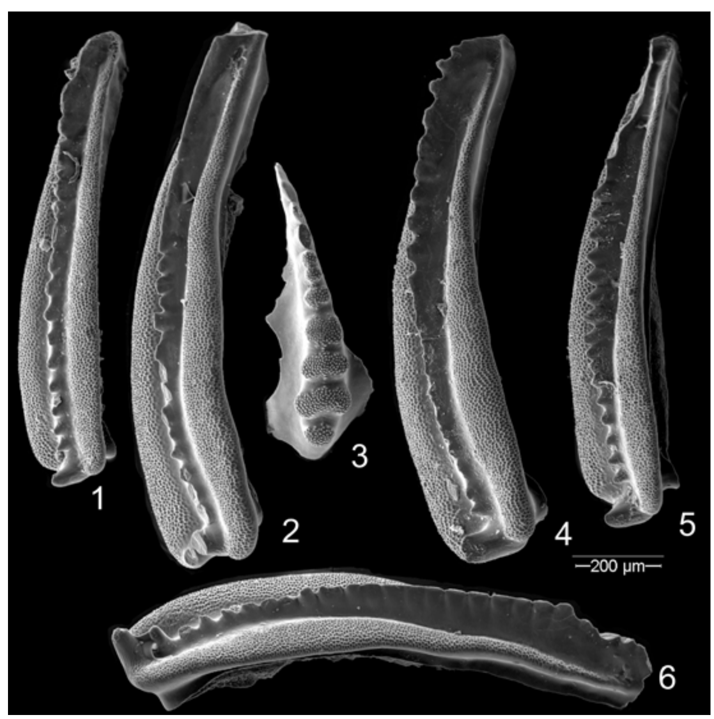

Fig. 6. Conodonts recovered by C. Henderson in samples collected in 2007 to test reproducibility; additional detailed samples were provided by V. Davydov on a later separate trip to fill in gaps. 1. *Mesogondolella arcuata* transitional to *M. uralensis* from 51.4 m. 2. *M. uralensis* from 52.05 m. 3. *Sweetognathus merrilli* transitional with *Sw. binodosus* from 52.65 m. 4-6. *M. uralensis* from 52.65 m.

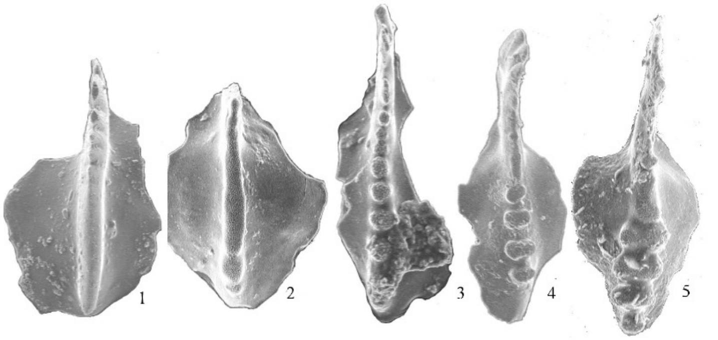

Fig. 7. The evolutionary lineage *Sweetognathus* aff. *expansus* – *Sw. binodosus* in the Usolka section: 1 – *S.* aff. *expansus* (Perlmutter), bed 14; 2 – transitional from *Sw.* aff. *expansus* to *Sw.* aff. *merrilli* bed 21/2; 3 – *Sweetognathus* aff. *merrilli* Kozur, bed 26 (54.3 м from the beginning of section); 4, 5 – *Sweetognathus binodosus* Chern., bed 26 (55.4 m from the base of section).

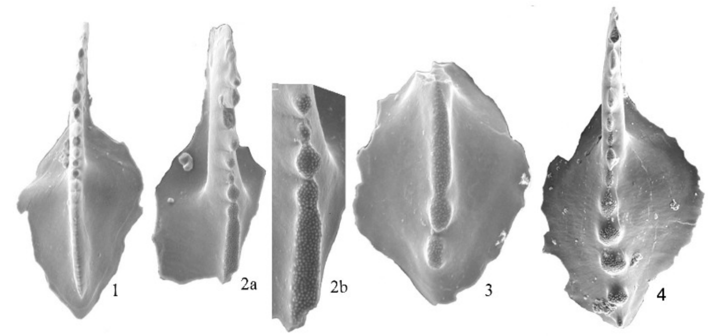

Fig. 8. The evolutionary lineage *Diplognathodus* aff. *stevensi* – *Sweetognathus* aff. *merrilli* Kondurovsky section: 1 – *D.* aff. *stevensi* Clark and Carr, the middle of the bed 16; 2, 3 – forms transitional from *Sw.* aff. *expansus* to *Sw.* aff. *merrilli* Kozur (2b - the increased fragment of fig. 2a), upper part of the bed 16; 4 – *Sw.* aff. *merrilli*, bed 18.

traditionally adopted (on the basis of fusulinaceans) boundary of Sakmarian Stage.

This sequence of conodonts is established in both 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* (Figs. 5, 6). Asselian-Sakmarian species of *Mesogondolella* are recognized in many localities in NA 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**, which can 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. 7). The identical evolutionary sequence of this species has been established also in the Kondurovsky section (Fig. 8).

The level of appearance of *Sw.* aff. *merrilli* in the Usolka section nearly coincides with the first appearance of *M. 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 layer 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 metres 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*, 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 9 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.

The first sweetognathids defined as *Sw. merrilli* Kozur are

*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 *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).

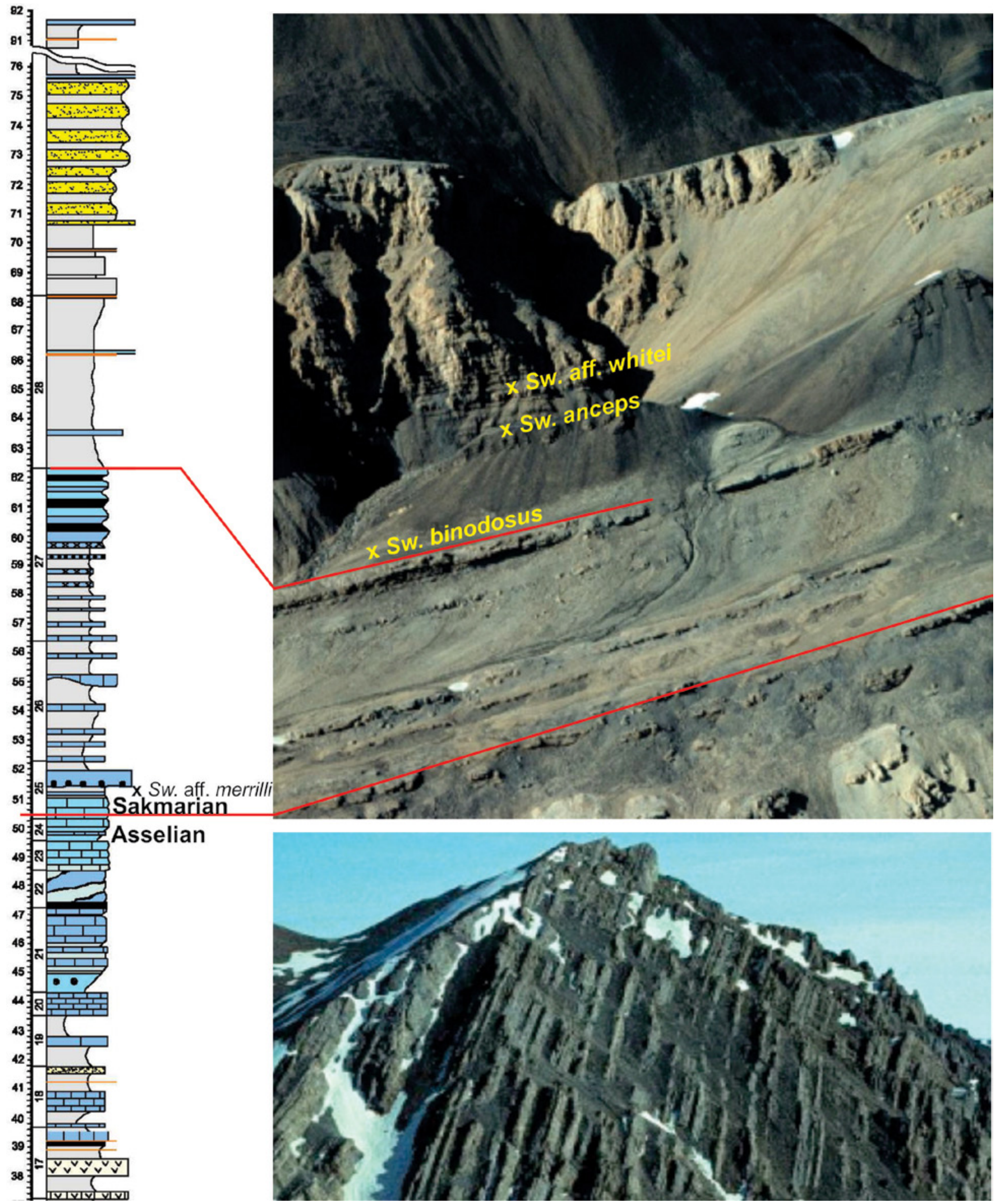

Fig. 9. A combination of lithologic pattern and biostratigraphy as a means of correlation. A strong correlation can be made on the basis of conodonts and the nature of cyclothem cyclicity. Potential correlation between Arctic Canada (Beauchamp and Henderson, 1994; photos by C. Henderson) and Usolka (section 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).

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 Pei-quan et al., 1987) contains Asselian deposits, including beds 17-21, where are recognized *Mesogondolella striata* Chern. (according to the author's determination - *M. bisselli*) and *Adetognathus paralautus* Orchard. The first forms close to *Sw. anceps* Chern., 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.

Fusulinaceans

Fusulinaceans in this section do not form a continuous series, but they are found at several levels, 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 radiolaria 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 form 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* Scherb is found only in the upper part of bed 25.

The lower boundary of the Tastubian horizon (thickness of 10 m) is determined according to a change in the species. In the upper four metres of the 10 metre 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* (Moell.).

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. 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.

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.

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 (Fig. 10).

1. A gradually increasing trend in carbonate carbon isotope ($\delta^{13}C$) 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.

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, 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 Gondwanal; this also accounts for the cyclothemic pattern change (see Fig. 9). 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.

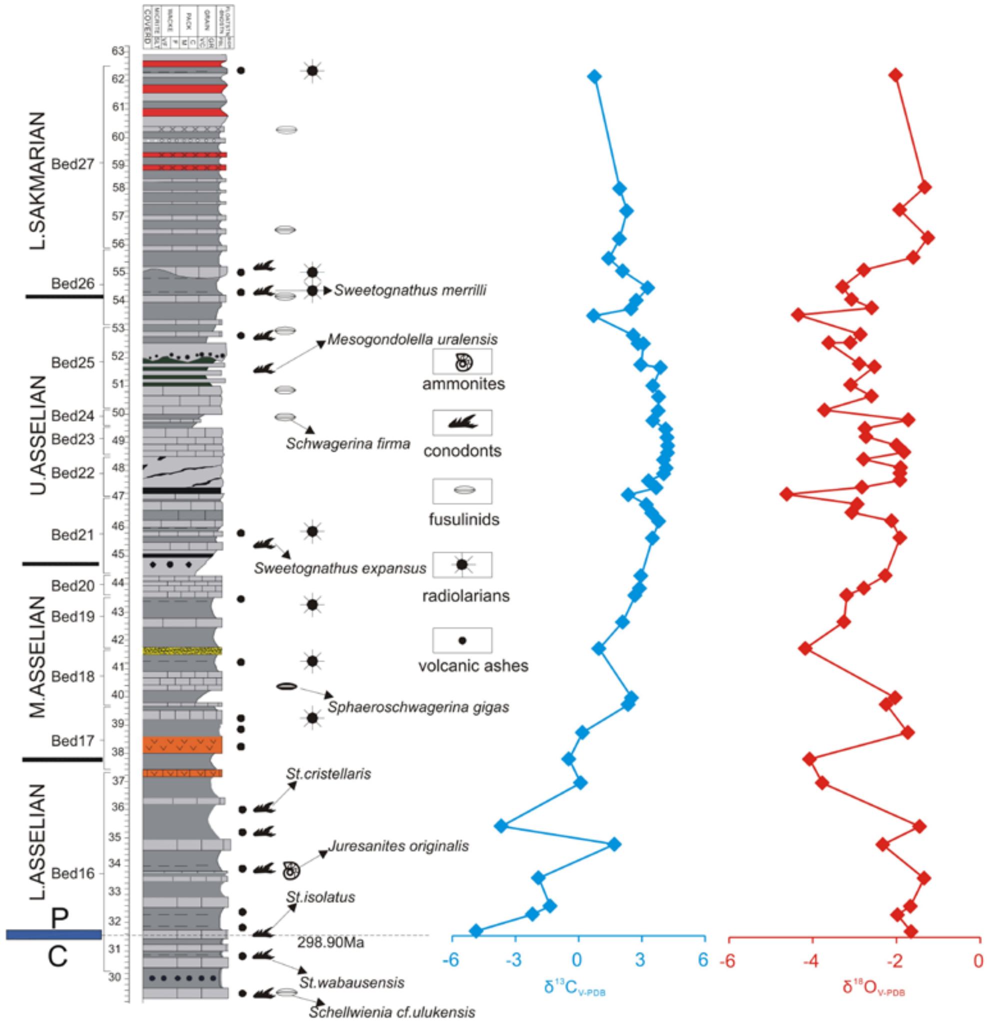

Fig. 10. Carbon and oxygen isotopic trends of the Usolka section (Zeng et al., 2012). Explanation in the text.

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

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Introduction

Considerable data have been generated and our understanding has considerably improved regarding a potential GSSP level for the base-Artinskian since the report provided in Permophiles v. 41 (Chuvashov et al., 2002). Work has focused on the Dal'nyTulkas Section in Russia. A field workshop was conducted June 25-July 4, 2007 in order to determine the reproducibility of the three potential Lower Permian GSSP sections for the base-Sakmarian, base-Artinskian and base-Kungurian. This workshop was reported in Permophiles v. 49 (Davydov and Henderson, 2007) with Boris Chuvashov, Valeri Chernykh and Viktor Puchkov as hosts and Vladimir Davydov, Emir Gareev, Charles Henderson, Elena Kulagina, Tamra Schiappa, Mark Schmitz, Shuzhong Shen and Michael Stephenson also in attendance. Since this field meeting, productive conodont samples have confirmed the FAD position of the conodont *Sweetognathus* aff. *whitei**. We also have geochronologic ages, carbon isotopes and Sr isotopic data on conodonts that provide additional constraints on how to correlate the GSSP into other regions. These facts were reported in a series of communications with Galina Kotlyar in Permophiles 54 (2009, p. 5). The Russian stratigraphic Commission has voted in favour of the FAD of *S.* aff *whitei* at Dalny Tulkus section for the GSSP level.

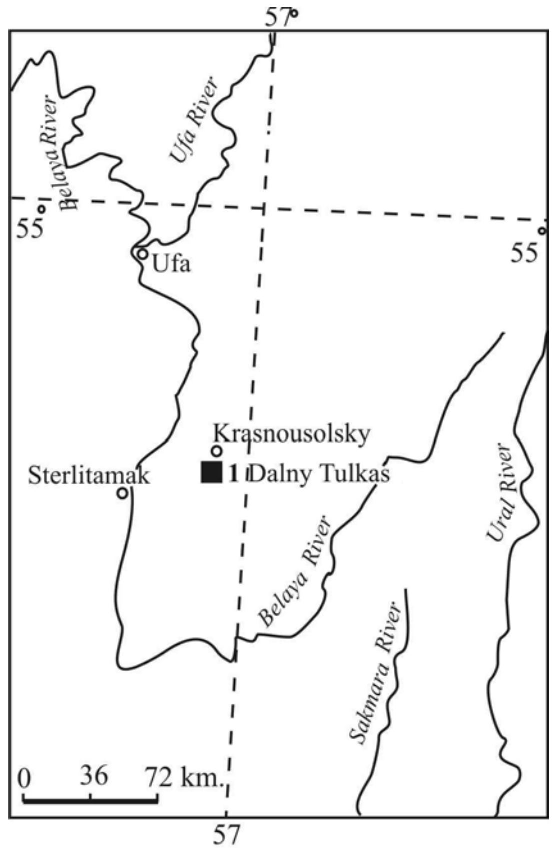

Fig. 1. Location of the Dal'ny Tulkas section. Bed 3/upper location is 53.88847N and 056.51615E.

Historical Considerations and Lithologic Succession

The boundary deposits of Sakmarian and Artinskian are

*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 the *Streptognathodus* lineage also significantly overlaps the *Sweetognathus* lineage. The older lineage is thus marked by *Sweetognathus expansus* to *Sweetognathus merrilli* to *Sweetognathus whitei* within the Asselian. The younger lineage in Russia, which represents an ecologic replacement of *Streptognathodus*, includes *Sweetognathus expansus* (a long ranging form species), *Sw.* aff. *merrilli*, *Sw. binodosus*, *Sw. anceps* and finally *Sw.* aff. *whitei*; the FAD of the latter defining the base-Artinskian GSSP. Despite the nomenclatural issue these two lineages are clearly separated in time as determined by strontium isotopes and geochronology (Henderson and Schmitz, in preparation).

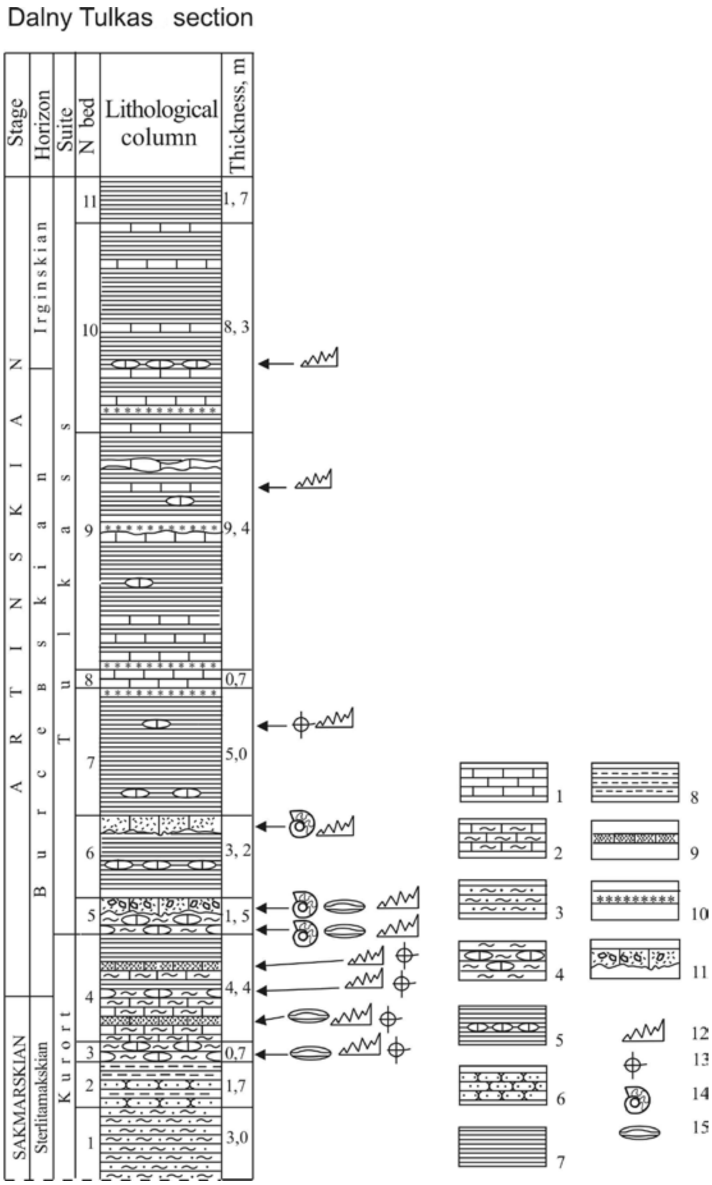

Fig. 2. Stratigraphic column with distribution of samples collected for conodonts, fusulinaceans, radiolarians and ammonoids; 1- limestone; 2- carbonate mudstone; 3- silty mudstone; 4- mudstone with carbonate concretions; 5- shale with carbonate concretions; 6- sandstone; 7- shale; 8- siltstone; 9- bioclastic limestone (grainstone and rudstone); 10- ash tuffs; 11- limestone with limestone intraclasts; pointers show productive levels: 12- conodonts, 13- radiolarians, 14- ammonoids, 15- fusulinaceans

represented most fully in the section on the stream Dal'nyTulkas, located on the southern end of the Usolka anticline near the eastern outskirts of the settlement Krasnousol'sky, Bashkortostan (Fig. 1). In the Dal'nyTulkas section boundary interval are the deposits of the Kurort suite of the predominantly Sterlitamak horizon of Sakmarian Stage and the Tulkas suite of the Artinskian Stage (Chuvashov et al., 1990).

Along the Dal'ny Tulkas stream, the Kurort suite includes beds of dark-coloured carbonate mudstone, argillite, sandstone, and occasional bioclastic limestone with fusulinaceans, radiolaria, rare ammonoids, and bivalves.

The overlying deposits of the Sterlitamak horizon in the interval transitional to the Artinskian Stage are typically poorly exposed. In 2003 a bulldozer clearing of this part of the section exposed all beds, which include "striped" sandy-argillaceous limestone with rare interbeds of detrital limestone and carbonate-clay concretions with selected fusulinacean, ammonoid and conodont samples. Practically all conodont samples in the striped interval proved to be productive. In the Artinskian part of the section there are four ash tuff layers.

The lower boundary of the Artinskian Stage is determined by the level of the appearance in the middle of bed 4 of the cosmopolitan conodont *Sweetognathus* aff. *whitei* in the phylogenetic lineage – *Sw.* aff. *merrilli* →*Sw. binodosus*→*Sw. anceps* → *Sw.* aff. *whitei* → *Sw. clarki*. The first Artinskian complex of fusulinaceans is noted in the section at 2.5 m higher in the base of bed 5, which also includes complexes of Artinskian ammonoids and conodonts.

The schematic lithologic column of the Dal'nyTulkas section with indications of the

paleontologic samples is given below (Fig. 2) including detailed description and lists of identified ammonoids, fusulinaceans and conodonts.

Section description

Sakmarian Stage
Sterlitamak horizon
Kurort suite

Bed 1. This unit is ash-grey on fresh surface and brownish-grey on the weathered surface and includes silty carbonate mudstone that forms layers from 2 to 5 cm thick. Organic remains include rare shells of ammonoids, fish-scales, and long stems of non-calcareous algae. In the middle of the layer, in the trench, there was discovered in the original bedding (?) an argillaceous and calcareous concretion with fusulinaceans, but it was impossible to make oriented thin-sections of them...3 m

Bed 2. Strongly calcareous and clayey siltstone and fine-grained sandstone forming 15-20 cm thick beds. Organic remains include long thin thalli of non-calcareous algae and thin detritus of terrestrial plants …………………………………..................1.7 m

Bed 3 (Fig. 3D). Limestone is brownish-grey with 10-15 cm thick layers at the base and top of the unit; platy carbonate mudstone with shells of calcitized radiolaria compose the middle part of the layer. In the limestone near the top of the unit there are carbonate concretions with conodonts and rare fusulinaceans. Oriented sections from fusulinaceans could not be made. Conodonts include *Sweetognathus* cf. *obliquidentatus* (Che rn.)...0.7 m

Bed 4a (Fig. 3A). Monotonous unit of brownish dark grey platy carbonate mudstone, with some interbeds of siltstone. Texture of rock is platy, with thickness of plates at 1-5 cm, in one case to 10 cm. In the lower part of the unit there are recessive (5-7 cm) interbeds of bioclastic (fusulinacean, bryozoans, crinoids) rudstone, from which the following fusulinaceans are determined: *Pseudofusulina* of *callosa* Raus., *P. callosa proconcavutas* Raus., *P. jaroslavkensis fraudulenta* Kireeva, *P.* cf. *parajaroslavkensis*

Fig. 3. A. Trench for GSSP portion of Dalny Tulkus section; V. Davydov and B. Chuvashov for scale). B. Close-up of beds 4b and 5; base-Artinskian at base of photo. C. Arrow points to hammer positioned at the GSSP level. D. Bed 3 and GSSP trench above. Photos by C. Henderson during Cisuralian workshop in 2007.

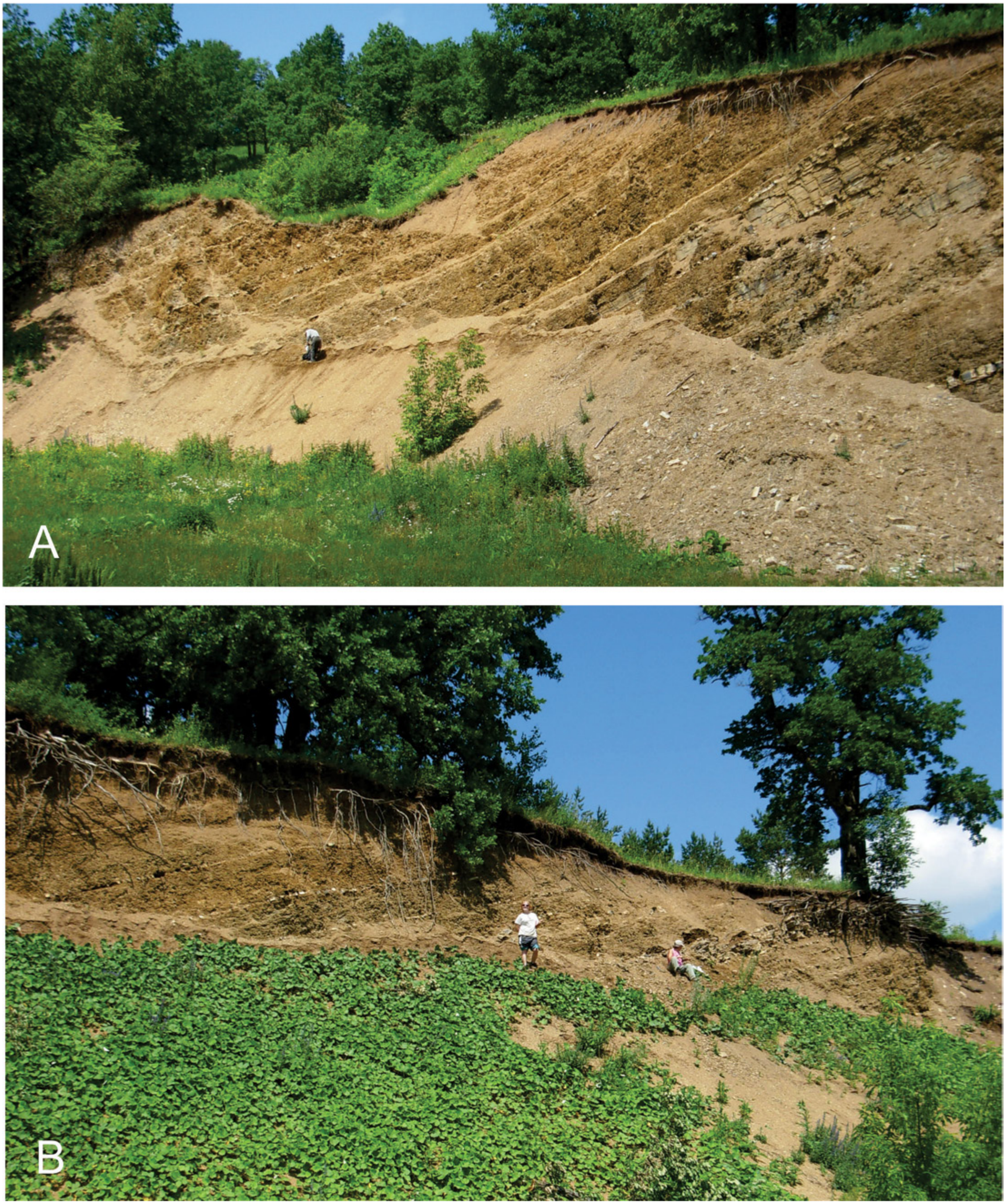

Fig. 4. A. Upper part of the outcrop showing nature of bedding. B. Tamra Schiappa is collecting ammonoids at bed 8 (see report above).

Kireeeva, *P. blochini* Korzh. The given complex of fusulinaceans indicates the upper part of the Sakmarian Stage. The same bed includes Sterlitamakian conodonts: *Mesogondolella bisselli* (Clark and Behnken), *Sweetognathus anceps* Chern., *Sw. obliquidentatus* (Chern.), transitional forms from *Sw. anceps* Chern. to *Sw.* aff. *whitei* (Rhodes) with the fragmentary mid-carinal connecting rid ge.…………………..1.8 m

Artinskian Stage
Bursevskian horizon

Bed 4b (Fig. 3B). Through a 0.6 m interval in the calcareous concretions, which occur in a carbonate mudstone unit, are found the conodonts *Mesogondolella bisselli* (Clark and Behnken), *Sweetognathus anceps* Chern., transitional forms from *Sw. anceps* Chern. to *Sw.* aff. *whitei* (Rhodes), and *Sw.* aff. *whitei* (Rhodes *sensu* Chernykh); the latter indicating the Artinskian. 1.2 m above, within the section, in a unit of small carbonate concretions is found also the Artinskian complex of conodonts including *Mesogondolella bisselli* (Clark and Behnken), *Sw. obliquidentatus* (Chern.), *Sw.* aff. *whitei* (Rhodes *sensu* Chernykh); arrow in Fig. 3C points to approximate base-Artinskian position. A layer (0.42 m) of resistant, silicified bioclastic (fusulinacean, bryozoans, crinoids) grainstone-rudstone with graded bedding lies in the upper part of the unit. The fusulinaceans determined from this layer include: *Pseudofusulina aff. longa* Kireeva, *P. fortissima* Kireeva, *P. anostiata* Kireeva, *P. plicatissima* Raus., *P. urdalensis abnormis* Raus. The given complex is characteristic of the Sterlitamak horizon and conodonts include: *Mesogondolella bisselli* (Clark and Behnken), *Sw. obliquidentatus* (Chern.) ....2.6 m

Tulkas suite

Bed 5 (Fig. 3B). The lower part of the layer (60 cm) is brownish-grey, unstratified silty carbonate mudstone, in which are scattered numerous calcareous concretions. The numerous fusulinaceans found in the cementing mass include: *Pseudofusulina callosa* Raus., *P. plicatissima* Raus., *P. plicatissima irregularis* Raus., *P. urdalensis* Raus., *P. fortissima* Kireeva, *P. concavutas* Viss., *P. juresanensis* Raus., *P. consobrina* Raus., *P. paraconcessa* Raus. This complex of fusulinaceans indicates lower Artinskian Stage.

The upper part of the bed is represented by laminated mudstone, with lenses of detrital and breccia-like bioclastic material, and platy at the top. In the lower part of the layer and in the breccia limestone are found numerous ammonoids, from which M.F. Bogoslovskaya determined: *Popanoceras annae* Ruzh., *P. tschernowi* Max., *P. congregale* Ruzh., *Kargalites* sp., *Neopronorites skvorzovi* Tschern. The given complex of ammonoids definitely indicates an early Artinskian age. Also there is rare *Artinskia* sp. here. The conodont samples were selected from the lower and upper parts of the layer. In them are forms identical with the Artinskian complex of conodonts: *Mesogondolella bisselli* (Clark and Behnken), *Sweetognathus* aff. *whitei* (Rhodes *sensu* Chernykh), *Sw. obliquidentatus* (Chern.), and *Sw. gravis* Chern.

Bed 6. A major portion of the layer is argillaceous, dark-greenish-grey, fissile with isolated carbonate concretions. The unit top includes an interbed (20 cm) of bluish- grey mudstone with an admixture of thin detrital material. In this mudstone, and also in the concretions there are rare shells of ammonoids whose taxonomic composition is identical with bed 5. The complex of conodonts present here includes: *Mesogondolella bisselli* (Clark and Behnken), *M. bisselli* n. sub sp. ....3.2 m

Bed 7. Argillite, dark-brownish-grey in the fresh state and greenish-grey on the weathered surface, is platy and occasionally fissile. At the top of the layer are six (thin) interbeds of steel-grey pelitomorphic limestone. At 1.1 m below the layer top, there is a large (0.5 x 20 cm) concretion of mudstone with numerous radiolaria and conodonts including *Mesogondolella bisselli* (Clark and Behnken) ……………………………………………........5 m

Bed 8 (Fig. 4B). Limestone, bluish-grey on the fresh surface and whitish on weathered surface, pelitomorphic, with subordinate layers and lenses of detrital material and ammonoids. Lower 20 cm of the limestone contain interbeds of argillite with thickness up to 4 cm. Both below and above the limestone are interlayers of yellowish-grey silicified ash tuff with thickness up to 10 cm. The thickness of limestone decreases westward.....................0.7- 0.5 m.

Bed 9. Above is mostly argillite, in which periodically (through 1-2.5 m) are repeated the interbeds (5-10 cm by thickness) of steel-grey pelitomorphic limestone. More frequent are the interlayers of yellowish-light-grey silicified ash tuffs with thickness of 1-5 cm. There are also several lenticular concretions of steel-grey clayey limestone. In the middle of the bed one concretion contained numerous radiolarian and conodonts including *Mesogondolella bisselli* (Clark and Behnken) ………………………………..9.4 m

Bed 10. Includes primarily argillite as in bed 9, but in contrast, this bed contains more frequent and thicker (15-20 cm) interbeds and concretions of steel-grey pelitomorphic and more often detrital limestone, within which frequently there are layers (3-10cm) of yellowish-light-grey silicified ash tuff. In the limestone, numerous calcitized radiolarian and conodonts are found in limestone concretions, which indicate the Irginskian substage. The conodonts include: *Sweetognathus* aff. *whitei* (Rhodes *sensu* Chernykh), *Sw. clarki* (Kozur), *Sw.* aff. *binodosus* Chern., *Mesogondolella bisselli* (Clark and Behnken), *M. laevigata* Chern.............................8.3 m

Bed 11. Above there is an argillitic layer with rare small carbonate concretions without any interbeds of limestone .....1.7 m

The nature of outcrop of the higher portions of this Artinskian succession is shown in Fig. 4A.

Conodonts

Conodonts were considered the primary biostratigraphic tool, which made it possible to clearly fix the desired boundary and also to carry out its global correlation on the appearance of the cosmopolitan form – *Sweetognathus* aff. *whitei*, whose position in the chronomorphocline (Fig. 5) *Sw. binodosus-Sw. anceps-Sw.* aff. *whitei* is confirmed by the study of the Dal'nyTulkas section, which provides among the greatest information with respect to conodonts of the genus *Sweetognathus* in the region.

In order to explain the value of these new data, let us recall the previously published information about the development of this group of conodonts in the Usolka section (Chernykh and Chuvashov, 2003). The primitive form, *Sweetognathus* aff. *expansus* (Perlmutter), in which the beginning of the carinal differentiation (Fig. 5.1) occurs, appears in Upper Asselian. In early Tastubian it evolves into *Sweetognathus* aff. *merrilli* Kozur

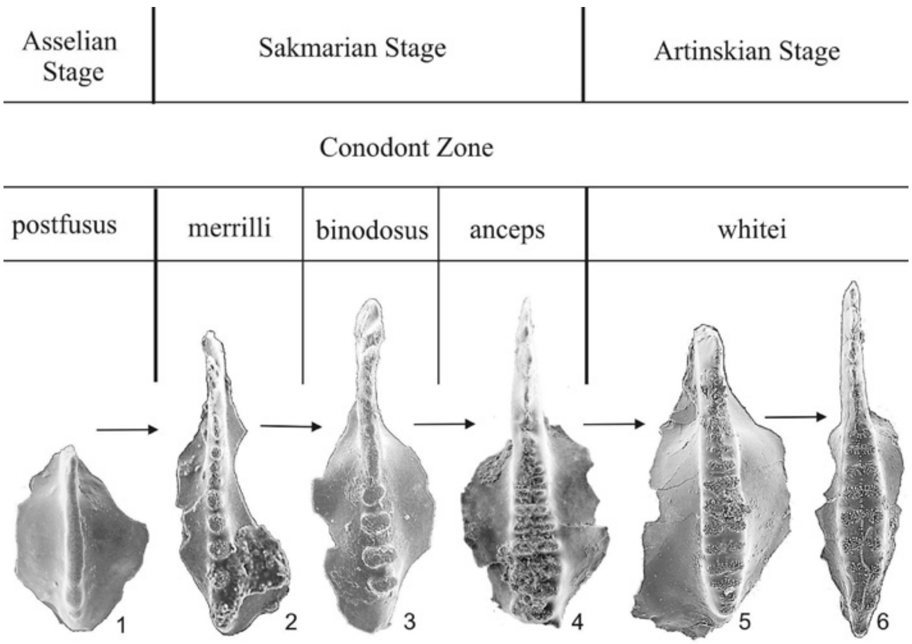

Fig. 5. The evolutionary lineage *Sweetognathus* aff. *expansus* (Perlmutter) - *Sw.* aff. *whitei* (Rhodes). 1 - *Sweetognathus* aff. *expansus*, Usolka section, from bed 21; 2 - *Sw.* aff. *merrilli* Kozur, Usolka section, from bed 26/2; 3 - *Sw. binodosus* Chern., Usolka section, from bed 26/3; 4 - *Sw. anceps* Chern., Dal'nyTulkas section, from bed 4a; 5 - transitional from *Sw. anceps* to *Sw*. aff. *whitei*, from bed 4b; 6 - *Sw*. aff. *whitei* (Rhodes), Dal'nyTulkas section, from bed 4b.

with carinal development forming rounded nodes in upper view (Fig. 5.2). Further evolution of this group leads to the appearance in the Tastubian horizon of such forms, which have few carinal nodes, but that are laterally elongated with a tendency toward the bilobate dumbbell-like structure. These forms are referred to as the species *Sweetognathus binodosus* Chernykh (Fig. 5.3).

The special features of further evolution of this group during Sterlitamakian and Artinskian time are revealed in the trenched part of the Dal'ny Tulkas section. The development of the carina of Sterlitamakian representatives of the line *Sweetognathus* aff. *expansus* - *Sw.* aff. *merrilli* - *Sw. binodosus* continues in the direction of the differentiation of carinal nodes, that led to the appearance of *Sw. anceps* Chernykh (Figs. 5.4) that possess dumbbell-like nodes. In addition to these forms, there appear forms that include fragmentary development of the pustulose, mid-carinal connecting ridge, which we consider as transitional to *Sw.* aff. *whitei* (Rhodes). Forms of *Sw. anceps* with the rudiments of mid-carina pustulose ridge continue to be encountered above in the section until finally there appear specimens of *Sweetognathus* with fully developed dumbbell-like nodes and a complete middle pustulose connecting ridge. We identify such forms to the species *Sweetognathus* aff. *whitei* (Figs. 5.5, 5.6, 6) whose representatives are widely known in many regions where deposits of Sakmarian-Artinskian age are present. Proposals to use the appearance *Sw. whitei* for determining the lower boundary of Artinskian Stage were noted previously by different researchers (Kozur, 1977; Ritter, 1986); however, at the time there was insufficient knowledge about the early members of the evolutionary lineage of this group of conodonts. Those forms, which we isolated into the independent species *Sweetognathus anceps*, also occurred widely, but until now they were encountered together with the typical *Sw.* aff. *whitei*, and the majority of researchers identified their specimens, without the fully developed middle connecting ridge, in open nomenclature as *Sweetognathus* cf. *whitei*. We traced the gradual passage from *Sw. anceps* to *Sw.* aff. *whitei* for the first time and to thus give the complete picture of the development of these conodonts in the evolutionary line *Sweetognathus* aff. *expansus* - *Sw.* aff. *merrilli* - *Sw. binodosus* - *Sw. anceps* - *Sw.* aff. *whitei* (Fig. 5).

The chronomorphocline *S. binodosus*-*S.* aff. *whitei* can also be recognized in the lower Great Bear Cape Formation (see Sakmarian GSSP proposal), southwest Ellesmere Island (Henderson, 1988; Henderson, 1999; Beauchamp and Henderson, 1994; Mei et al., 2002). In China, in the Loudian section (Guizhou) there is a sequence *Sw. binodosus*-*Sw.* aff. *whitei* at 316 m above the base of the section (Wang Zhi-hao, 1994), and also in Korea (Su-In Park, 1989) in the limestone of the Unomasa Formation in a "Stream bed" section, 18 m above base.

However, specimens in the Florence limestone of the Chase Group Kansas (Boardman et al., 2009) are now considered older and equivalent to specimens from the Tensleep Sst of Wyoming where Rhodes (1963) described the holotype of *Sw. whitei*. This

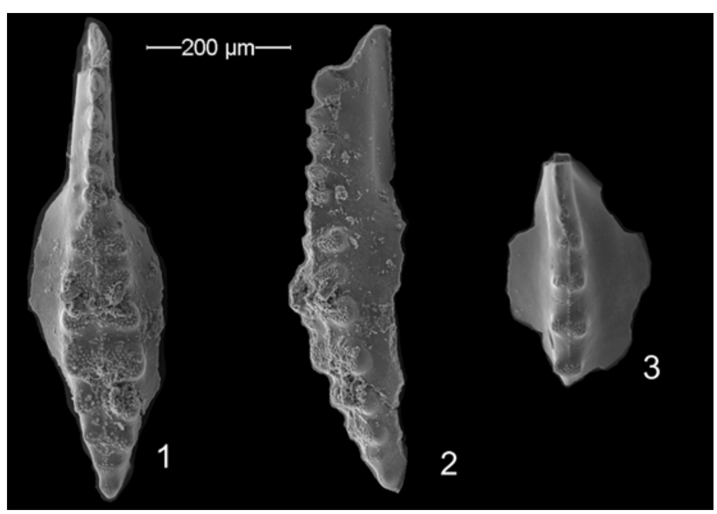

Fig. 6. Two specimens of *Sw*. aff. *whitei* from the GSSP level at 1.8 m above base of Bed 4. Collected by C. Henderson as a reproducibility check (sample C13, bed 4b,

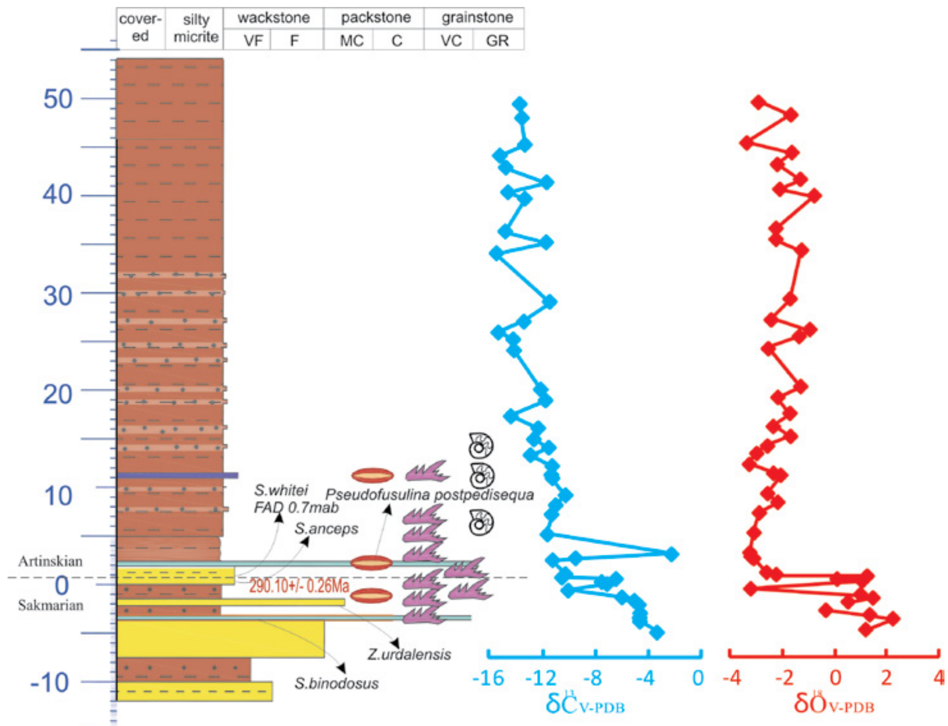

Fig. 7. Carbon and oxygen isotopic trends of the Dal'nyTulkus section (from Zeng et al., 2012). Explanation in the text.

older form has also been recognized in Bolivia (Riglos Suárez et al., 1987).

Ammonoids

Bed 8 includes *Sakmarites postcarbonarius*, *Agathiceras uralicum*, *Kargalites typicus*, *Paragastrioceras* sp., and *Crimites subkrotowi*. Identifications from Tamra Schiappa (Dept. of Geography, Geology and the Environment, Slippery Rock University, Slippery Rock, PA 16057).

U-Pb geochronology

M. Schmitz and V. Davydov (2012) carried out radiometric studies, based upon high-precision, isotope dilution-thermal ionization mass spectrometry (ID-TIMS) U- Pb zircon ages for interstratified ash beds in the parastratotype sections of the southern Urals, including in the Dal'ny Tulkas section. Here they selected ash tuffs at three levels - in the upper part of bed 2 (4 m lower than base of Artinskian, in the upper part of bed 7 (10.5 m higher than base of Artinskian) and in the base of bed 9 (2 m higher than the previous sample).

In bed 2, of eight analyzed grains of zircon, six grains yielded a weighted mean $^{206}Pb/^{238}U$ date of 290.81 ± 0.09 Ma. Seven of eight analyzed grains from bed 7 produced a weighted mean $^{206}Pb/^{238}U$ date of 288.36 ± 0.10 Ma. And from the third interlayer of ash tuff (bed 9) all eight investigated grains gave a $^{206}Pb/^{238}U$ date of 288.21 ± 0.06 Ma. "The three dated samples allow the calculation of a relatively constant accumulation rate through the lower portion of the section" (Schmitz and Davydov, 2012, p.561). Volcanic ash beds provide an extrapolated geochronologic age of 290.1 Ma (Schmitz and Davydov, 2012) for the base-Artinskian (Henderson et al., 2012).

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-Artinskian was approximately 0.70765 (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 Artinskian Stage is now calculated at $^{87}Sr/^{86}Sr$ = 0.70767 (Chernykh et al., 2012).

Carbon isotope chemostratigraphy

A group of Chinese researchers with the participation of V.I. Davydov (USA, Boise State University) conducted a study of carbon and oxygen stable isotopes in the GSSP candidate sections of the South Urals – Usolka, Dal'ny Tulkas and Kondurovsky (Zeng et al., 2012). Basic results, obtained from the section Dal'nyTulkas are given below.

In the Dal'nyTulkas section the curves of $\delta^{13}C$ and $\delta^{18}O$ display a general concurrent tendency of change and are characterized by a rapid and sharp drop near the Sakmarian-Artinskian boundary and a long-term depletion in the subsequent interval of the Artinskian Stage. The values of $\delta^{13}C$ present a dramatic depletion from −4.7‰ to −11.7‰ near the Sakmarian-Artinskian boundary in the Dal'ny Tulkas section, and for a long time remains a deeply negative level higher in the Artinskian Stage, with exception of one point with a value of −2.2‰ in the early Artinskian (Fig. 7). A somewhat similar trend, but with very different values (4‰ to 2‰) is shown by Buggisch et al. (2011) near the Sakmarian-Artinskian boundary at Luodian, China.

These very low values would normally be attributed to diagenesis, and Zeng et al. (2012) noted that the sharp drop in $\delta^{13}C$ and its retention for a long time and its associated normal $\delta^{18}O$ values between 1.1‰ to -2.2‰ is difficult to explain. One potential explanation for those anomalous negative values is that the incorporation of ^{12}C derived from oxidized organic matter from organic-rich sediments with low $CaCO_3$ around the Sakmarian/Artinskian boundary at the Dal'nyTulkas section. A similar excursion is also present around the Wuchiapingian-Changhsingian boundary GSSP at the Meishan section in South China (Shen et al., 2013). Another possible interpretation of such sharp variation in the $\delta^{13}C$ value is due to isotopic refractionation of the microbial chemosynthetic processes on the buried organic matter. However, significant $\delta^{13}C$ excursions from Sakmarian to Artinskian at the Luodian section in South China were also revealed (Buggisch et al., 2011) although precise correlation between South China and southern Urals still needs further study. If a similar sharp excursion is confirmed during further study in other regions, it could be very useful for the correlation of the distant sections.

Summary

In conclusion, the lower boundary of Artinskian can be established on conodonts, fusulinaceans and ammonoids in the Dal'ny Tulkas section. The occurrence of the evolutionary lineage *Sw. binodosus-Sw. anceps-Sw.* aff. *whitei* with transitional forms between the named species makes it possible to assume the absence of interruptions in sedimentation for the Sakmarian-Artinskian interval of the Dal'ny Tulkas section. The diversity of the paleontological remains, the presence of ash tuffs, the accessibility of the section for subsequent study and the possibility of the global correlation of the established boundary – all make the FAD of *Sw*. aff. *whitei* at 1.8 m above the base of bed 4 at the Dal'ny Tulkas section as an excellent Global Stratotype Section and Point (GSSP) for base-Artinskian Stage. A geochronologic age (290.1 Ma), Sr isotopic value (.70767), other fossils and carbon isotopic trends provide additional means for correlation.

Finally, Davydov et al. (2007) reported in Permophiles v. 50 that government agreement has been reached to protect all of the defined and proposed Cisuralian GSSP sites.

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Report of the Chinese, Iranian, Italian working group: The Permian-Triassic boundary sections of Julfa and Zal revisited

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At the end of September 2013, a research group composed of a Chinese party with S.Z. Shen and D.X. Yuan, an Iranian party with M. Bahrammanesh, M. Birjandi and S. Abbasi and an Italian party with L. Angiolini, G. Crippa and C. Garbelli, visited the sections of the Ali Bashi Mountains near Julfa and the section of Zal, in NW Iran (Figs 1-2).

Fig.1. The Chinese-Iranian-Italian research team in Zal, NW Iran. From the left: S. Abbasi, Mr. Eshghi, C. Garbelli, M. Bahrammanesh, L. Angiolini, G. Crippa, Mr. Takhtchin, D. Yuan, M. Birjandi, S. Shen.

The main aim of the field trip was to sample in great details, for conodonts, brachiopods and geochemistry, the sedimentary succession extending from the upper part of the Julfa Formation, through the Ali Bashi Formation and the Boundary Clay to the base of the Elikah Formation (Figs 3-4) in order to:

1) establish a refined conodont biozonation for the Changhsingian of NW Iran through a very detailed sampling and a direct comparison and correlation with the biozonation of South China based on a consistent taxonomy, i.e. conodont study performed and revised by S.Z. Shen and D.X. Yuan, thus minimizing bias due to systematic subjectivity;

2) study the brachiopod evolution approaching the Permian-Triassic boundary with particular emphasis on the analysis of how biomineralization processes are affected by the change in the chemical condition of the oceans. This is part of a larger research project focused on biomineralization changes at the PTB (C. Garbelli, PhD thesis);

3) perform a very detailed geochemical analysis of bulk rock samples, conodont apatite and brachiopod calcite. The latter two groups will be considered suitable for geochemical analyses only after preservation screening and very careful taxonomic identification, in order to avoid to report geochemical data from undermined conodont elements or brachiopod shells that lead to palaeoecological and palaeoclimatic misinterpretations;

4) clarify the hotly debated correlation between Ali Bashi section 1 and section 4 of Teichert et al. (1973). Interestingly Permophiles has been the forum for most of these discussions (Shen, 2007; Henderson et al., 2008; Baud, 2008) and still it remains (Ghaderi et al., this issue).

Notwithstanding the large number of studies on these sections, some of which very recent (e.g. Sweet and Mei, 1999a, b; Kozur 2004, 2005; Henderson et al., 2008; Baud, 2008; Shen and Mei, 2010; Leda et al., 2013; Schobben, et al. in press), we have still found new data, confirming how important it is to revisit sections several times from different perspectives and how field work is central to palaeontological research.

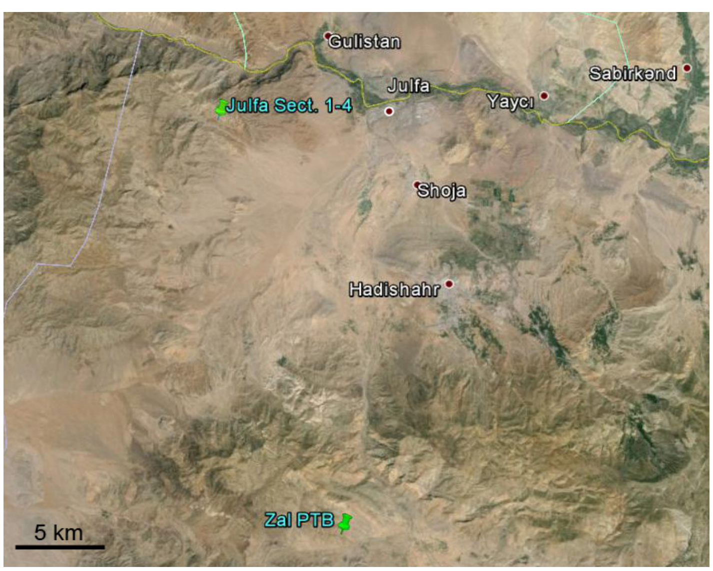

Fig. 2. Satellite map of NW Iran showing the location of the sections in the Ali Bashi Mountains and at Zal.

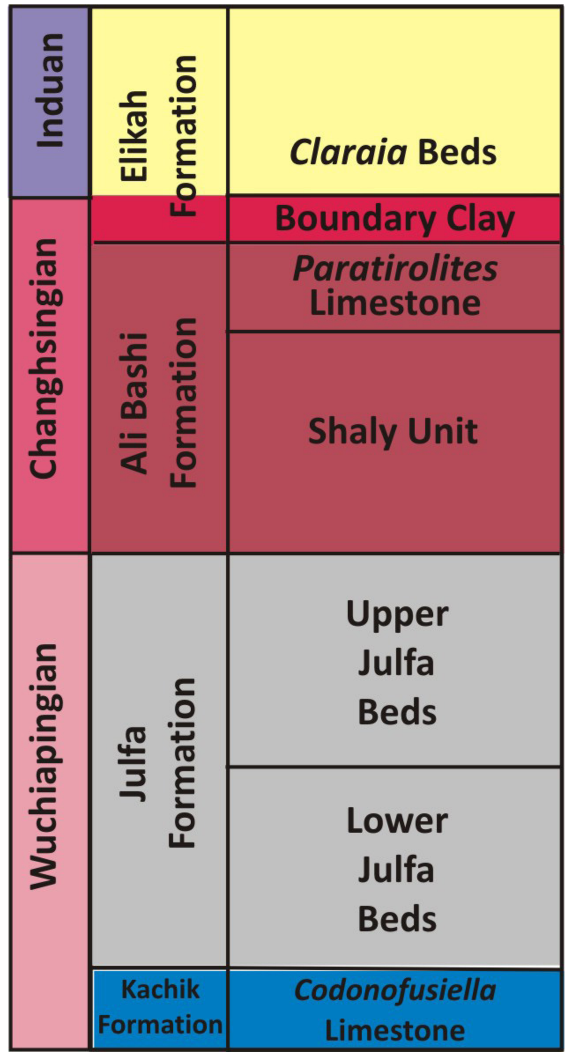

Fig. 3. Stratigraphic classification of the Permian-Triassic succession of NW Iran. The Julfa Formation comprises bioclastic grey to red marlstones with nodular limestones. The Ali Bashi Formation consists of a lower unit of red shales and marlstones with intercalation of limestones and an upper unit with red nodular limestones and marlstones (*Paratirolites* Limestone). The Boundary Clay comprises mainly red and green marlstones with yellowish marly limestones and calcareous siltstones. The lower part of the Elikah Formation consists of yellowish thin platy marly limestones.

In particular we were able to dig and investigate in details the Boundary Clay in the Ali Bashi sections 1 and 3 and at Zal, finding out minor differences in lithology and stratigraphy than what previously reported. We also recorded a more continuous fossiliferous record in the the upper part of the Ali Bashi Formation up to the top of the Boundary Clay, that will be very important to understand the biotic and geochemical change across the PTB.

About the problems of correlation of Ali Bashi sections 1 and 4, also discussed in this issue by Ghaderi et al., we agree with their synthesis. As written by Henderson et al. (2008, p. 9), Teichert et al. (1973) ”… apparently did not finish the section at Locality 4…” and this was probably due to the steepness of the section and to the occurrence of an overhanging cliff formed by the upper part of

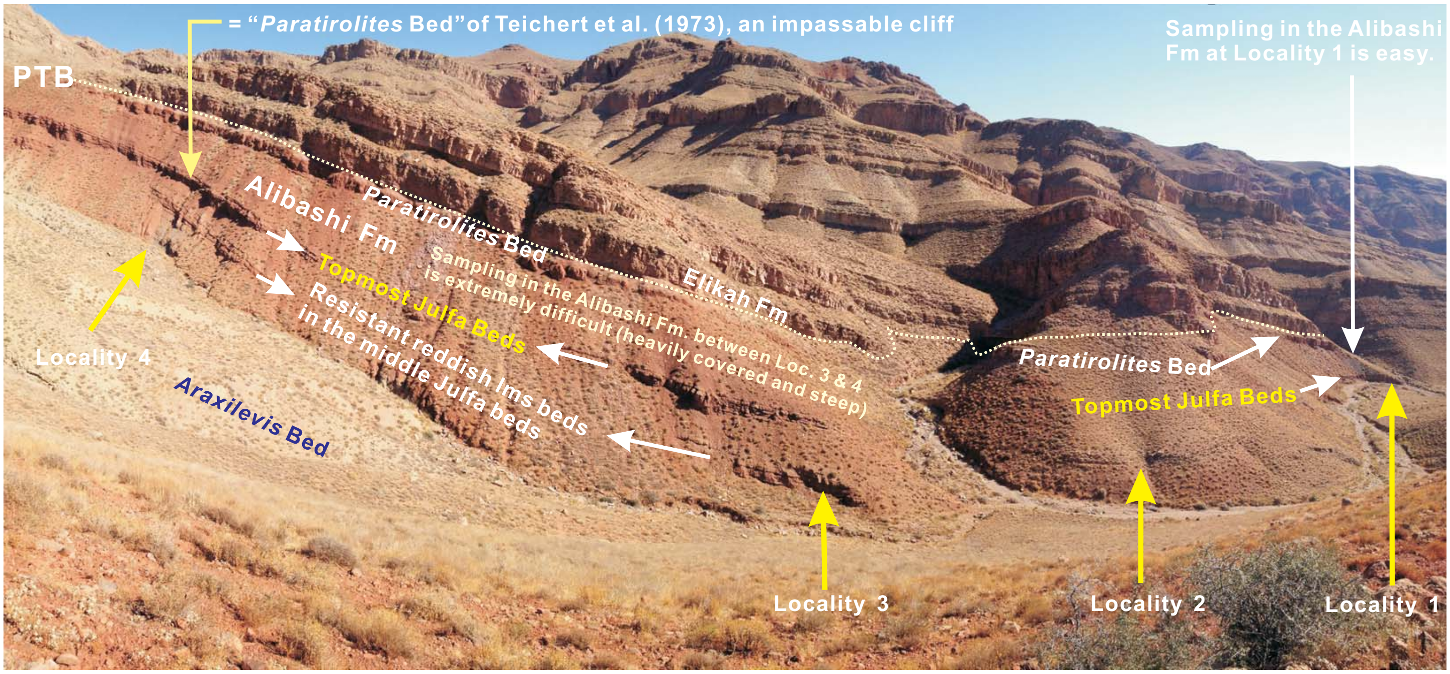

Fig. 4. Photo of the Ali Bashi sections 1 to 4, pointing to NE.

the Julfa, which need unsafe rock climbing or a consistent lateral displacement to be overpassed (Fig. 4). So Teichert et al. (1973) only measured and collected the Julfa Formation in Locality 4, whereas they sampled from the top of the Julfa Formation to the Boundary Clay in Locality 1. Subsequently, this original miscorrelation was made more problematic by questions in conodont taxonomy.

We are confident that the huge volumes of rocks collected (especially for conodonts!) will allow us to obtain new interesting results which we will be happy to share with the Permian community as soon as the laboratory analyses and the preparations will be performed.

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Age assignment of section 4 of Teichert et al. (1973) at Ali Bashi Mountains (Julfa, NW Iran)

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The Permian –Triassic succession in the Ali Bashi Mountains, NW of Iran has been studied by Stepanov et al. (1969) for the first time. Then, Teichert, Kummel and Sweet (1973) established the Ali Bashi Formation in four sections (localities 1 to 4) in Kuh-e-Ali Bashi near Julfa, northwestern Iran. This formation iscomprised between the Dzhulfian (Wuchiapingian) Julfa Formation (below) and the uppermost Changhsingian (Dorashamian) to lowermost Triassic Elikah Formation (above) and contains a rich Changhsingian macrofauna of ammonoids, brachiopods and crinoids as well as a rich microfauna of ostracods, foraminifers, conodonts and holothurians sclerites. The age assignment of section at 'Locality 4' is disputed.

Sweet (in Teichert et al., 1973) first studied Lopingian - Lower Triassic conodonts from three of the four sections measured by C. Teichert and B. Kummel at Kuh-e-Ali Bashi (Localities 1, 2, 4). According to Teichert et al. (1973) all four sections were contemporaneous and straddle the Permian-Triassic boundary.

Sweet and Mei (1999) restudied the conodont material of Sweet, but they never revisited the sections and did not study new material from Kuh-e-Ali Bashi. Their re-examination showed that the Ali Bashi Formation at Locality 1 and the Changxing Limestone at Meishan, South China have the same conodont succession, but that conodonts in Locality 4 represent species characteristic of the lowermost of the *Clarkina* based biozones reported from the Wuchiapingian of South China (Mei et al., 1994, 1998). *Clarkina orientalis* (Barskov and Koroleva, 1970) had an important role in their final results as a key easy determinable species for late Wuchiapingian of Iran. Sweet and Mei (1999) recognized this species in the sample 69SC-7 from the uppermost part of the section 4, which was regarded to be the *Paratirolites* Limestone and thus uppermost Changhsingian in age by Teichert et al. (1973). Sweet and Mei (1999) also recognized *C. orientalis* from sample 69SA-0 at the base of section 1 of Teichert et al. (1973). So, they came to a quite different result as they concluded the sections at localities 1 and 4 in the Kuh-e-Ali Bashi area are the upper and lower parts, respectively, of a continuous succession, not laterally equivalent sections as Teichert et al. (1973) originally concluded.

Later, Kozur (2004, 2005) restudied the four sections and also the conodont material of Teichert et al. (1973). He found upper Wuchiapingian to earliest Triassic conodonts and thus confirmed the biostratigraphical results and correlation of Teichert et al. (1973). Also, he determined two new species from the latest Changhsingian of Iran: *Clarkina abadehensis* Kozur, 2004 and *Clarkina iranica* Kozur, 2004 and established a new biozone in the latest Changsingian, named after *Clarkina iranica,* and located below the *C. hauschkei* zone. Subsequently. Shen and Mei (2010) regarded the species *Clarkina iranica* Kozur, 2004 as a synonym of *C. abadehensis* Kozur, 2004, and changed the name of *Clarkina iranica* zone to *C. abadehensis* zone. This synonymy is not confirmed by Kozur, because he believes *C. abadehensis* is the forerunner of *C. iranica* and also very common in the lower part of the zone but more rare in the upper part; however the occurrences of both species are the same in Kozur (2005). This is not important for the correlation of the sections in localities 1 and 4.

Clarkina iranica has a strong homeomorphy with *C. orientalis* which is distinguished by a gradual narrowing and lowering of the anterior platform. Moreover, the platform outline of *C. orientalis* is mostly more drop-like, widest in the posterior third. According to Kozur (2004, 2005), Sweet and Mei (1999) determined the latest Changhsingian *Clarkina iranica* as the Late Wuchiapingian *C. orientalis* (Barskov and Koroleva) while *C. iranica/abadehensis* occurs only in the uppermost part of the Alibashi Formation immediately below the Elikah Formation. He wrote also that Sweet and Mei (1999) assigned the older beds of the Ali Bashi Formation of section 4 below *C. orientalis* (in reality the latest Changhsingian *C. iranica*) to the lower to middle Wuchiapingian *C. dukoensis* to *C. transcaucasica* zones. None of the lower to middle Wuchiapingian conodont zones mentioned by Sweet and Mei (1999) was recognized by Kozur. As Sweet and Mei assumed that section 4 is much older than section 1, they assumed the section 4 lies stratigraphically below section 1 (Sweet and Mei, p. 44, Fig 1) and the correlation in Teichert et al. (1973) which indicates the same Changhsingian age for sections 1 and 4 is a serious miscorrelation. These results were then confirmed by Shen (2007), Baud (2008) and Henderson et al. (2008).

New investigations by the authors and bed by bed sampling and correlation of the sections in Kuh-e-Ali Bashi show that some results by Sweet and Mei (1999), Shen (2007), Henderson et al. (2008), Baud (2008) and Shen and Mei (2010) are correct.

In fact, the most important problem in correlation of the sections in localities 1 and 4 is the first incomplete sampling and miscorrelation by Teichert et al. (1973). We confirm the sentence "they [Teichert et al. (1973)] apparently did not finish the section at Locality 4, and somehow failed to show that in their notes or subsequent papers" as written by Henderson *et al*. (2008).

Uppermost Julfa Beds and the Ali Bashi Formation in all 4 sections have the same range and their successions are laterally continuous in Locality 1 and 4. Section 4 begins with the *Araxilevis* Beds of Lower Julfa Beds, however several meters to northward in the valley, the uppermost part of dark gray shallow water *Codonofusiella* Limestone cropr out after a minor fault.

The section follows continuously in a deepening trend by rich brachiopod succession of Lower and Upper Julfa Beds (Wuchiapingian). Uppermost *Codonofusiella* Limestone very closed to the base of section 4 comprise Wuchiapingian foraminifera such as *Agathammina* sp., *Codonofusiella kwangasiana*, *Codonofusiella nana, Climacammina* sp., *Frondina permica*, *Frondina* sp., *Hemigordius* spp., *Nankinella* sp. This horizon is very poor in conodonts.

Lower Julfa Beds in Locality 4 comprise gray and green limestone, marl and shale, same as the succession in the Main Valley section of Ali Bashi Mountain, while Upper Julfa Beds

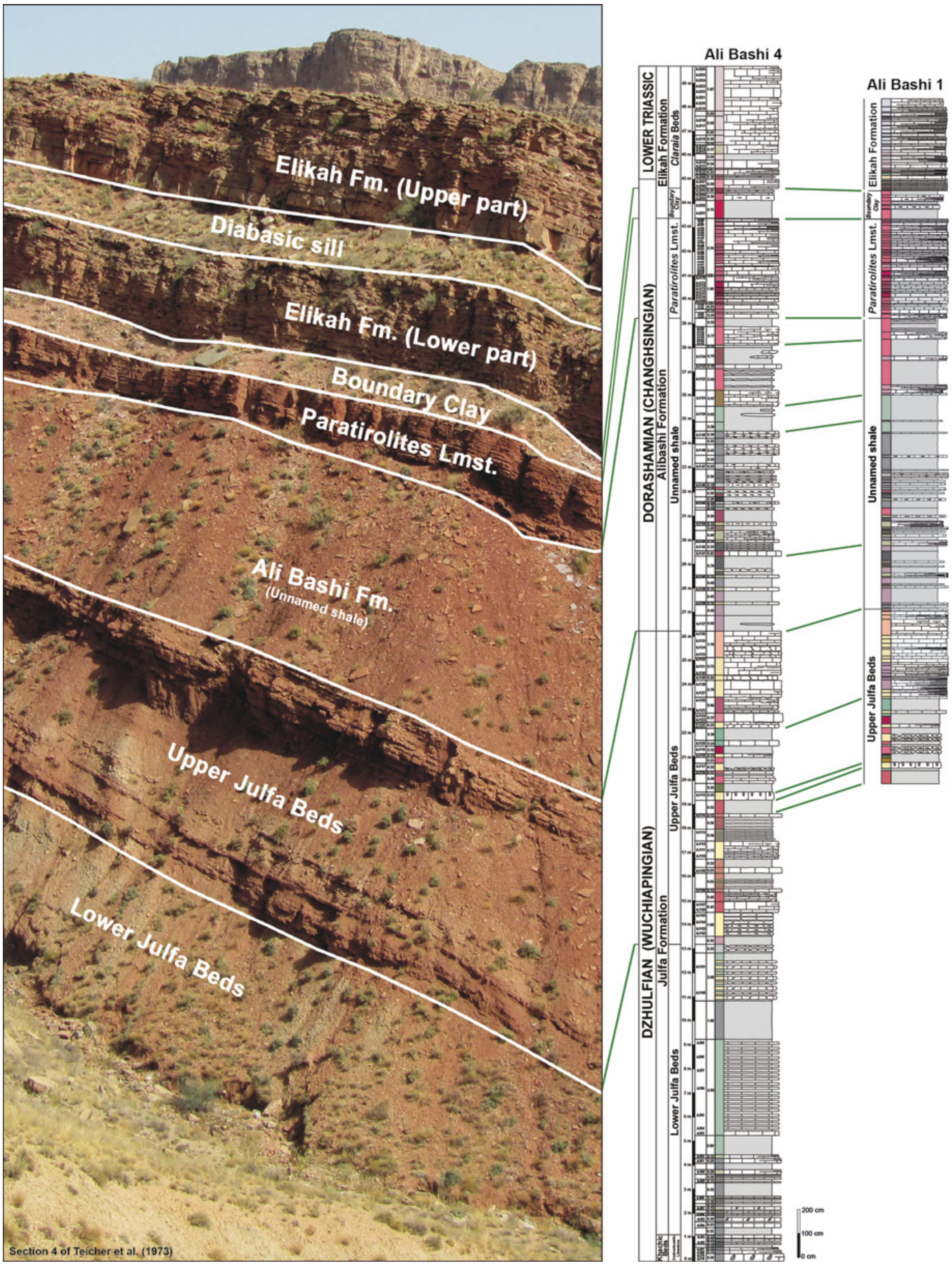

Fig. 1. Left: view of locality 4; right: correlation of the sections at localities 1 and 4.

are cream to red in color and composed of marlstone and nodular limestone. Julfa Beds have typical rich Wuchiapingian *Araxilevis* and *Permophricodothyris* brachiopod fauna and conodont biozones from *C. dukouensis* to *C. orientalis*. The topmost part of the Upper Julfa Beds is characterized by an approximately 4-m-thick unit of reddish, platy, and marly limestones, very similar to the *Paratirolites* limestone (Changhsingian). Although, the carbonate microfacies of the *Paratirolites* Limestone differs in a much more pronounced nodular fabric and the abundance of intraclasts from the red limestones of the upper Julfa Beds which are characterized by mass occurrences of ostracods (Baud, 2008; Leda et al., 2013). The *C. dukouensis* (Lower Wuchiapingian) in the sample 69SC-1 is mentioned as the lowermost conodont zone of the Locality 4 by Sweet and Mei (1999a, 1999b) and Shen and Mei (2010). Kozur (2004) affirmed that "*C. dukouensis* Zone is not present in Julfa area because this level is too shallow for the presence of gondolellid conodonts". Moreover, he believed that neither the *Codonofusiella* Beds nor the *Araxilevis* Beds and the *Araxoceras* ammonoid faunas (all mentioned by Mei in Sweet and Mei, 1999. P. 44, Fig.1) are exposed in sections 1-4 of Kuh-e-Ali Bashi.

New investigations confirm *C. dukouensis* Zone and Wuchiapingian age for the base of Lower Julfa Beds at Locality 4, while this interval was wrongly regarded to lower part of the Alibashi Formation (Changhsingian) by Teichert et al. (1973). Occurrence of Wuchiapingian *Araxilevis* brachiopods at the base of section 4 also confirms this interval belongs to Lower Julfa Beds not Ali Bashi Formation.

With a gradual contact, Julfa beds are overlain by the Ali Bashi Formation (Unnamed shale unit and *Paratirolites* limestone), and then by the Boundary clay and the Elikah Formation on top in Locality 4 (Fig. 1). The Ali Bashi Formation is, at both localities, composed of the *Paratirolites* Limestone at the top, with about 4-m thickness, and a succession of predominant dark shales and some intercalated marly limestones below. The Ali Bashi Formation contains Changhsingian ammonoids (*Dzhulfites* to *Abichites*) and the conodont biozones from. *C. wangi* to *C. hauschkei*, overlain by the *Hindeodus parvus* zone in the basal part of Elikah Formation on top of section 4.

It is obvious that section 4 which extends lithostratigraphically from Lower Julfa Beds to Elikah Formation and biostratigraphically from *C. dukouensis* to *Isarcicella isarcica* does not finish with the Upper Julfa Beds. Section 4 in truth is the most complete rock succession which its upper half is identical to 'Locality 1', but the only difference between these 2 localities is where they begin. Section 4 begins with Lower Julfa Beds, but section 1 with Uppermost Julfa Beds. So, section 1 is correctable only with upper part of section 4. In the other words, section 4 is much thicker (with Wuchiapingian – Lower Triassic beds) than section 1 (with uppermost Wuchiapingian – Lower Triassic beds).

Clearly Teichert et al. (1973) measured section 4 incompletely. As the upper part of section 4 is very steep and cliffy, we are sure they had measured the section until the upper Julfa Beds (*C. orientalis* zone) and then they put erroneously this incomplete measuring of Locality 4 lower part in front of Locality 1 in their famous correlation. This miscorrelation and unfinished sampling are the main reason of their misinterpretation and for the long controversial story of the Julfa region stratigraphic sections. Also, most of their ammonoids from the Ali Bashi Mountains localities are from the float and they have not been collected in situ. So, their findings based on ammonoids are not reliable (e.g. the position of some *Paratirolites kittli* Stoyanov in Locality 4). Because Sweet and Mei (1999) worked on the material collected by Teichert and Kummel in Teichert et al. (1973) and they did not visit and access to the sections, they wrongly extended the range of *Paratirolites kittli* Stoyanov from the Changhsingian *Paratirolites* Limestone to the Wuchiapingian, based on the float specimens of Teichert et al. (1973).

Thus, we have to emphasize that the conclusion by Sweet and Mei (1999) that sections at localities 1 and 4 in the Kuh-e-Ali Bashi area are the upper and lower parts of a continuous succession can be correct, if we consider incompleteness of the sampling not incompleteness of the section at locality 4. Section 1 is equal to upper part of a more complete section in Locality 4 which comprises all ammonoid and conodont zones of the Wuchiapingian – Lower Triassic time intervals. So, in contrast to some previous studies, Locality 4 comprise the best, most complete and well preserved section in the Ali Bashi Mountains and can be considered as a standard section for the Lopingian – Early Triassic in the Julfa region.

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Report of field excursions 2012/2013 of the "Sino-German Cooperation Group on the Late Palaeozoic Palaeobiology, Stratigraphy and Geochemistry" between Europe and China

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With financial support of the Sino-German Center for Research Promotion, a "Sino-German Cooperation Group on Late Palaeozoic Palaeobiology, Stratigraphy and Geochemistry" was established in 2012. The major goal of this working group which is coordinated by Xiangdong Wang (Nanjing) and Hans Kerp (Muenster) is to realize a better correlation between the Carboniferous and Permian sequences in China and Europe using multiple approaches. Participants mainly include colleagues from the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, and a number of German universities including Muenster University, TU Bergakademie Freiberg, Universität-Erlangen-Nuernberg and Munich University, as well as several important research museums like the Natural History Museums in Chemnitz and Schleusingen, the Carboniferous-Permian Museum Geoskop of Thallichtenberg. According to the plan, joint field excursions and research to study selected sequences in China and Europe, and bilateral workshops in China and Europe are organized. In August and September 2012, the first workshop took place in Nanjing, China. This was followed by field excursions to Shanxi, Inner Mongolia, Gansu and Guizhou to see marine and transitional marine-terrestrial Carboniferous-Permian, and Triassic sequences in North China and the classical Permian-Triassic boundary sections in South China. The field excursions in China were guided by Wang Jun, Xiangdong Wang and Shuzhong Shen. Mark Schmitz and Vladimir Davydov from

Photo 1. The Sino-German team visited the Carboniferous-Permian sequences at the Palougou section in Baode, Shanxi Province, North China. Participants sit on the unconformity between the Ordovician and Late Carboniferous.

Photo 2. Participants visiting the Carboniferous and Permian sequence at Rattendorfer Sattel in the Carnic Alps near the border between Italy and Austria.

Boise University, USA, joined the field excursion for sampling of volcanic ashes for isotopic age determinations.

In September 2013, the field excursion in Europe were organised and guided by Joerg W. Schneider, Hans Kerp, Michael Joachimski, Werner Buggisch, Karl Krainer, Evelyn Kustatscher, Ronny Rößler, Frank Scholze, Sebastian Voigt and Ralf Werneburg. Joint field work was carried out in Carboniferous and Permian successions in a number of Late Palaeozoic basins in Europe including the Carboniferous, Permian and Triassic sequences of central Germany in Saxony, Saxony-Anhalt and Thuringia, the paralic Carboniferous of the Ruhr district in North Rhine-Westphalia, the Late Carboniferous and Early Permian sequences of the Saar-Nahe Basin and Pennsylvanian and Permian-Triassic successions in the Southern Alps in Italy and the Carnic Alps in Italy and Austria. We appreciate Maria Cristina Perri and Enzo Farabegoil who guided us in the Permian-Triassic Bulla section in Italy.

The major goal of this cooperative research project is to initiate a series of studies for the correlation of the Carboniferous and Permian sequences between Europe and China, which will form the basis for the reconstruction of biotic responses to climatic and environmental changes during the Late Palaeozoic and around the PT boundary in both regions. The field work in China and Germany was very informative and productive. The first PhD project resulting from this cooperation was launched in September this year at the TU Bergakademie Freiberg. Funded by the German Research Foundation (DFG) it brings together scientists from China, Russia, Hungary, Poland and Germany with the aim to construct a "Multistratigraphic framework for continental Permian-Triassic boundary sections of northern Pangaea as a key to a better understanding of the ecological consequences of the end-Permian crisis in the terrestrial realm." Further PhD research projects are in preparation. Scientists interested in marine - non-marine correlations of Late Palaeozoic/Early Triassic deposits are invited to join our cooperation group.

ANNOUNCEMENTS

August 27, 2013

Greetings Ladies and Gentlemen:

Guadalupe Mountains National Park values the geological and paleontological research done by Permian researchers. We wish to extend our heart-felt thanks to all of you who have contributed to the scientific body of knowledge about the Permian, whether done at Guadalupe Mountains National Park or elsewhere in the world. Your efforts to expand our knowledge of earth history are greatly appreciated.

Guadalupe Mountains NP recovered a number of silicified fossil specimens from different formations within the park. The project, to assemble a representative collection of fossils from all fossiliferous units within the park, has been on-going for a number of years. Begun under the auspices of the previous geologist, Dr. Gorden Bell, and continuing under present management, we have a moderately large collection of silicified specimens processed by acidizing samples with acetic acid. Most of these specimens have been identified only to phylum or class. We wish to make the collections more accessible to the research community. Our goal is two-fold: 1) to publish a taxonomic list of specimens available for study and 2) to make the general public aware of the diversity of the shelf, reef, and basin communities in the Permian. In order to accomplish these goals, we wish to refine our taxonomic identifications of specimens in our collections.

On behalf of the Superintendent of Guadalupe Mountains National Park, I wish to extend an invitation to conduct research at the park. In exchange for twenty hours per week working in our collections refining the taxonomic identifications, the Superintendent offers fully equipped apartments for your use. You may conduct research within the park or on adjacent lands (with permission of appropriate landowners) during the remainder of your time.

You will need to obtain research permits if you intend to collect within Guadalupe Mountains NP. Research applications may submitted online at: https://irma.nps.gov/rprs/Home. If you intend to work on adjacent state or federal lands, you will need to obtain permits from the specific land management agency. Guadalupe Mountains NP will help facilitate obtaining the permits where possible.

Thank you again for all your hard work. If you have any interest or questions involving research at Guadalupe Mountains National Park, please feel free to contact me via email at Jonena_Hearst@nps.gov or by letter at Dr. Jonena Hearst, Geologist, Guadalupe Mountains National Park, 400 Pine Canyon Dr., Salt Flat, TX, USA 79847.

With highest regard

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Announcement of Field Meeting on Carboniferous and Permian Non-Marine – Marine Correlation, July 2014, Freiberg, Germany

This year, during the International meeting on the Carboniferous and Permian Transition in Albuquerque, New Mexico, the chairs of the C and P subcommissions, Barry Richards and Shuzhong Shen, agreed to organize a joint working group on the global correlation between Carboniferous and Permian marine and non-marine deposits. As the kick off for this working group, a **Field Meeting on Carboniferous and Permian Non-Marine – Marine Correlation** will be held at the TU Bergakademie Freiberg in Germany from July 14 to July 20, 2014.

A look at the current International Time Scale shows that nearly all marine stage boundaries of this time interval are ratified or will be ratified in the very near future. But, nearly nothing is known about the correlation of these boundaries into the vast continental deposits on the CP earth. Consequently, there is an urgent need to focus future activities of both the subcommissions on marine – non-marine correlation. Therefore, the aim of the meeting will be to bring together all colleagues who are interested in the correlation of CP continental deposits with the global marine scale. The subject of the meeting will be the use of any and all correlative age-relevant data from marine and non-marine deposits for the solution of the above mentioned problem. In particular, the workers in their own continental basins are asked to promote their detailed local to regional knowledge toward our global aims.

Time frame:

July 13, 2014 arrival; July 14 to July 15, 2014: lectures; July 16 to July 20, 2014, 5 days field excursions to the most important Carboniferous and Permian outcrops in East Germany and the Czech Republic, including Permian-Triassic transitional profiles.

The meeting will be accompanied by a SPS business meeting as well as a meeting of the Sino-German Cooperation Group on Late Palaeozoic Palaeobiology, Stratigraphy and Geochemistry.

Detailed information will be distributed by e-mail to the members of both subcommissions in the second half of December 2014.

Organizers: Joerg W. Schneider, Spencer G. Lucas, Olaf Elicki
Joerg.Schneider@geo.tu-freiberg.de, spencer.lucas@state.nm.us, elicki@geo.tu-freiberg.de

Dear colleagues:

It is the honor and our pleasure to invite you to the XVIII International Congress on Carboniferous and Permian to be held in the Kazan Federal University, city of Kazan, Russia, in August 2015.

Venue

The city of Kazan is one of the ancient cities in Russia . The population is 1,2 million people. It is cultural and industrial center included in UNESCO World Heritage list. The combination of the Muslims and Christian monuments create the unique atmosphere and scenery. The city of Kazan is easy available from Europe through Frankfurt, Moscow and Saint-Petersburg. The location of Kazan in the center of the European Russia allows to propose the observation of the variety of sections and outcrops located in the several districts of Russia.

Host and Conference Language

The XVIII ICCP will be held in the Kazan Federal University on August 7-15, 2015. The official congress language will be English.

Congress topics

Carboniferous and Permian high resolution stratigraphy

Carboniferous and Permian stage boundaries and worldwide correlation - progress and perspectives

Climatic and biotic changes during Late Paleozoic glaciation

Permian continental biota- approach to a new geochronological scale

Non-marine Late Paleozoic world - paleogeography, migration, fauna and flora

Sedimentary sequences and depositional environments during Carboniferous and Permian

Carboniferous and Permian marine biota

Geological pre-congress excursions:

1a. Lower Carboniferous of the Saint-Petersburg region (northwestern Russia).

1b.Moscow basin. Stratotypes of the Serpukhovian, Moscovian, Kasimovian and Gzhelian stages.

1c. Southern Urals. Deep water successions of the Carboniferous and Permian.

1d. Middle Permian – Lower Triassic continental sequences in Vologda and Arkhangelsk regions (North of the European Russia) and localities of flora, tetrapods, non-marine fishes and invertebrates.

Geological post-congress excursions

2a. Volga and Kama Region. Middle and Upper Permian.

2b. Central Urals. Carboniferous-Permian marine succession.

2c. Carboniferous reference sections, Southern Urals.

2d. Permian of Omolon massif, North-Eastern Russia

Mid-congress excursion:

3. Permian deposits along the Volga River.

Accommodations. A large variety of hotels is available in the city of Kazan.

Organizing committee

A.S.Alekseev, I.V.Budnikov, A.S.Byakov, B.I.Chuvashov, I.R.Gafurov, V.G.Golubev, N.V.Goreva, O.L.Kossovaya, G.V.Kotlyar, E.I.Kulagina, D.K.Nourgaliev, S.V.Nikolaeva, V.V.Silantiev

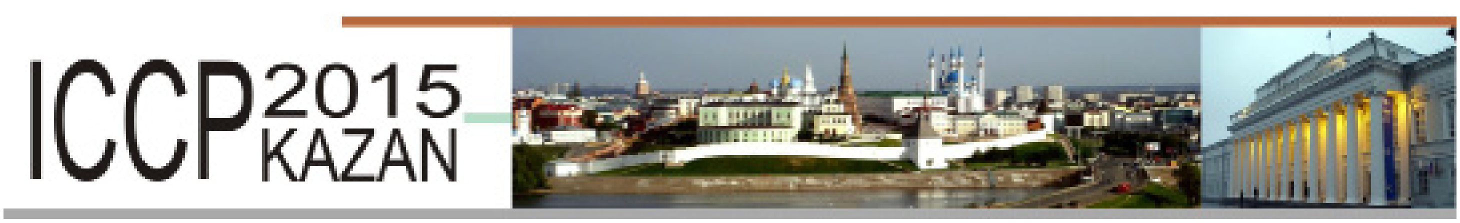
For further information, please contact: iccp2015@ksu.ru

The information will be also available through web site: www.iccp2015.ksu.ru

Organizers: Russian Academy of Sciences, Interdepartmental Stratigraphical Committee of Russia, Carboniferous and Permian Subcommissions of Russia, Kazan Federal University, Moscow State University, All-Russian Research Geological Institute, International Subcommission on Carboniferous Stratigraphy International Subcommission on Permian Stratigraphy

XVIII INTERNATIONAL CONGRESS ON CARBONIFEROUS AND PERMIAN

KAZAN, RUSSIA, August 7-15, 2015

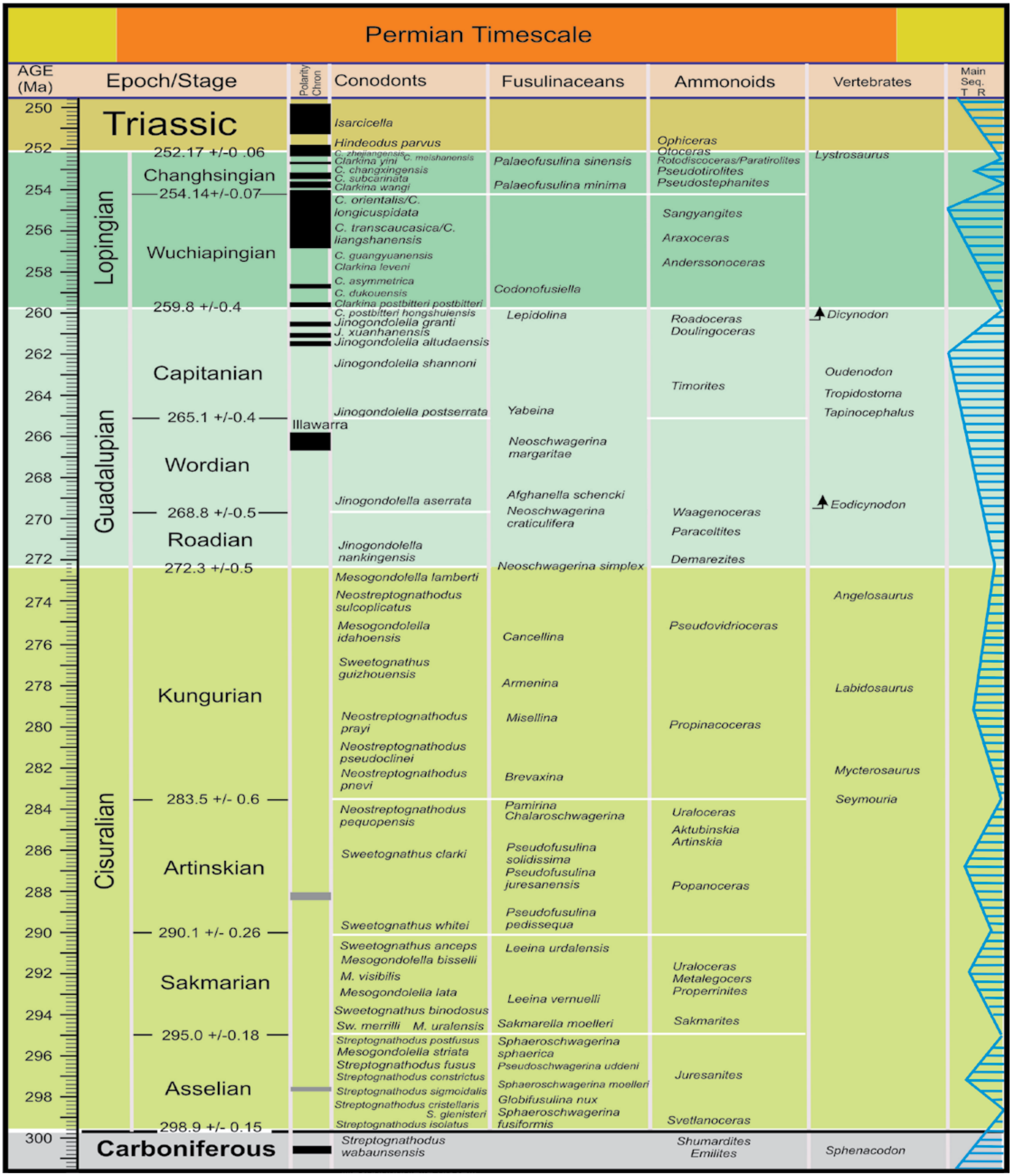


SUBMISSION GUIDELINES FOR ISSUE 59

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

Prof. Lucia Angiolini (new SPS secretary)
Università degli Studi di Milano, Dipartimento di Scienze della Terra "A. Desio", Via Mangiagalli 34, 20133 MILANO Italy, e-mail: lucia.angiolini@unimi.it

The deadline for submission to Issue 59 is February 28, 2014.



Note: This is the latest version of the Permian timescale which SPS recommend. We welcome any comments to improve it. All the information will be updated from time to time here. Geochronologic ages are combined from Shen et al., 2011 (Science) for the Lopingian; Schmitz and Davydov, 2012 (GSA Bulletin) for the Cisuralian, Henderson et al. (2012, *Permophiles*) for the base of Kungurian and the current ICS International Chronostratigraphic Chart for the Guadalupian. Tetrapod biochronology is after Lucas (2006, Geological Society, London, Special Publications, Vol. 265, p. 65-93).