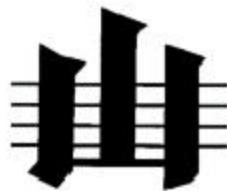
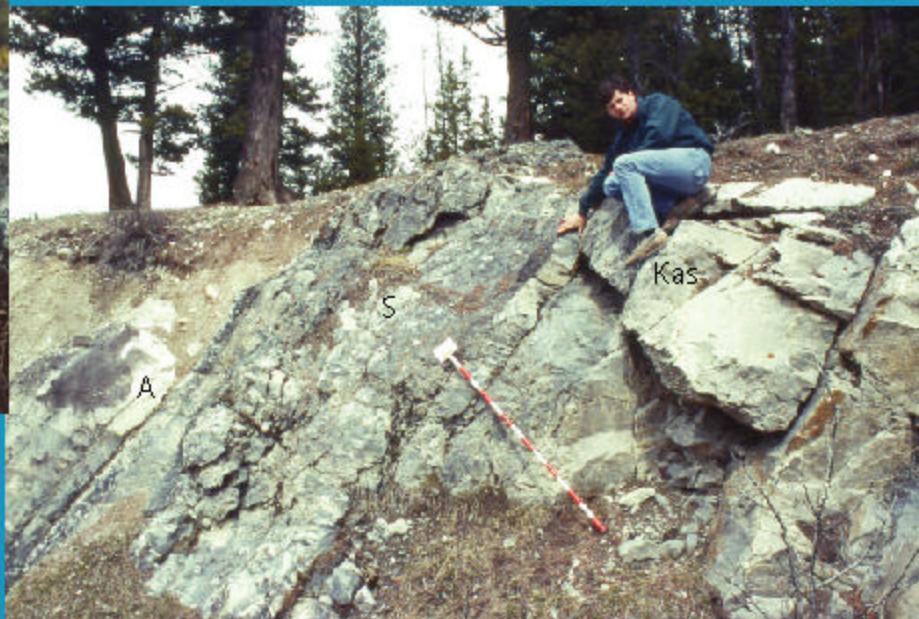
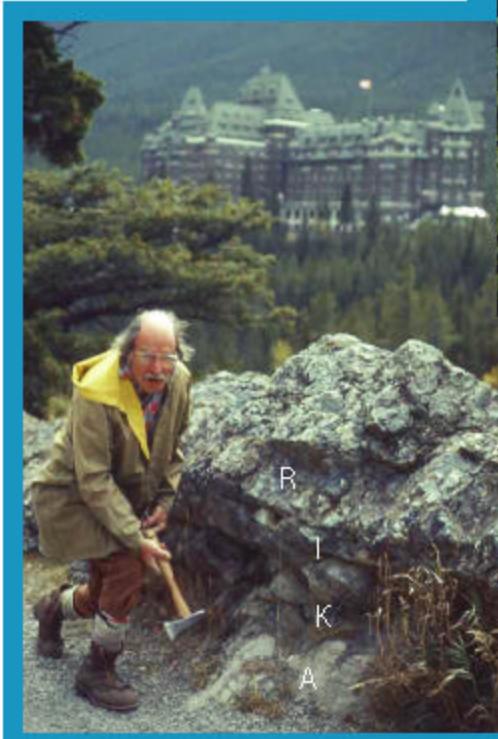
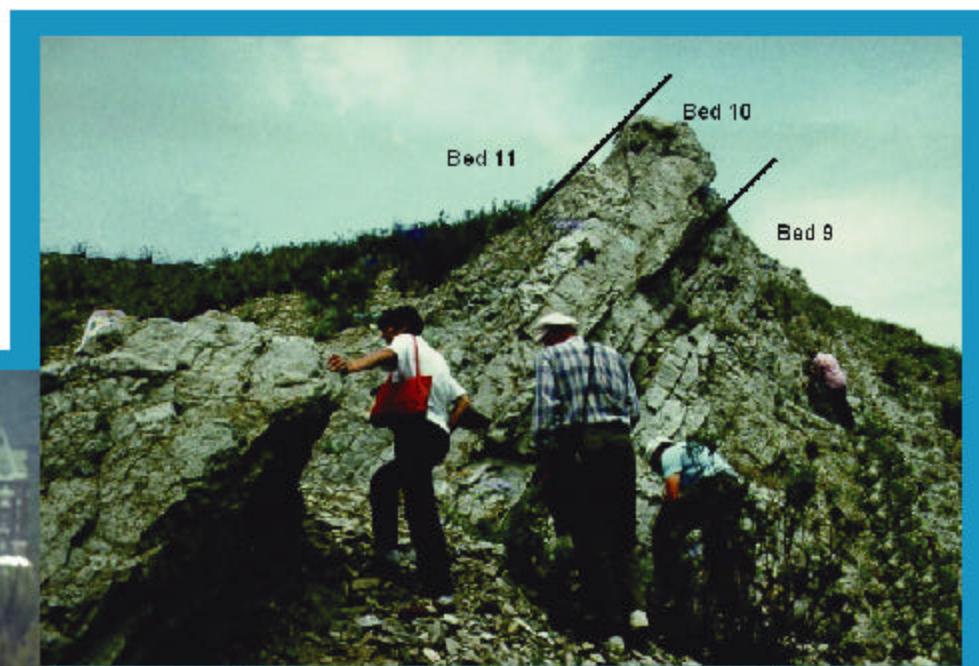


Permophiles

International Commission on Stratigraphy
International Union of Geological Sciences



Newsletter of the
Subcommission on Permian Stratigraphy
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Cover Photos of Cisuralian in Russia and Canada: Upper: View of proposed GSSP for the base of the Sakmarian stage (see Chuvashov <i>et al.</i> , this issue, p. 4). Middle: Alan McGugan (p. 63) in front of the intra-Permian unconformity (I) at Banff, Alberta with Roadian (R) above and Artinskian (A) and a very thin part of the Kungurian (K) below; a microkarst separates Artinskian and Kungurian in the Johnston Canyon Formation. Lower: The SPS Secretary at the same Tunnel Mt. outcrop in Banff; my feet are on Kasimovian dolomitic sandstone (Kas). The condensed 1.5 metres of rock above my hand is Upper Asselian to Lower Sakmarian (S). Bedded rocks above are uppermost Sakmarian to Artinskian (A).	

EXECUTIVE NOTES

Notes from the SPS Secretary Charles M. Henderson

Introduction and thanks

I want to thank those individuals who contributed articles for inclusion in the 41st issue of *Permophiles* and those who assisted in its preparation. Bruce Wardlaw and I did all of the editorial work for this issue during a hectic 3 days at the USGS in Reston, Virginia. We thank Robert Nicoll, Prof. Dr. G. Kowalczyk, Marc Durand, J. Keith Rigby, Brian F. Glenister, Robert Stanton, Smiljana Stojanovic, Gregory P. Wahlman, Hisaharu Igo, W. John Nelson, Edward C. Wilson, Prof. Giuseppe Cassinis, Michael Mawson, Juergen Kullman, Yugan Jin, Xiangdong Wang, Wei Wang, Shen Shuzhong, Neil Archbold, and Garner Wilde for financial contributions to the *Permophiles* publication fund in support of this issue. We also thank Laurie Vaughan (Department of Geology and Geo-physics, University of Calgary) for handling the donations. Continuing publication and mailing of *Permophiles* requires additional contributions; readers are referred to the last page of this issue. *Permophiles* is currently distributed to 285 individuals and institutions and donations have not typically covered expenses. However, I am pleased that so many generous donations came in this year; we have sufficient funds to print this and the upcoming issue. Thankyou! Please remember to specify Canadian or USA dollars (\$25US = \$40Can.). *Permophiles* is recognized by the ICS as an exceptional newsletter and the continuing support of our readers is necessary to maintain that quality.

Previous SPS Meetings and Minutes

There are no meetings to report.

Business Arising from the Minutes

There is no business arising.

Future SPS Meetings

The next scheduled SPS meetings will be held at the XV International Congress on the Carboniferous and Permian (ICCP) at Utrecht, the Netherlands, August 10–16, 2003. Please visit the XV ICC-P website for information [<http://www.nitg.tno.nl/eng/iccp/index.shtml>]. The SPS business meeting will be held during the Permian Stratigraphy Workshop, currently scheduled for the morning of Tuesday, August 12, 2003.

Future Issues of *Permophiles*

Issue 42 will be finalized in September 2003 and we request that all manuscripts be sent such that Charles Henderson receives them no later than Friday September 12, 2003. Issue 42 will be compiled at the University of Calgary. Please see the attached note regarding the preferred method of manuscript submission and format. Following the format as closely as possible makes our

job of preparing *Permophiles* easier. *Please follow the format (especially for references); you too can add those commas and colons!* *Permophiles* now has an ISSN number and it is increasingly referred to in many papers, which means that our reports should be professional and address scientific rather than personal issues. The primary function of *Permophiles* is for discussion of Permian issues so we are always interested in replies to the various contributions. These must also follow the format as outlined elsewhere.

Our database is still missing a number of e-mail addresses so if you haven't written to me recently I would appreciate receiving a very short e-mail after receiving *Permophiles* 41; put *Permophiles* as the subject. Send to henderson@geo.ucalgary.ca (after Sept. 1, 2003 to charles.henderson@ucalgary.ca).

Report on the SPS vote for the Guadalupian-Lopingian boundary

A proposal (only very slightly revised from that reported in *Permophiles* 39) and ballot was sent in January 2003 to SPS voting members. A successful and conclusive vote requires 60% of the group to vote at least a 60% majority. The SPS Voting Members have voted 14-1-1 in favour (88%) and it is here declared that the Guadalupian-Lopingian boundary as defined by the FAD of *Clarkina postbitteri postbitteri* at the base of bed 6k at the Penglaitan Section has passed the Subcommission on Permian Stratigraphy.

The results are as follows:

Prof. Giuseppe Cassinis	Yes
Dr. Boris I. Chuvashov	Yes
Dr. Clinton Foster	Yes
Prof. Brian F. Glenister	Yes
Prof. Charles M. Henderson	Yes
Dr. Jinzhang Sheng	Yes
Dr. Makoto Kato	Yes
Dr. Galina Kotlyar	Yes
Dr. Heinz Kozur	No
Prof. Ernst Ya. Leven	Yes
Dr. Manfred Menning	Abstain
Dr. Claude Spinosa	Yes
Dr. John Utting	Yes
Dr. Bruce R. Wardlaw	Yes
Dr. Yugan Jin	Yes
Dr. Zhouting Liao	Yes

SUBCOMMISSION ON PERMIAN STRATIGRAPHY

ANNUAL REPORT 2002

1. TITLE OF CONSTITUENT BODY

International Subcommission on Permian Stratigraphy (SPS)

2-3. OVERALL OBJECTIVES, AND FIT WITHIN IUGS SCIENCE POLICY

Mission Statement and Goals

The Subcommission's primary goal is to define the series and stages of the Permian, by means of internationally agreed GSSPs, and to provide the international forum for

scientific discussion and interchange on all aspects of the Permian, but specifically refined regional correlation.

Fit within IUGS Science Policy

The objectives of the Subcommission relate to two main aspects of IUGS policy:

- (i) The development of an internationally agreed scale of chronostratigraphic units, fully defined by GSSPs where appropriate and related to a hierarchy of units to maximize relative time resolution within the Permian period;
- (ii) Establishment of frameworks and systems to encourage international collaboration in understanding the evolution of the Earth during the Permian Period.

4. ORGANIZATION

The Subcommission has an Executive consisting of a Chair, two Vice-Chairs, and Secretary, who are all Voting Members of the Subcommission. There are sixteen total Voting Members. The objectives of the Subcommission are pursued by Working Groups, both Stratigraphic and Thematic, that are disbanded upon completion of their directed task. For example, the Working Groups on the Carboniferous and Permian Boundary and on the Guadalupian (Middle Permian) and its constituent stages have been disbanded on the successful establishment of their defining GSSPs. The current Working Groups are: the Cisuralian, the Lopingian, Continental Permian, Transitional biotas as gateways for global correlation. The Subcommission also supports a special project titled "The Permian: from glaciation to global warming to mass extinction"

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

The SPS receives strong support from Russian, Chinese, and American governments and individuals when working on the specific Series and Stages proposed in each country. The University of Calgary (Canada) and Boise State University (USA) helped support our operations. Individual donors and the U.S. Geological Survey strongly supported the activities of SPS this year.

6. INTERFACE WITH OTHER INTERNATIONAL PROJECTS

The SPS interacts with many international projects on formal and informal levels. SPS is taking a very active role on the development of integrated chronostratigraphic databases participating on **CHRONOS**, initially an NSF funded initiative. SPS is active with IGCP Project 359: Correlation of Tethyan, Circum-Pacific and marginal Gondwanan Permo-Triassic and the Permian Research Group of SE Asia.

7 & 9. CHIEF ACCOMPLISHMENTS AND PRODUCTS IN 2002

The proposal for the GSSP of the Lopingian pass the working group by a 92% favorable vote and is now being readied for the vote of the full subcommission.

Planning and funding for a January, 2003, Cisuralian Working Group Meeting in Boise was a major accomplishment and will include Russian, American and Canadian participants.

Chief products in 2002 include:

- (i) Publication of and distribution of some 300 copies of The Guadalupian Symposium, Smithsonian Contribution to Earth Sciences, number 32, 415 p.
- (ii) Two major publications submitted to journals and through review on establishing the detailed evolution on which the two stages of the Lopingian (Upper Permian) will be based.

These articles are: Mei, Henderson and Cao, Conodont population approach to defining the base of the Changhsingian Stage, Lopingian Series, Permian, in a special volume of the Geological Society, London; and Lambert, Wardlaw, Nestell and Nestell, Latest Guadalupian (Middle Permian) conodonts and foraminifers from West Texas, in *Micropaleontology*.

- (iii) SPS Newsletters 39 and 40 were produced in 2002 and circulated to a mailing list of 280 and placed on our internet site hosted by Boise State University. The newsletter, *Permophiles*, now has an ISSN number (ISSN 1684-5927).

8. CHIEF PROBLEMS ENCOUNTERED IN 2002

None.

10. SUMMARY OF EXPENDITURES IN 2002:

INCOME	\$15,300
EXPENDITURE	\$15,300

11-14. WORK PLAN, CRITICAL MILESTONES AND ANTICIPATED RESULTS TO BE ACHIEVED FOR NEXT YEAR:

- (a) Formal vote on the Lopingian GSSP by the Subcommission.
- (b) Submittal of the formal proposal for the Changhsingian GSSP
- (c) Submittal of the formal proposal for the Sakmarian GSSP
- (d) Development at the Cisuralian Working Group Meeting of viable proposals for the Artinskian and Kungurian and a proposal timeline.
- (e) Produce two issues of *Permophiles*
- (f) Conduct a Permian Workshop and Annual Business Meeting at the International Congress on the Carboniferous and Permian Stratigraphy (ICCP) at Utrecht this summer.

15-16. BUDGET AND ICS COMPONENT FOR 2003

TOTAL 2003 BUDGET	\$16,000
TOTAL BUDGET REQUEST (ICS)	1,000

17. REVIEW CHIEF ACCOMPLISHMENTS OVER LAST FIVE YEARS (1998-2002)

The SPS has approved the general divisions of the Permian and has now made 4 successful GSSP proposals for Stages (Asselian, Roadian, Wordian, Capitanian). Support for documentation (field work, publication) of the various chronostratigraphic methods for the establishment of the GSSPs has been the most outstanding and differentiating character of this Subcommission. *Permophiles* has become an internationally respected newsletter/journal.

18. OBJECTIVES AND WORK PLAN FOR NEXT 5 YEARS (2003-2007)

Finish the establishment of all the GSSPs of the constituent stages of the Permian.

2003 Formal completion of the Lopingian GSSP.

2004 Formal completion of the Sakmarian and Changhsingian GSSPs.

2005 Formal completion of the Artinskian GSSP

2006 Formal completion of the Kungurian GSSP

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SUBMISSION GUIDELINES FOR ISSUE 42

It is best to submit manuscripts as attachments to E-mail messages. Please send messages and manuscripts to my E-mail address followed by hard copies by regular mail. Please only send a single version by E-mail and in the mail; if you discover corrections before the deadline, then you may resubmit, but indicate the file name of the previous version that should be deleted. Manuscripts may also be sent to the address below on diskettes (3.5" or zip disks) prepared with a recent version of WordPerfect or Microsoft Word; printed hard copies should accompany the diskettes. Word processing files should have no personalized fonts or other code and should be prepared in single column format. Specific and generic names should be *italicized*. Please refer to recent issues of *Permophiles* (Glenister *et al.*, *Permophiles* #34, p. 3) for reference style, format, *etc.* Maps and other illustrations are acceptable in tif, jpeg, eps, bitmap format or as CorelDraw files. The preferred formats for Adobe Pagemaker are Microsoft Word documents and tif files for images. We use Times Roman 12 pt. bold for title and author and 10 pt. for text. Indents for paragraphs are .25"; not your spacebar. Word processing documents may include figures embedded at the end of the text, but these figures should also be attached as separate attachments in tif format or as CorelDraw or Adobe Illustrator files. Do not include figure captions as part of the image; include the captions as a separate section within the text portion of the document. If only hard copies are sent, these must be camera-ready, i.e., clean copies, ready for publication. Typewritten contributions may be submitted by mail as clean paper copies; these must arrive well ahead of the deadline, as they require greater processing time. Any versions that require translation must also be submitted well ahead of the deadline. All paper versions of articles for *Permophiles* will be destroyed after the deadline of the subsequent issue, unless a request is made for return.

Please note that we prefer not to publish articles with names of new taxa in *Permophiles*. Readers are asked to refer to the rules of the ICZN. All manuscripts will be edited for consistent use of English only.

I currently use a Windows 2000 PC with Corel Word Perfect 10, Corel Draw 10, Adobe Page Maker 6.5, Adobe Illustrator 9, and Microsoft Office 2000 programs; documents compatible with these specifications will be easiest to work with.

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**SUBMISSION DEADLINE FOR
ISSUE 42 is Friday September 12, 2003**

REPORTS

Proposal for the Base of the Sakmarian Stage: GSSP in the Kondurovsky Section, Southern Urals, Russia

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Introduction

The Sakmarian is the second stage of the Lower Permian Cisuralian Series and one of the most widely used international standards for Permian stages. The base of the Permian and coincident base of the Asselian Stage was established at the Aidaralash Creek section, Kazakhstan. In the present paper we propose a definition for the base of the Sakmarian Stage and its position in the Kondurovsky section, Orenburg Province, Russia (see Figure 1 for location map). Conodont biostratigraphy combined with de-

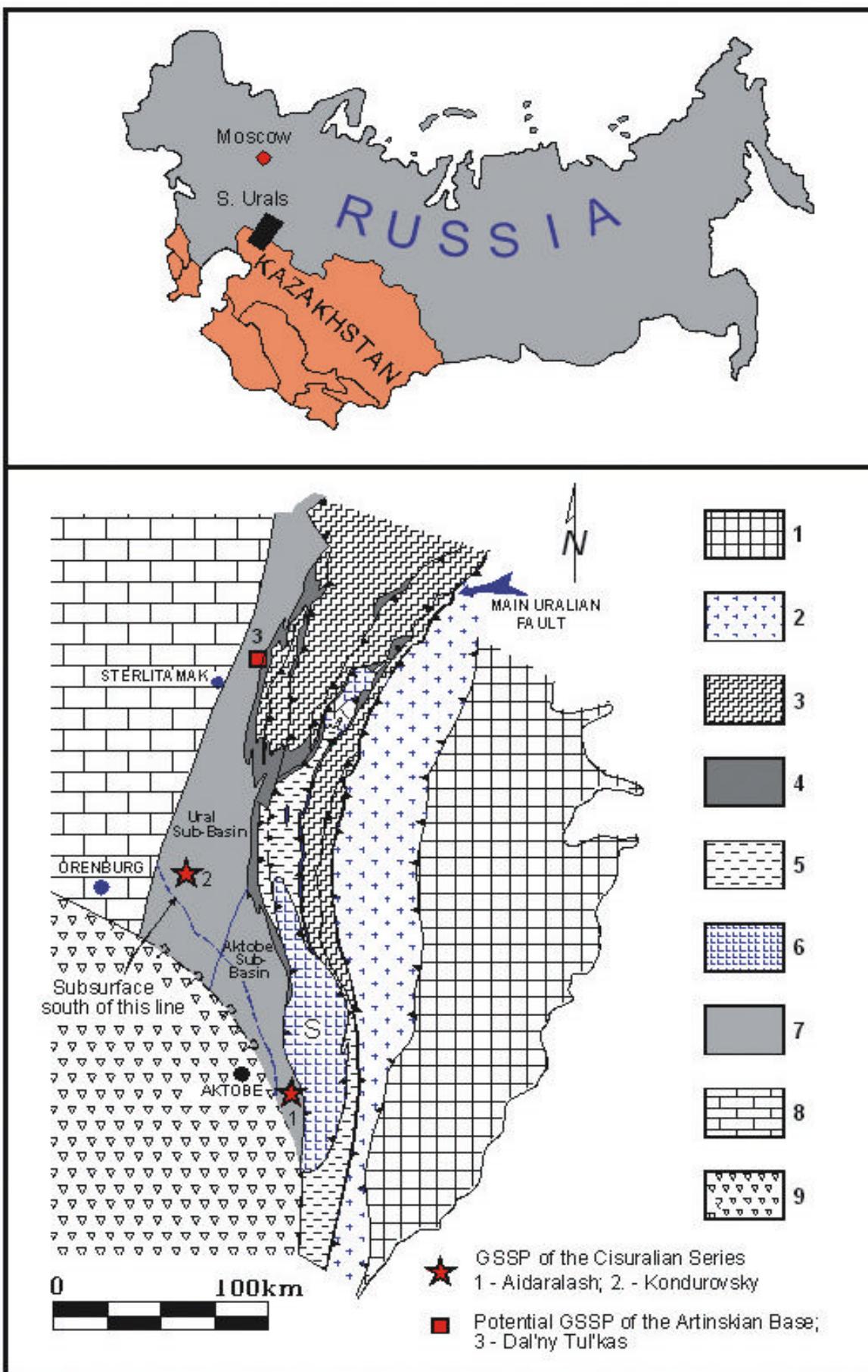


Figure 1. Location map for Cisuralian GSSP's including base of Sakmarian at Kondurovsky.

tailed fusulinacean occurrence data provide excellent bases in support of Kondurovsky as the basal Sakmarian Global Stratotype Section and Point (GSSP). A sweetognathid chronomorphoclone exhibiting the evolutionary change from *Sweetognathus expansus* (Pearlmutter) to *Sweetognathus merrilli* Kozur at 115 metres above base (MAB) (uppermost Bed 11 of Chuvashov *et al.*, 1993), provides excellent definition for the base of the Sakmarian Stage of the Cisuralian Series. We propose to place the base of the Sakmarian within Bed 11 (115 MAB) based on the first appearance (FAD) of *Sweetognathus merrilli* Kozur. This potential boundary is approximately 14 metres above the originally defined base of Sakmarian of Ruzhencev, 1950 (base of Bed 11, 91 MAB, Fig. 1).

Chuvashov *et al.* (2002) recently provided the review of the base of the Sakmarian, which is paraphrased below. “The Asselian-Sakmarian strata in the Kondurovsky section are represented by the Asselian Kurmaya and Karamurunskaya formations of the Sakmarian Tastubian Horizon. In the upper part of the Kurmaya Formation (Beds 6-10), Davydov found fusulinids *Pseudofusulina ex. gr. moelleri* (Schellwein) and Wardlaw and Schiappa discovered the conodont *Streptognathodus* aff. *S. barskovi* Kozur in the same interval (Bed 8). Taking into consideration these finds, our colleagues (Wardlaw *et al.*, 1999) proposed to place the base of Sakmarian at the lower level, namely at the base of Bed 8 of the Kurmaya Formation. Chuvashov and Chernykh contend that Beds 6-10 should be united into the *Pseudofusulina* aff. *P. moelleri-Streptognathodus* aff. *S. barskovi* zone corresponding to the upper part of the Asselian Stage. In this case, the base of the Sakmarian Stage should be placed near the base of the Karamurunskaya Formation that marks the occurrence level of a substantially different conodont assemblage of *Mesogondolella parafoliosa* Chernykh, *Mesogondolella uralensis* Chernykh, *M. lacerta* Chernykh, *Diplognathodus* aff. *D. stevensi*, *D. stevensi* Clark and Carr, *Sweetognathodus* aff. *S. merrilli* Kozur, and *Stepanovites* sp. This assemblage was found in the first member of laminated marls, argillites, and carbonate mudstones of the Karamurunskaya Formation, which lacks fusulinids. Diverse fusulinids of the *Pseudofusulina moelleri* group and accompanying species from the lower part of the Tastubian Horizon were identified in members II and III. Their assemblage coexists with some conodont species that are present in the lower member of the Karamurunskaya Formation. This allows us to refer the lower part of the Karamurunskaya Formation (members I-III) to the *Pseudofusulina moelleri-Sweetognathodus* aff. *S. merrilli-Diplognathodus stevensi* assemblage zone. The Asselian-Sakmarian boundary is placed at the base of this zone and marks the first appearance of *Sweetognathus* aff. *S. merrilli* in the *D. aff. D. stevensi*-*Sw. aff. S. merrilli* evolutionary lineage.

The Asselian-Sakmarian boundary is readily detectable based on fusulinids and conodonts in the Usolka section. The upper part of Bed 25 of the Usolka section yields the representative fusulinid assemblage of the upper zone of the Asselian Stage and the conodonts *Mesogondolella ex. gr. uralensis* and *M. pseudostriata* characterizing the lower part of the Tastubian Horizon. In materials sampled by Davydov from the same strata, Wardlaw and Schiappa found the conodont *Streptognathodus* aff. *S. barskovi*. In addition, we found the conodonts *S. aff. merrilli* and *M. uralensis* 1.5 metres above the base of Bed 26, confirming correctness of their proposed position of the Sakmarian lower boundary in the Kondurovsky section. Thus, the Usolka section

can function as a supplementary reference section for the Asselian-Sakmarian boundary.

As a result of the previous studies and substantial new biostratigraphic data, which allows interbasin correlation, the Kondurovsky section can serve effectively as the GSSP of the Sakmarian lower boundary.” (Chuvashov *et al.*, 2002, p. 325)

History of Asselian/Sakmarian Boundary Definition in Southern Urals

Karpinsky (1874, 1890) was the first to report an ammonoid fauna older than the typical Artinskian in the Sakmara River area, and designated the strata that contained this ammonoid fauna as the “lower belt of the Artinskian Stage”. Ruzhencev (1937) described this ammonoid fauna in detail and along with Gerasimov (1937) recognized that it belonged to the Permian System.

Ruzhencev (1951, 1954) and Ruzhencev and Bogoslovskaya (1978) established the Sakmarian Stage based on the first appearance of new ammonoid genera (*Synartinskia*, *Propopanoceras*, *Synuraloceras*, *Kargalites*, *Parametalegoceras*, *Thalassoceras*, *Uraloceras*, *Paragastrioceras*, *Metalegoceras*, *Medlicottia*, and *Crinites*). Six of these genera belong to three families that first appeared in Asselian time. *Synartinskia*, *Propopanoceras*, *Synuraloceras* occur in Russia only in the Sakmarian. Subsequently these authors recognized the extinction in the Sakmarian of many ammonoid genera that appeared in Orenburgian – Asselian time. Ruzhencev concluded that the Sakmarian was an important stage in ammonoid evolution, but not as significant as the period of Permian ammonoid evolution during the Asselian.

The Sakmarian Stage was proposed by Ruzhencev in 1936. However, at first the Sakmarian included everything between the top of the Orenburgian (latest Carboniferous) to approximately mid-Artinskian (Ruzhencev, 1936, 1938). Later, the Sakmarian was divided into two substages: the Asselian and Sakmarian (Ruzhencev, 1950) and subsequently both units became independent stages (Ruzhencev, 1954). Both ammonoids and fusulinids have served to make the Sakmarian well known and widely utilized in world stratigraphy (Ruzhencev, 1938, 1951; Rauser-Chernousova, 1940, 1949, 1965).

Although Ruzhencev did not share the concept of a stratotype, he described the Kondurovsky section as a type section for the Sakmarian Stage (Ruzhencev, 1950). His definition of Sakmarian was based on the evolution of ammonoids and fusulinids and related lithologic characteristics. He established the Asselian/Sakmarian boundary at the base of Karamurunskaya Formation because of the correlation of latest Asselian ammonoids occurring in the Shikhanian Horizon (Gerasimov, 1937) in the Shikhans (eastern margin of Russian Platform) to the underlying Uskalikskaya and Kurmainskaya Formations of the southern Urals (Ruzhencev, 1951). Typical Sakmarian ammonoids were found in the Sarabilskaya Formation. No ammonoids (except long-ranging *Agathiceras uralicum*) were described by Ruzhencev from the Karamurunskaya Formation. However, the Karamurunskaya Formation was included in the Sakmarian because of significant changes in lithofacies and fusulinid faunas.

Indeed, over most of the Russian Platform Asselian marine carbonates are replaced by sabkha evaporites of the Sakmarian. In the southern Urals (particularly in the Ural subbasin) predominantly carbonate sedimentation is replaced by predominantly

siliciclastic sedimentation (Ruzhencev, 1936, 1950; Snyder *et al.*, 1996).

The *Schwagerina* Horizon (in the sense of a stage) has been used in the Russian literature since the last century (Nikitin, 1886). The top of this “stage” is marked by the extinction of “*Schwagerina*” (= *Sphaeroschwagerina* in the modern sense). In the southern Urals it was believed that the *Sphaeroschwagerina* extinction occurred at the top of the Kurmainskaya Formation (Rauser-Chernousova, 1940, 1949, 1965). “*Pseudofusulina*” *moelleri* (= *Schwagerina moelleri* in the modern sense) was chosen as the index for the base of Sakmarian (Rauser-Chernousova, 1940, 1949, 1965). Therefore, the disappearance of *Sphaeroschwagerina* and appearance of *Schwagerina moelleri* at the base of the predominantly siliciclastic Karamurunskaya Formation marked the Asselian/Sakmarian boundary. This definition is widely accepted by most stratigraphers and geologists. However, our data show that the first appearance of the *Schwagerina moelleri* group actually occurs in the uppermost part of the Kurmainskaya Formation (see fusulinid section).

New ammonoids recovered from Bed 12 (172.5 MAB) in the Karamurunskaya Formation contain typical Sakmarian species including *Artinskia nalivkini*, *Propopanoceras postsimense*, *Sakmarites postcarbonarius*, *Neopronorites tenuis*, and *Paragastrioceras sintasense* (Schiappa, 1999).

Stratigraphy and Sedimentology of the Asselian-Sakmarian Boundary Units at Kondurovsky, Russia

The Kondurovsky section was originally described by Murchison *et al.* (1845), and Karpinsky (1874), with subsequent descriptions by Ruzhencev (1950; 1951), Rauser-Chernousova (1965) and Chuvasov *et al.* (1993). Ruzhencev and Rauser-Chernousova subdivided the section into several units: the Asselian Kurmainskaya Formation, the Sakmarian (Tastubian) Karamurunskaya and Sarabilskaya formations and the Sakmarian (Sterlitamakian) Maloikskaya and Kondurovskaya formations. Lowermost Artinskian strata are represented in this section.

Sedimentary Facies Description

The Cisuralian strata at Kondurovsky are divided into several major lithofacies, modified from Schiappa and Snyder, 1998 to reflect the mixed siliciclastic-carbonate nature of each lithofacies (Table 1). Sedimentologic, stratigraphic, and petrographic information indicates that the lithofacies reflect a mixed siliciclastic-carbonate, middle and outer ramp depositional environment consisting of fine to coarse silty to sandy limestones, occasional rudstones and floatstones, and very fine to coarse allochemic sandstones (Table 1).

Asselian-Sakmarian Facies Sequence **Asselian – Shikhanian Substage**

Shikhanian strata are exposed from the base of the section to 115 MAB at Kondurovsky section II and III; this corresponds to Beds 1 through the lowermost part of Bed 11. This interval is dominated by sM lithofacies interbedded with several 30 centimetres to 1 metre thick s/ssWPe and ssGe and 1.5 m RFL of Bed 8 and several metres thick RFL of Bed 10. The RFL lithofacies

of Bed 10 vary in thickness from one to several metres and contain large carbonate mud clasts, ranging from centimetres to metres in size (Fig. 2). This is probably related to lateral variation within the sediment gravity flow or perhaps this interval represents a succession of gravity flow deposits. A shallowing upward, outer ramp deposition is interpreted for this stratigraphic interval with the influx of event deposits possibly initiated by storms.

GSSP Boundary Interval

The boundary interval is characterized by a nearly continuous 7.5 metre monofacial succession of silty micrite (sM) from 114 – 121.5 MAB (Fig. 2).

Sakmarian - Lower Tastubian Substage

The basal units of the Sakmarian Stage (early Tastubian) are exposed from 115 to 220 MAB in sections II and III, Kondurovsky and are grouped into four lithofacies, sM, s/ssWPe, and ssGe. The sM facies dominates this interval, interbedded with numerous 30 centimetres to 1 metre thick s/ssWPe and ssGe units (Fig. 2). Outer to middle ramp deposition is interpreted for this stratigraphic interval with the incursion of event deposition, possibly driven by storms.

Depositional Environment

The Kondurovsky Asselian-Sakmarian succession reflects mixed siliciclastic-carbonate deposition on a storm-dominated, open, outer to middle ramp. The stratigraphic record does not contain any time-significant stratigraphic discontinuities, however a sea level lowstand may be represented by the RFL unit of Bed 10 (Fig. 2).

The lithofacies recognized at Kondurovsky reflect normal background, hemipelagic to pelagic sedimentation and episodic event deposition (see Table 1 for details). The sM and mS successions are interpreted as background deposition on the mid-outer ramp. The sM and mS lithofacies record continuous deposition with no evidence of subaerial exposure even during periods of relative sea level lowstands. This suggests that subsidence was uninterrupted, keeping up with eustasy, or that relative sea level changes were only a few tens of metres in magnitude. Ramps react differently to changes in relative sea level than rimmed platforms. A minor sea level fall will result in a basinward shift of depositional facies, leaving only the old inner ramp exposed, whereas on a flat-topped rimmed shelf, the whole platform interior will be exposed (Burchette and Wright, 1992).

The silty-sandy wackestone/packstone (s/ssWPe) and sandy grainstone (ssGe) lithofacies appear abruptly throughout the section. The clastic components (bioclasts and siliciclastic intraclasts) were derived from the inner to middle ramp and accumulated during event deposition. Systematic study of sedimentary structures was not conducted, but the majority of these event beds appear to lack sedimentary structures such as sole marks, hummocky cross stratification and wave ripples. This lack of sedimentary structures has made reconstruction of sedimentary dynamics difficult. However, the most plausible interpretation is that these event beds were storm-induced, accumulating below storm wave base. The offshore-directed bottom currents reflect contemporaneous trans-

FACIES

DESCRIPTION	
Carbonate-dominated	Siliciclastic-dominated
sM Light brown to brown silty micrite with pellets, sponge spicules, minor amounts of organic detritus; silt content up to approximately 25%	mS Micritic siltstone with sponge spicules and minor amounts of organic debris, carbonate mud content up to approximately 30%
s/ssWP Fossiliferous silty to sandy wackestone - packstone, fine to medium grained, with variable amounts of silt and fine sands, fusulinaceans, small foraminifera, bryozoans, pelmatozoan fragments, pelloids, and carbonate mud intraclasts. Bed thickness varies from a few centimetres to several metres.	aSS1 Very fine, structureless allochemic sandstone, interbedded with siltstone-mudstone with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix
ssG1 Fossiliferous sandy grainstone, fine to coarse grained, with fusulinaceans, small foraminifera, bryozoan, pelmatozoan, brachiopod and cephalopod fragments (allochems), pelloids, carbonate mud intraclasts, and variable amounts of extraclasts. Alignment of grains is visible in some samples. Laminar beds with lateral dimensions of a few centimetres to 0.75 metre in thickness.	aSS2 Fine allochemic sandstone with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix, grading apparent in some beds; parallel laminations common in most beds, thickness of a few centimetres, typically 15 to 30 cm, and up to 1.5 metres in amalgamated beds.
ssWPGe Wackestone-packstone-grainstone event beds ("e"); medium to coarse grained, locally graded and scoured bases with rare flute casts and load structure and rippled tops. Constituents same as s/ ssWP and ssG1. Beds vary from a few centimetres to several metres thick.	aSS3 Medium (coarse to fine) allochemic sandstone with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix, typically graded and parallel laminations; rippled tops common, but not ubiquitous; some exhibit erosive bases with flutes, tool marks, load structures and local hummocky cross stratification.
RFL Grey black and brown limestone pebble rudstone and floatstone, with minor fossiliferous debris (fusulinacean, pelmatozoan and bryozoan fragments) and carbonate mud clasts. Fine-grained micrite matrix. Carbonate mud clasts vary in size from 1 mm to several tens of cm, tend to be well rounded and oblate. Minor component of wackestone clasts with fusulinacean, small foraminifera and pelmatozoan fragments. Bed varies in thickness from 30 centimetres to several metres.	aSS4 Coarse grained allochemic sandstones to very fine pebble conglomerates with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix, thickness of several centimetres to 1 metre. Modifiers: m = micritic; applied to siliciclastics with < 50% carbonate, s/ss = silty/sandy; applied to carbonates with < 50% sand/silt, a = allochemic; carbonate bioclasts and lime clasts (Schiappa, 1999)

Table 1. Lithofacies description for the type Sakmarian Region, southern Ural Mountains, Russia (Schiappa, 1999).

port of pelmatozoan ossicles, bryozoan fragments, fusulinaceans, carbonate mud clasts and siliciclastics from near shore to deposition as event beds. There is no significant time reworking of the bioclastic debris. The unique occurrences of the rudstone/floatstone (RFL) units suggest that some major event triggered their deposition and that the mixed siliciclastic-carbonate ramp may have been steepened distally. A series of RFL beds occur at the same stratigraphic position in the Karamuruntai Range along the edge of the Sakmara River Valley (minimum of 10-30 km long along strike). Unlike the event beds, the RFL units are oligomicitic. These units are laterally extensive, typically 0.5 to a few metres thick and are characterized by well rounded, oblate carbonate mud clasts varying in size from 1 mm to several tens of cm (long dimension)

and minor fossiliferous debris (fusulinacean, pelmatozoan and bryozoan fragments) in a carbonate mud matrix. Storm deposition of these units is unlikely because they lack sedimentary structures and are oligomicitic as opposed to the polymictic nature typical of storm-induced strata. Storm induced strata are typically matrix-poor and better sorted than the mud-rich and poorly sorted RFL lithofacies. Therefore, two other possible interpretations for the origin of this lithofacies are suggested:

- 1). The RFL units were the result of slope collapse. During sea level lowstands, the exposed or shallower portion of the ramp is weakened by physical and chemical processes, and collapse of the distally steepened ramp results in limestone conglomerate accumulations (Burchette and Wright, 1992; Coniglio and Dix, 1992).

KONDUROVSKY SECTION
BIOSTRATIGRAPHY at
ASSELIAN-SAKMARIAN TRANSITION

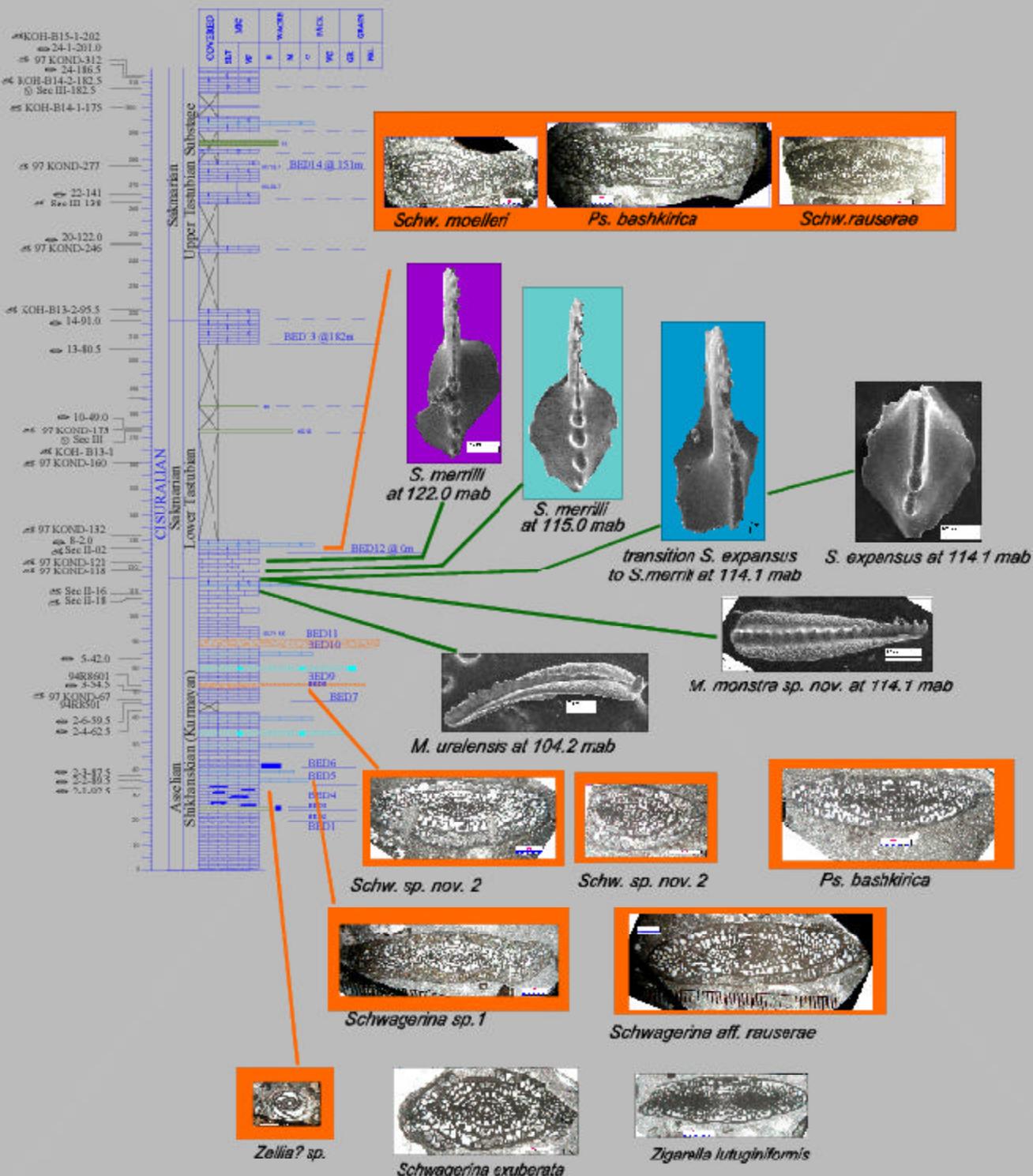


Figure 2. Detailed stratigraphic log and fossils for the Kondurovsky section, which is herein proposed as the base Sakmarian GSSP at 115 m above base.

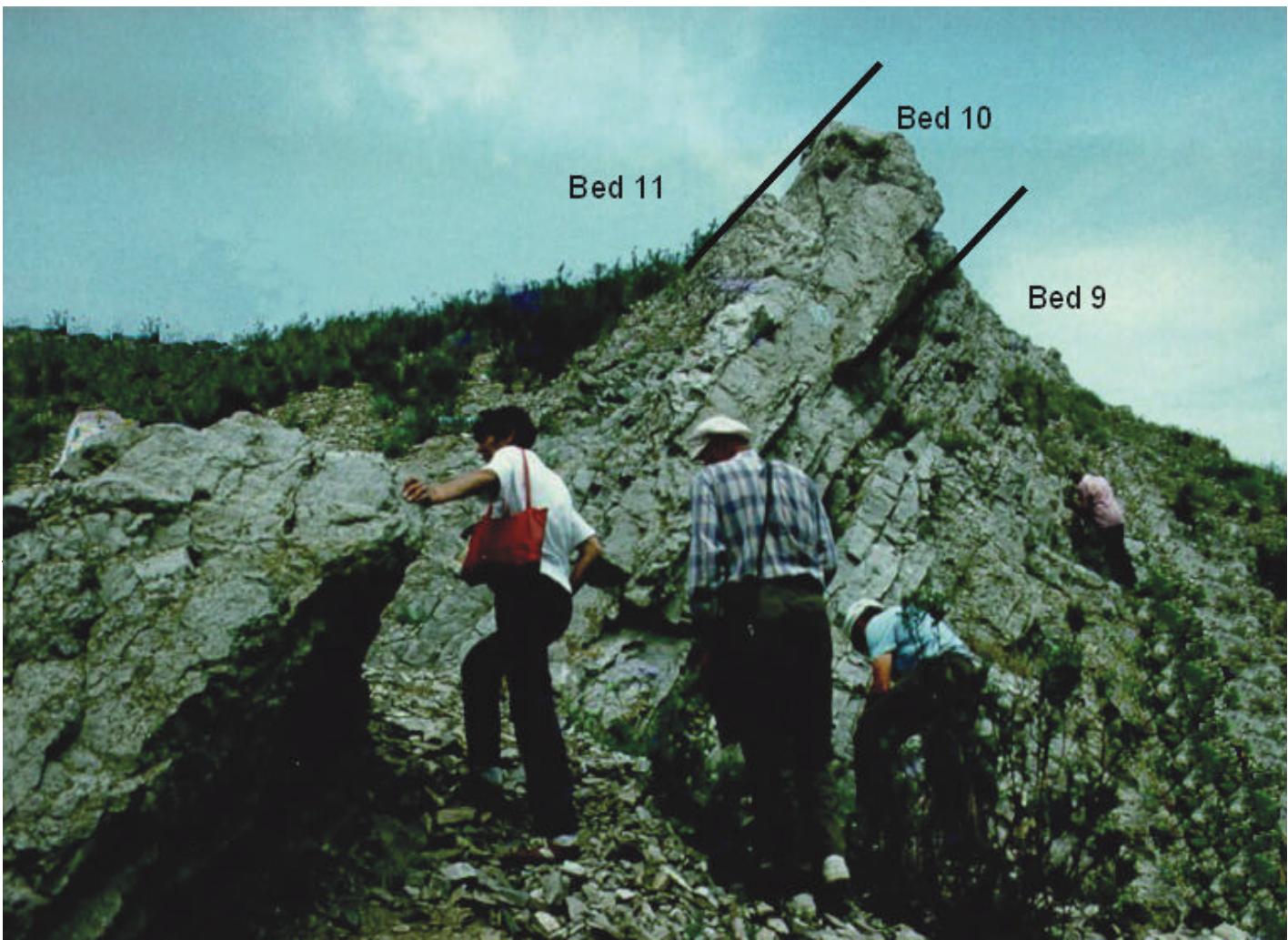


Figure 3. Photograph of Kondurovsky section; the base of bed 11 is the traditional boundary and the proposed GSSP is within bed 11 at 115 mab.

Accumulation of coarse limestone sediments is enhanced on distally steepened ramps. This interpretation for the mechanism of deposition would indicate that the Pre-Uralian ramp was distally steepened and not a homoclinal feature.

2). Another plausible scenario for production of these units is slope failure due to tectonism. Seismic activity may induce a slide and the carbonate mud blocks and clasts are rafted along in a mud slurry down a very low angle slope (Burchette and Wright, 1992; Coniglio and Dix, 1992). Because the entire southern Uralian region was tectonically active from Upper Carboniferous through late Cisuralian, it is possible that these units were seismically induced.

Fusulinid Biostratigraphy at the Asselian-Sakmarian Boundary in Kondurovsky Section

Fusulinids are important and most widely used as biostratigraphic tools for defining the base of the Sakmarian in the Russian Platform and Urals. Rauser-Chernousova in the Preurals (Rauser-Chernousova, 1940) and Shamov *et al.* (1936) in the subsurface of Russian Platform margin (Ishimbay oil-field area) proposed fusulinid biostratigraphic succession of the Asselian and Sakmarian. The boundary between these stages was placed at the base of the

horizon characterized by "*Pseudofusulina*" *moelleri* [= *Schwagerina moelleri* (Schellwien) in terms of modern taxonomy]. In the Preurals this boundary was defined between the Kuraminskaya Formation with advanced *Sphaeroschwagerina*, *Pseudofusulina* (*Ps. sulcata*, *Ps. declinata*), and *Schwagerina* (*S. idelbajevica*, *S. parajaponica*, *S. sphaerica* and *S. firma*) and the Karamurunskaya Formation with "*Pseudofusulina*" *moelleri* and related species. *Sphaeroschwagerina* is believed to have become extinct by the end of Asselian (Rauser-Chernousova, 1940, 1949, 1965). Ruzhencev (1951) and Rosovskaya (1952) listed the occurrence of "*Pseudofusulina* *moelleri*" in the Kuraminskaya Formation, suggesting that the unit should be included within the Sakmarian. However, these data have never been included in definition of the base of the Sakmarian.

Fusulinid studies during the last decade (Davydov *et al.*, 1995, 1997, 1998) have recognized several new aspects of fusulinid biostratigraphy at the Asselian-Sakmarian transition in the Kondurovsky section. In Beds 5-7, the assemblage is represented by typical late Asselian fusulinids including *Schwagerina firma* (Shamov), *S. idelbajevica* (Shamov), *S. parva* (Belyaev), *S. exuberata* (Shamov), *Schwagerina?* *declinata* (Korzhinskyi), *Schwagerina?* *composita* (Korzhinskyi), *Pseudofusulina sulcatiformis* Leven and Scherbovich, *Schwagerina?* *gareckyi*

(Scherbovich), *Zigarella lutuginiformis* (Rauser), and numerous and diverse *Rugosofusulina*. Two poorly preserved specimens of the Tethyan fusulinid ?*Zellia* sp. were also identified.

Within Bed 6 two specimens of *Schwagerina* sp. 1 which is related to the fusulinids of the *Schwagerina moelleri* (Schellwien) group were identified. At four and a half volutions, the test is relatively small (5 mm and 8.5 mm in length), and coiled smoothly throughout its growth. Irregular septal fluting is significant only in the inner volutions, and in the outer two volutions fluting is intense mostly in the polar regions. Only rare (one or two) phrenotheca were recognized in the outermost volution of these specimens.

In Bed 8 the fusulinid assemblage is generally the same as in the underlying beds. However, two specimens of *Schwagerina* sp. 2 (which will be described as a new species) were found. They are very similar and certainly very closely related to *Schwagerina moelleri* (Schellwien), resembling that species in shape of the test of all volutions: similar non-regular coiling – compact in the first three-four volution and high in the fourth-fifth and following volutions. However these specimens differ from true *Schwagerina moelleri* in smaller size of their corresponding volutions and less developed septal fluting, particularly around the tunnel area. These forms also have phrenotheca, but they are rare. Other specimens of this species were found near the base of Kurmainskaya Formation at the Novogafarovo section.

One additional specimen of *Schwagerina* sp. 2 was found in Bed 30 at the Aidaralash section. In 1986 this bed was correlated with the Sakmarian (Davydov & Popov, 1986, Davydov, 1986) because of the occurrence of this new species and particularly because of the occurrence of many taxa (first primitive *Darvasites*, and numerous new species of *Pseudofusulina* and *Rugosofusulina*) described from Sakmarian beds in the Darvaz region (Leven & Scherbovich, 1980). However, the base of Sakmarian at Aidaralash was later tentatively placed at the base of Bed 34.

In Bed 12 at Kondurovsky, the fusulinid assemblage includes some species that appear in older strata, but most of the Asselian *Schwagerina* species disappeared and *Schwagerina* sp. 2 becomes numerous in this bed. Typical *Schwagerina moelleri* (Schellwien) first appeared in Bed 12 of the Karamurinskaya Formation.

Based on these new data, we suggest that the nearest fusulinid evolutionary event to the base of the Sakmarian is the first appearance of *Schwagerina* sp. 2. So this would place the fusulinid biozonal boundary at 72 MAB, 42 metres below the Sakmarian GSSP at the Kondurovsky section. This fusulinid biozonal boundary can also be recognized at the base of Bed 30 in the Aidaralash Creek section and at 551 MAB in the Novogafarovo section and at the base of Bed 26 at Usolka.

Conodont Definition

It is proposed that the base of the Sakmarian Stage be defined by the first appearance of *Sweetognathus merrilli* Kozur in the evolutionary chronomorphocline of *Sweetognathus expansus* to *Sweetognathus merrilli*. *Sweetognathus expansus* evolved into *Sweetognathus merrilli* through short-lived transitional morphotypes that are best displayed in the Pa element showing the progressive development of clearly defined nodes along the carina, starting at both the posterior and anterior ends of the carina and developing toward the middle through time. *Sweetognathus merrilli* is recognized as the first form that displays clearly defined

nodes along the entire carina of the Pa element. This chronomorphocline is displayed in both the Kondurovka (ramp) and Usolka (basin) sections in the PreUralian Foredeep and the Eiss Limestone of the Bader Limestone in Kansas, Midcontinent, USA (Wardlaw *et al.*, 2003). The chronomorphocline is well displayed in Bed 11 of the Karamurinskaya Formation of the Kondurovka section, and the base of the Sakmarian is defined by the first appearance (FAD) of *Sweetognathus merrilli* at 115 m above the base of the section, just below the acme of the fusulinid *Schwagerina* sp. 2. The taxonomy and distributional controls of *Sweetognathus* species was recently summarized by Mei *et al.* (2002).

Numerical Age

The poor temporal resolution of the Late Pennsylvanian through Early Permian geologic time scale limits substantially our ability to clarify and correlate many aspects of late Paleozoic geologic history. Commonly cited time scales differ by as much as 14 Ma in the estimated age of the Pennsylvanian-Permian boundary, and vary by 500% in the inferred duration of various stages. Significant uncertainties in this part of the time scale arise because the numerical ages assigned to period and stage boundaries are based on linear interpolation between relatively sparse control points. Moreover, the existing control points were obtained from stratigraphic sections in different parts of the world, assigned positions in the time scale using several different taxa, and dated by several different radiometric techniques. Because many fundamental aspects of geologic research depend directly on the accuracy and precision of the geologic time scale, improving its age calibration is critical and requires a robust, well constrained, and internally consistent framework of biostratigraphic and geochronologic data for the Late Carboniferous through Early Permian. Numerous volcanic ash layers occur within the Upper Pennsylvanian and Cisuralian successions in Usolka and the Dal'ny Tulkas sections where most of these ash layers contain abundant, well-preserved conodonts and less well preserved radiolaria. The conodont-radiolaria-zircon bearing ashes in the Pennsylvanian and Cisuralian sections of the southern Urals provide an exceptional opportunity to develop a well constrained numerical time scale and Graphic Correlation Composite Standard Section for the Pennsylvanian-Cisuralian geological time period, and to examine rates of ecological processes in the late Paleozoic. Further, the Usolka section provides a significant reference section, not only for the base of the Sakmarian, but also for the Carboniferous/Permian boundary. It contains numerous ash layers that can be used to constrain both boundaries.

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Introduction

The following is paraphrased from Chuvashov *et al.* (2002). “A potential stratotype for the Artinskian lower boundary is located in the Kondurovsky section. The Artinskian Stage corresponds here to the Kondurovka Formation, which is about 100 metres thick and composed of alternating thick units (30-40 m) of sandy-clayey rocks and thin (1-9 m) limestone and limestone breccia units. Earlier, Chuvashov *et al.*, (1991) substantiated the position of the Artinskian lower boundary based on the first occurrence of the fusulinid *Pseudofusulina pedissequa* Viss. group in

the upper part of the section. The additional study allowed the boundary to be specified.

First Artinskian fusulinids *Pseudofusulina prima* Ogneva and Mor., *P. adelpha* (Raus.), and *P. irginaeformis* Shirink. are found in the detrital limestone interlayer of Bed 46, slightly below where a diverse assemblage of Sakmarian ammonoids occur. At 13 metres above the base of Bed 46, an interlayer of sandy limestone yields the first Artinskian cephalopods including *Neopronorites skvorzovi* Ruzh., *Artinskaia artiensis* (Gruen.), *Neoshumardites triceps* Ruzh., *Paragastrioceras tchernovi* Ruzh., and *Eothinites* sp. Sediments located 20 metres above this level include Artinskian ammonoids and the conodonts *Sweetognathus whitei* (Rhodes) and *Mesogondolella bisselli* (Clark and Behnken).

The Sakmarian-Artinskian boundary deposits are well represented in the Dal'ny Tulkus section, a counterpart of the Usolka section. The upper part of the Sakmarian Stage (Beds 28-31) at the Usolka River and Bed 18 at the Dal'ny Tulkus Section are composed of dark-coloured marl, argillite, and carbonate mudstone, or less commonly, detrital limestone with fusulinids, radiolarians, rare ammonoids, and bivalves. The upper part of the stage encloses fusulinids characteristic of the Sterlitamakian Horizon including *Pseudofusulina longa* Kir., *P. fortissima* Kir., *P. plicatissima* Raus., *P. urdalensis* Raus. and *P. urdalensis abnormis* Raus.

The Artinskian Stage begins with a member of brecciated landslide limestones (0-6 metres) overlain by the Tyul'kas Formation (Chuvashov *et al.*, 1990) mainly composed of calcareous argillites and marls with rare interbeds and concretions of carbonate mudstone and single layers of detrital limestone. The upper boundary of the formation is placed at the appearance of sandstone beds.

The brecciated limestone (Bed 19) located 1.5 metres above the formation base yields fusulinids including *P. callosa* Raus., *P. urdalensis* Raus., *P. karagasensis* Raus., *P. concavatus* Raus., *P. ex. gr. jurasanensis* Raus., and *P. uralensis* (Raus.) that characterize the Artinskian Stage. The fusulinids are accompanied by the conodont assemblage including *Mesogondolella bisselli* (Clark and Behnken), *Sweetognathus obliquidentatus* (Chern.), *N. ex.gr. ruzhencevi* Kozur and Movsh., and *Sweetognathus whitei* (Rhodes). The upper part of the brecciated layer includes the ammonoids *Popanoceras annae* Ruzh., *P. tchernowi* Max., and *Kargalites* sp.; *Neopronorites skvorzovi* (Tschern.), *Popanoceras annae* Ruzh., and *P. congregale* Ruzh. are found 3.5 m higher and characterize the lower part of the Artinskian Stage. The brecciated limestone of Bed 19 and several levels in the formation yielded the conodonts *Mesogondolella bisselli* (Clark and Behnken) and *Sweetognathus whitei* (Rhodes). Several levels within the Tyul'kas Formation at the Usolka section have yielded radiolarians of the *Enactinosphaera crassicalthrata-Quinqueremis arundinea* Zone. Given the above biostratigraphic characteristics, the Usolka Section could be considered as a supplementary reference section for the base of the Artinskian.

The historical stratotype of the Artinskian Stage is in the vicinity of the Arti Settlement along the Ufa River. Karpinskii (1891) who defined the stage studied abundant and diverse ammonoids in several exposures along the right-hand bank of the Ufa River between the Pristan' and Kordon villages. The so-called Gora Kashkabash exposure of sandstones and conglomerate is located in the same area. Ammonoids studied by Karpinskii were sampled from natural exposures and small quarries. The taxonomically diverse ammonoid assemblage from the indicated area was distinctly

more advanced than the Sakmarian one in terms of cephalopod evolution and this stimulated Karpinskii (1874) to define two belts with ammonoids; the lower at the Sakmara River and the upper at the Ufa River. The Artinskian ammonoid assemblage was so distinctly advanced that the corresponding name was extrapolated onto the entire sequence with ammonoids. Within the framework of the modern biostratigraphic scheme, the upper belt of Artinskian ammonoids at the Ufa River section is correlated with the Sarga and Sarana horizons. According to current views, the Sarana Horizon is referred to the Kungurian Stage."

Conodont Definition

The best section appears to be the Dal'ny Tulkas section in Russia, but a point cannot be defined precisely except that the definition will be the FAD of *Sweetognathus whitei* within a chronomorphocline from *S. binodosus*. Additional samples are required from the lower part of the section including from a trench below the current section base before a precise point can be defined. A sample from the Dal'ny Tulkas section (5045-8a) includes *S. binodosus* n.sp. and *S. whitei* (including specimens with well defined pustulose fields and others with poorly developed and irregular fields). In a lower sample (5045-4a), *Sweetognathus obliquidentatus* and *S. sulcatus* co-occur; these taxa represent a near homeomorph of *Neostreptognathodus* by developing a shallow and partial sulcus separating the nodes. *Sweetognathus sulcatus* was previously reported from the Cerro Alto Formation in the Franklin Mountains of West Texas in an interval associated with *Diplognathodus stevensi* and *S. binodosus* n.sp. (his *S. inornatus*). It is possible that these neostreptognathodid-like elements represent evolutionary experimentation during the speciation event leading to *S. whitei* in which the bilobed nodes of *S. binodosus* n. sp. separate in a very irregular fashion. This is reminiscent of the irregular nodes of *S. merrilli* in the lower part of its range and of *Sweetognathus clarki* (which includes *S. transitus*, *S. ruzhencevi*, *S. tschuvashovi* in synonymy) during the evolution of *Neostreptognathodus pequopensis*.

The defining chronomorphocline can be recognized also in the lower Great Bear Cape Formation on southwestern Ellesmere Island, Sverdrup Basin, Canadian Arctic (Henderson, 1988; Beauchamp and Henderson, 1994, Mei *et al.*, 2002) and in the Schroyer to Florence limestones of the Chase Group in Kansas, USA (Wardlaw *et al.*, 2003).

Potential base-Kungurian GSSP

Introduction

The following is paraphrased from Chuvashov *et al.* (2002). "The stratotype of the Kungurian Stage was not defined when the stage itself was established (Stuckenbergs, 1890). Later on, the carbonate-sulphate section exposed along the Sylva River upstream of the town of Kungur was arbitrarily accepted for the stratotype. In line with a new position of the Kungurian lower boundary at the base of the Sarana Horizon (Chuvashov *et al.*, 1999), the stratotype section in this area spans the following units (from the base upward): (1) the Sarana Horizon including the Sylva Formation of reefal limestones and its lateral equivalent Shurta Formation composed of marls and clayey limestone, (2) the Filippovskian Horizon

including clayey limestone, marl, dolomitic marl, and argillite, (3) the Iren' Horizon consisting of three carbonate and four sulphate members. The last horizon is represented in the stratotype section only by three members including in ascending order the Ledyanaya Peshchera (gypsum-anhydrite), Nevolino (dolostone), and Demidkovo (gypsum-anhydrite) members.

A disadvantage of the section is the poor paleontologic characteristics of the limy Kamai Formation underlying the Sarana Horizon; it contains only small foraminifers, bryozoans, and brachiopods inappropriate for age determination. Nevertheless, many features indicate that the formation corresponds to the Sarga Horizon.

The Shurtan Formation and lateral facies of Sylva bioclastic limestone yield conodonts of the *Neostreptognathodus pnevi* Kozur and Movsh. Zone. The section under discussion could be considered as the stage stratotype, but it does not meet requirements of the GSSP project, according to which a substantial paleontological characteristic is needed for the underlying stratigraphic unit. Thus, another section of the Artinskian-Kungurian boundary deposits located near the Mechetlino settlement at the Yuryuzan' River was selected for a probable stratotype of the Kungurian lower boundary. Units exposed here are the upper part of the Gabdrashitovo Formation, overlying Sarana layers, and Ismagilovo Member of carbonate mudstone referred to the Filippovskoe Horizon.

Previously, the section was repeatedly described (Chuvashov *et al.*, 1990, Chuvashov and Chernykh, 2000) and a description of key parts of the section as exposed along the right bank of the Yuryuzan' River downstream of the Mechetlino settlement follows. Beds 1-18 are Artinskian Stage, Sarga Horizon, Gabdrashitovo Formation. Bed 13 comprises dark grey argillite with irregularly alternating thin layers of fine-grained sandstone and includes ammonoids and conodonts including *Neopronorites permicus* (Tchern.), *Medlicottia orbigniana* (Vern.), *Uraloceras fedorowi* (Karp), *Sweetognathus aff. whitei* (Rhodes), and *Stepanovites* sp. (Sb and Sc elements), all characteristic of the Sarga Horizon. Bed 15 is an olistostrome with a matrix comprising fusulinids, solitary rugose corals, brachiopods, bryozoa, crinoids, and calcareous algae. The fusulinid assemblage includes abundant *Pseudofusulina kutkanensis* Raus., *P. aff. kusjanovi* Raus., *P. franklinensis* Raus., *P. postsolida* Tchuv., *P. makarovi* Raus., and *Parafusulina solidissima* Raus. Bed 17 is composed of highly calcareous, dark grey argillite with grey, calcareous, fine-grained sandstone. This bed has yielded the conodonts *Neostreptognathodus kamajensis* Chern., *N. pequopensis* Behnken, *N. aff. ruzhencevi* Kozur, and *Sweetognathus ex. gr. whitei* (Rhodes) represented by aberrant specimens with reduced carinae. Bed 18 is a highly calcareous, yellowish-grey sandstone with thin interbeds of greenish-grey argillite and abundant plant detritus, but lacks conodonts and fusulinids. Beds 19-20 are Kungurian Stage, Sarana Horizon, Mysovsk Formation, Transitional Member. Bed 19 comprises steel-grey carbonate mudstone with an admixture of extremely fine-grained clastics and rare argillite interbeds. The basal part includes *Neostreptognathodus clinei* Behnken, *N. pnevi* Kozur and Movsh., *N. kamajensis* Chern., *N. pequopensis* Behnken, and *Stepanovites* sp. (M element). Bed 20 is a yellowish-grey, thin-bedded, fine-grained, calcareous sandstone with thin argillite interbeds and abundant plant debris. Beds 21-22 are Filippovskoe Horizon, Mysovsk Formation, Ismagilovo Member. Bed 21 is composed of

steel-grey carbonate mudstone and rare interbeds of microclastic limestone that yield the ostracod *Paraparchites burkemis* (Mart.) characteristic of the *Paraparchites humerosus* Zone and the conodonts *Neostreptognathodus pequopensis* Behnken, *N. pnevi* Kozur and Movsh., *N. aff. ruzhencevi* Kozur, and *N. tschuvashovi* Kozur."

Conodont Definition

The best section appears to be the Metchetlino section or a nearby section in Russia, but a point cannot be defined precisely except that the definition will be the FAD of *Neostreptognathodus pnevi* within a chronomorphocline from advanced *Neostreptognathodus pequopensis*. Bed 17 yields *N. kamajensis* and *N. pequopensis* and bed 19 includes *N. kamajensis*, *N. pequopensis*, *N. clinei*, and *N. pnevi*. Bed 18 is a sandy lithofacies that has not yielded conodonts. A laterally equivalent section includes limestone facies within Bed 18; additional samples from this section are required from bed 18 and 19 in this section near the Metchetlino section before a precise point can be defined.

The defining chronomorphocline can also be recognized in the upper Great Bear Cape Formation and upper Trappers Cove Formation on southwestern Ellesmere Island, Sverdrup Basin, Canadian Arctic (Henderson, 1988; Beauchamp and Henderson, 1994, Mei *et al.*, 2002).

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radiolarian presence in sediments of Mid and Early Carboniferous age, nor in sediments of Late Permian age here. Distribution of radiolarians to the north from the named areas can be assumed, but is not yet proved. Currently there are no distribution data for radiolarians in Upper Paleozoic sediments in the extensive territory of the Eastern slope of Urals and Zauralie (Trans-Urals). In adjacent regions it is possible to name the territory Northern PreCaspian where Late Paleozoic sections with radiolarians occur frequently, starting from Mid-Carboniferous to the Artinskian Stage inclusive (Afanasieva, Zamilatskaya, 1993; Afanasieva, Amon, 2002). In Late Paleozoic sections of the Russian platform, Western Siberia and Central Asia, radiolarians of Permian age are not as yet recognized.

Radiolarian abundance varies within different facies. Their fossil remains frequently occur in thin-bedded, fine-grained terrigenous rocks, their abundance is reduced in medium- and coarse-grained siliciclastics, and they are almost completely absent in clean reef limestones and dolostone. Radiolarians appeared in Late Paleozoic Preduralian Sea coincident with basin formation during the mid-Carboniferous when a relatively deep-water marine basin with clayey-siliceous sediments grading upward into sandy-argillaceous flysch-like sediments during the Late Carboniferous (Chuvashov *et al.*, 1999; Amon, 1999).

The east border of radiolarian distribution served as the coastal zone, which currently is only fragmentary in the Preduralie. The western border of radiolarian distribution is defined by a linear trend of bioherms up to, and including Artinskian time. During Kungurian time and later this border was a zone of increased water salinity. At the western and eastern limits of the area of radiolarian distribution they exhibit sporadic occurrences during the Permian and are frequently absent for significant stratigraphic intervals. Sections of the east slope of the Preduralian foredeep in a thin flysch zone and depressional zone show the most complete distribution of radiolarians (Chuvashov *et al.*, 1999).

Radiolarians began to be used for practical Lower Permian stratigraphy in the region after the detailed research made by Drs. B. Nazarov and A. Ormiston (Nazarov, Ormiston, 1985, 1993, 1990; Nazarov, 1988). Local radiolarian faunas or biozones were singled out and described by B. Nazarov in the territory of the Western slope of Southern Urals, in the Southern part of the Preduralian foredeep and in the Southern Preduralie. The stratotypes for these faunas or biozones are located in an extended strip of thick Upper Carboniferous - Permian sedimentary rocks in the Orenburg-Aktyubinsk region from Aidaralash River in the south up to Malaya Syuren in the north. Late Carboniferous (Gzhelian Stage) and Lower Permian (Asselian, Sakmarian, Artinskian Stages) radiolarian associations or complexes are here described from rare continuous sections and more often from fragmentary sections. Reference sections are located in outcrops along the following rivers and creeks: Ural, Sakmara, Akma, M. Syuren, Akberda, Alimbet, Chiili, Sintas, Zhaman-Kargala, Ortash, Assel, and Uskalyk. The exact stratigraphic position of several radiolarian layers within the preliminary radiolarian biozonation scheme developed by B. Nazarov, was not absolutely correct. Nazarov did not trace the lateral limits of geographical distribution of his biozones and was not clear how far they could be traced outside of the stratotype area.

In the present report we provide the results of additional

Radiolarian biostratigraphy of the Sakmarian Stage (Lower Permian) in Southern Urals

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Abstract

In sediments of Lower Permian Sakmarian Stage in the Southern Urals region, five radiolarian biozones are revealed in stratigraphic succession from the top, down: *Rectotormentum fornicatum*, *Camptoalatus monopterygius*, *Entactinia pycnoclada* – *Tomentum circumfusum*, *Helioentactinia ikka* – *Haplodiacanthus perforatus*, *Copicyntra* sp. / *Tetragregnon vimineum* – *Copieillintra diploacantha*. The characteristics, geographic distribution, correlation possibilities, and problems of these are discussed.

Introduction

In the Upper Paleozoic deposits of the Uralian region, radiolarians are largely restricted to the Southern Urals and Southern Preduralie (Cis-Urals), and to a smaller degree they are found in Mid Urals and Mid Preduralie areas (Nazarov, 1988; Nazarov, Ormiston, 1985, 1993; Amon, 1999; Chuvashov *et al.*, 1999; Afanasieva, Amon, 2002) (fig. 1). In Southern and Mid Preduralie radiolarians are found in various rocks of Late Carboniferous and Early Permian age (ranging from Kasimovian up to the Kungurian Stage), but there are no reliable data on

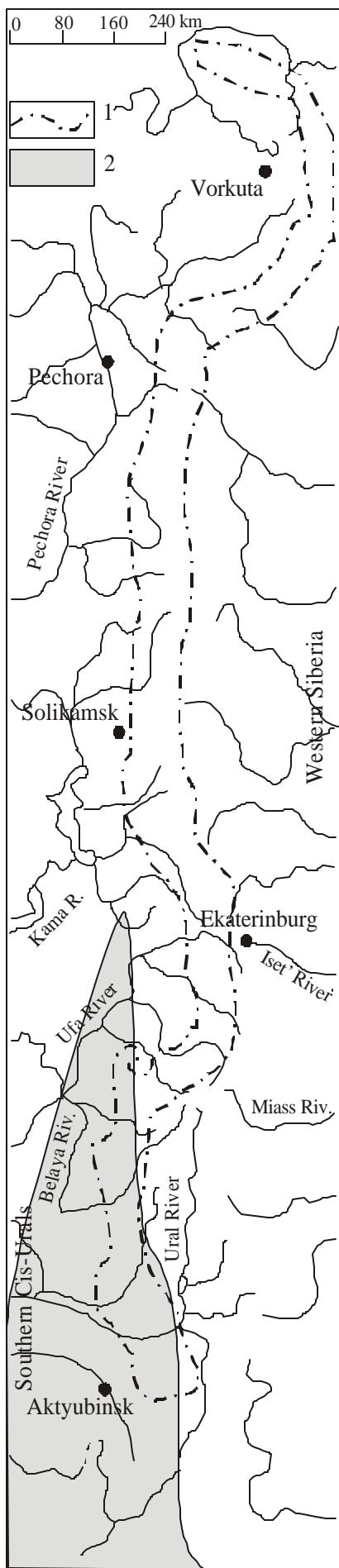


Fig. 1. Map-scheme of radiolarian distribution during the Late Carboniferous – Early Permian sediments in the territory of the Urals. 1 – Recent borders of Uralian mountain country; 2 – a field of radiolarian distribution. After Amon, 1999.

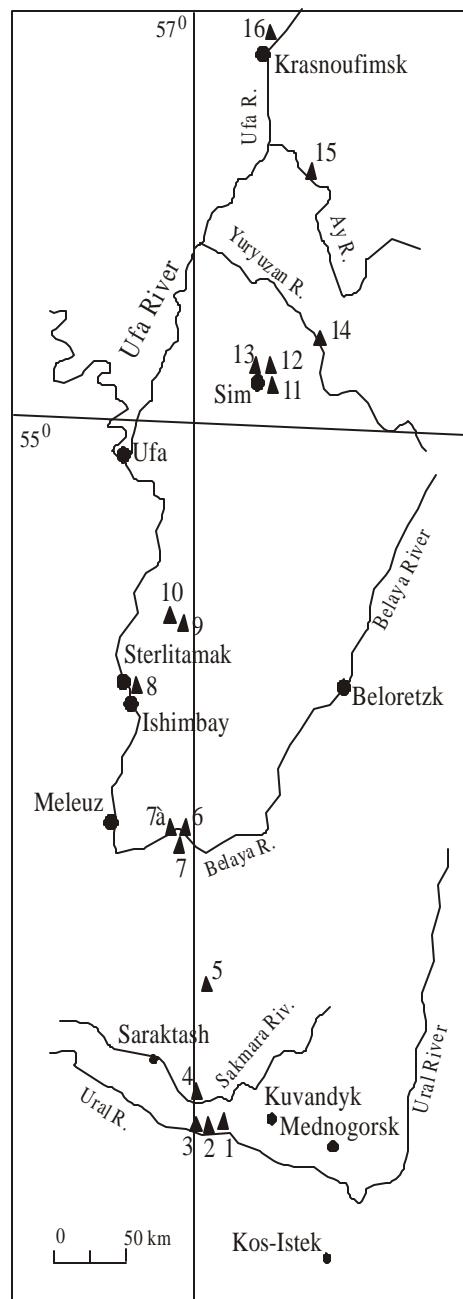


Fig. 2. Location of Late Carboniferous – Early Permian reference sections.
1 – Donskoy; 2 – Nikolsky; 3 – Verkhneozerny; 4 – Kondurovsky; 5 – Shafeevka; 6 – Siryat; 7 – Nizhnee Bikkuzino; 7а – Ishtuganovo; 8 – Sterlitamaksian shikhanes; 9 – Usolka; 10 – Tyulkas; 11 – Sim Town; 12 – Sim railway station; 13 – Bianka; 14 – Yuryuzan; 15 – Alegazovo; 16 – Alexandrovsky. After Amon, 1999.

research, which have been made by us in stratotype areas and in more northern areas of the Southern and Mid Preduralie in Bashkiria (fig. 2). According to these new data derived from the study of radiolarians, and also due to results of the study of accompanying fossils (mainly fusulinids and conodonts – Chuvalov *et al.*, 2002), we specify more exactly the stratigraphic positions of radiolarian biozones, correlate them with zones based on other fossil groups (see text-table 1) and clear up the limits of their geographical distribution. Only the radiolarian associations of the Sakmarian Stage are described briefly herein.

*Layers and radiolarian complex with *Copicynta* sp.*

The fauna was singled out by B. Nazarov in the highest layers of the Uskalyksk Suite and in limestones of the Kurmainsk Suite (Asselian Stage), as well as in rocks of the

Stage	Horizon	Foraminifers	Conodonts	Radiolarians
Kurgurian	Solikamskian	-	-	-
	Irenskian	<i>Parafusulina aff. solidissima</i> – <i>Nodosaria sexangulata</i>	<i>Neostreptognathodus pnevi</i> – <i>Stepanovires sp.</i>	<i>Ruzhencevisponges uralicus</i>
	Philippovskian	<i>Nodosaria pugioidea</i>	<i>Neostreptognathodus clinei</i> – <i>N. cf. prayi</i>	
	Saraninskian	<i>Hemigordius saranaensis</i>	<i>Neostreptognathodus pnevi</i> – <i>N. cf. prayi</i> – <i>N. clinei</i> – <i>Stepanovires sp.</i>	
Artinskian	Sarginskian	<i>Parafusulina solidissima</i>	<i>Neostreptognathodus pequopensis</i>	<i>Polyentactinia lautitia</i>
	Irginskian	<i>Pseudofusulina juresanensis</i> – <i>Eoparafulina lutugini</i>	<i>Neostreptognathodus clarki</i> – <i>N. ruzhencevi</i>	<i>Tetracircinata reconda</i>
	Burtzevskian	<i>Pseudofusulina pedissequa</i> – <i>Eoparafulina lutugini</i>	<i>Sweetognathus whitei</i>	<i>Entactinosphaera crassicalthra</i> – <i>Quinqueremis arundinea</i>
Sakmarian	Sterlitamakskian	<i>Parafusulina urdalensis</i>	<i>Sweetognathus primus</i>	<i>Rectotomentum fornicatum</i>
	Tastubskian	<i>Pseudofusulina verneuili</i> – <i>Eoparafulina tschernyshcewi</i>	<i>Diplognathodus aff. stevensi</i> – <i>Sweetognathus aff. merrilli</i>	<i>Campoalatus monopterygius</i>
		<i>Pseudofusulina moelleri</i>	<i>Mesogondolella lacerta</i> – <i>M. uralensis</i>	<i>Entactinia pycnoclada</i> – <i>Tomentum circumfusum</i>
	Shikhanskian	<i>Sphaeroschwagerina sphaerica</i> – <i>Globifusulina firma</i>	<i>Streptognathodus postfusus</i> – <i>S. barskovi</i>	<i>Helioentactinia ikka</i> – <i>Haplodiacanthus perforatus</i>
		<i>Pseudoschwagerina uddeni</i>	<i>Streptognathodus constrictus</i>	<i>Tetragregnon vimineum</i> – <i>Copiellintra diploacantha*</i>
Asselian	Kholodnolozhskian	<i>Globifusulina nux</i>	<i>Streptognathodus postfusus</i> – <i>S. cristellaris</i>	<i>Copicynta sp.</i>
		<i>Sphaeroschwagerina fusiformis</i>	<i>Streptognathodus glenisteri</i> – <i>S. isolatus</i>	<i>Tomentidae</i>
		<i>Bosbytauella bosbytauensis</i> – <i>Ikella robusta</i>	<i>Streptognathodus wabaunsensis</i>	<i>Haplodiacanthus anfractus*</i>
	Nikolskian		<i>Streptognathodus longilatus</i>	<i>Latentifistula crux</i>

Dashed line shows problem borders, by light grey - the biozones having distribution only in areas of stratotypes. The asterisk marks radiolarian biozones, for the first time singled out by us (Amon, 1999).

Text-table 1. Biostratigraphy of Lower Permian deposits in Southern Urals and Preduralie based on forams, conodonts, radiolarians. After Nazarov, 1988; Chuvashov *et al.*, 1999, 2002; Amon, 1999; Chernykh, 2002.

Radiolarian species	Layers with complex		
	<i>H. anfractus</i>	<i>T. vimineum</i> - <i>C. diploacantha</i>	<i>T. reconda</i>
<u>Stauroxonic radiolarians</u>			
1. <i>Tomentum circumfusum</i> Nazarov and Ormiston	F	F	
2. <i>Tetratormentum narthecium</i> Nazarov and Ormiston		F	
3. <i>Latentidiota</i> sp.		F	
4. <i>L. semilamina</i> Nazarov		F	
5. <i>Ruzhencevisponges</i> aff. <i>laqueus</i> Nazarov and Ormiston	F		
6. <i>R. aktastiensis</i> Nazarov and Ormiston		F	
7. <i>R. cataphractus</i> Nazarov and Ormiston		F	
8. <i>Nazarovisponges</i> sp.		F	
9. <i>N. permicum</i> Kozur		F	
10. <i>Latentifistula</i> sp.		F	
11. <i>L. valdeinepta</i> Nazarov and Ormiston		F	
12. <i>L. astricta</i> Nazarov		F	
13. <i>Latentibifistula triacanthophora</i> Nazarov and Ormiston		F	
14. <i>Quadriremis gliptocauda</i> Nazarov and Ormiston		F	
15. <i>Tomentidae</i> gen. et sp. indet.	A		
16. <i>Latentifistulidae</i> gen. et sp. indet.	F		
<u>Spherical radiolarians</u>	A	A	A
1. <i>Entactinia</i> sp.		R	F
2. <i>E. praematura</i> Nazarov	C		
3. <i>E. dolichoacus</i> Nazarov	C	F	
4. <i>E. austrouralica</i> Nazarov	F	F	
5. <i>E. spinifera</i> Amon and Braun			R
6. <i>E. densissima</i> Nazarov and Ormiston			F
7. <i>E. aff. pycnoclada</i> Nazarov and Ormiston		F	
8. <i>Astroentactinia</i> sp.			F
9. <i>A. inscita</i> Nazarov		F	
10. <i>A. mendosa</i> Nazarov		F	
11. <i>A. luxuria</i> Nazarov and Ormiston		F	F
12. <i>Entactinosphaera</i> sp.		F	
13. <i>E. calthra</i> Nazarov	R	F	
14. <i>E. aerigma</i> Nazarov	F		
15. <i>E. cf. crassicathrata</i> Nazarov and Ormiston		F	
16. <i>Helioentactinia</i> sp.			R
17. <i>H. bieoxsphaera</i> Nazarov	A	C	C
18. <i>H. ikka</i> Nazarov and Ormiston	R		
19. <i>Tetragregnon sphaericus</i> Nazarov	F		
20. <i>T. pyramidatus</i> Nazarov	F		
21. <i>T. nitidus</i> Nazarov and Ormiston		F	
22. <i>T. vimineum</i> Amon and Braun		R	
23. <i>Tetracircinata reconda</i> Nazarov and Ormiston			F
24. <i>Spongientactinia</i> sp.			F
25. <i>S. simensis</i> Amon and Braun			F
26. <i>Polyentactinia</i> sp.		F	F
27. <i>P. multifora</i> Nazarov	F	F	
28. <i>P. centrata</i> Nazarov and Ormiston		F	
29. <i>Pluristratoentactinia</i>			F
30. <i>Copicyntra</i> sp.		R	F
31. <i>C. acilaxa</i> Nazarov	C	F	
32. <i>C. trigona</i> Nazarov	F	F	
33. <i>C. phymatodonta</i> Nazarov and Ormiston	F	F	F
34. <i>C. cuspidata</i> Nazarov and Ormiston		F	C
35. <i>C. simulens</i> Nazarov and Ormiston			F
36. <i>Copiellintra</i> sp.		R	
37. <i>Copiellintra diploacantha</i> Nazarov and Ormiston	F	F	R
38. <i>Entactinidae</i> gen. et sp. indet.	F		
<u>Albaillellids</u>	R	C	
1. <i>Haplodiacycanthus</i> sp.	F	F	
2. <i>H. anfractus</i> Nazarov and Rudenko	R	F	
3. <i>H. perforatus</i> (Kozur)		R	
4. <i>H. permicus</i> (Kozur)		F	
5. <i>Parafollicucillus sakmarensis</i> Kozur	F	R	
5. <i>P. nazarovi</i> Kozur	F	R	
6. <i>Albaillella</i> sp.	F	F	
7. <i>Pseudoalbaillella globosa</i> Ishiga and Imoto	F		
8. <i>P. bulbosa</i> Ishiga	F		
9. <i>P. u-forma</i> Holdsworth and Jones	F		
10. <i>Albaillellidae</i> gen. et sp. indet.	F		

Alphabetic codes of relative quantitative variety of species: F – few, 0.1-5.0 % of general species number in sample; R – rare, 5.0-10.0 %; C – common, 10.0-40.0%; A – abundant, more than 40.0 %.

Text-table 2. The characteristics of distribution of radiolarians in biozones.

Karamurunsk Suite and in the lower part of the Sarabilsk Suite (Sakmarian Stage). We observed this complex in the Karamurunsk Suite in the Kodurovsky reference section (fig. 3). The complex is represented mostly by spherical recrystallized radiolarian skeletons belonging to the genera *Copicyntra* and *Copiellintra*. There are recrystallized blade fragments of representatives of Latentifistulidae and convex subtriangular representatives of Tormentidae less often.

B. Nazarov (1988) indicated that the upper boundary of layers with *Copicyntra* sp. were positioned quite conventionally in the upper part of the Sarabilsk Suites (Sakmarian Stage), somewhere in the middle of *Pseudofusulina verneuili* Zone. According to a more modern view on regional stratigraphy of the Orenburg area, the stratigraphic position of this layer corresponds to the Tastubskian horizon of the Sakmarian Stage and, probably, to some upper part of the Shikhanskian horizon of the Asselian Stage. Our data indicates that the stratigraphic interval with *Copicyntra* sp. is equivalent to part of the range of the *Sphaeroschwagerina sphaerica* – *Pseudofusulina firma* fusulinid zone and to the *Pseudofusulina moelleri* Zone, and also to the conodont zones, *Mesogondolella pseudostriata* and *Mesogondolella uralensis* (according to the zonal scale from Chuvashov et al., 2002).

The composition of the radiolarian fauna associated with *Copicyntra* sp. includes *Copicyntra* sp. indet., *Copiellintra* sp. indet., Latentifistulidae gen. et sp. indet., and Tormentidae gen. et sp. indet. Layers with *Copicyntra* sp. are traced into the Orenburg Preduralie territory and into more northern areas of Bashkiria. A diagnostic feature of this biozone is the abundance of *Copicyntra* sp.

It is necessary to remark that representatives of the *Copicyntra* genus are rather widely distributed in many sections of Lower Permian sediments in the Southern Preduralie and frequently occur in many radiolarian biozones. Skeletons of *Copicyntra* are massive enough and possess a significant number (up to 15) of densely packed concentrically arranged inner shells, connected by numerous crosspieces and columns, such that they are resistant to dissolution. This characteristic means that layers with *Copicyntra* sp. may be untrustworthy for biozone recognition because diagenetic and catagenetic recrystallization of radiolarian skeletons can affect any stratigraphically significant radiolarian association. Recrystallized skeletons of *Copicyntra* will obviously prevail in such modified complexes, which can lead to erroneous conclusions.

Layers and complex with Tetragregnon vimineum – Copiellintra diploacantha

This complex is a stratigraphic and facial analogue to layers with *Copicyntra* sp. in sections of the Orenburg Preduralie. The stratotype for this new radiolarian biozone is the Kondurovsky section located on the right bank of the Sakmara River near the Kondurovka railway station (Amon, 1999), where a series of outcrops forms an excellent stratotype section for the Cisuralian Sakmarian Stage (Chuvashov et al., 2002). This radiolarian complex is established in samples taken from the lower part of the Karamurunsk Suite (fig. 3). The most informative samples not only correlate with the conodont zone *Mesogondolella lacerta* – *M. uralensis* and the fusulinid zone *Pseudofusulina moelleri*,

but also radiolarians are identified in the same sample with the conodonts *Mesogondolella parafoliosa* Chern., *M. longifiliosa* Chernykh, and *M. lacerta* Chernykh.

Diagnostic species associated with *Tetragregnon vimineum* – *Copiellintra diploacantha* (plate I) are *Tetragregnon vimineum* Amon and Braun, *Helioentactinia biexosphaera* Nazarov and Ormiston, *Copicyntra* sp., *C. cuspidata* Nazarov and Ormiston, *C. phymatodonta* Nazarov and Ormiston, *Copiellintra* sp., *C. diploacantha* Nazarov and Ormiston. The complex is traced into sections of the Orenburg Preduralie, but not established in territories of the Aktyubinsk Preduralie and in more northern areas of Bashkiria. The general characteristics regarding the frequency of occurrence of species is provided in text-table 2.

Layers and complex with Helioentactinia ikka – Haplodiacanthus perforatus

This complex was established by B. Nazarov in the upper part of the Sarabilsk Suites in Orenburg-Aktyubinsk Preduralie. This part of the Sarabilsk Suite contains the fusulinid zone *Pseudofusulina verneuili*. According to our data the Sarabilsk Suite interval (bedded and pelitic limestone with thin interbedded sandstone, argillite and organogenic-detritic limestone) is the upper part of the regional Tastubskian horizon of the Sakmarian Stage and is equivalent to the fusulinid zone *Pseudofusulina verneuili* – *Eoparafusulina tschernyshcevi* and to the conodont zone *Mesogondolella lacerta* – *M. uralensis* (Chuvashov et al., 2002). Recent additional study of the Verkhneozerny reference section, located on the right bank of the Ural River (Leven et al., 2002), has shown that, according to foraminifers, the Sarabilsk Suite of the Tastubskian horizon in this section corresponds to the *Pseudofusulina verneuili* Zone, but according to conodonts, the general picture is not quite clear. Reimers (Leven et al., 2002) reports that at the highest levels of the Sarabilsk Suite in the Verkhneozerny section (where for the first time, radiolarians of the complex *Helioentactinia ikka* – *Haplodiacanthus perforatus* have been described by B. Nazarov) two conodont species *Mesogondolella bisselli* Clark and Behnken and *M. striata* Chernykh co-occur. According to these conodonts, it is possible to simultaneously attribute the upper part of the Sarabilsk Suites as both the Shikhanskian horizon and the Sterlitamakskian horizon.

Typical, diagnostic species of this complex are (plate I) *Haplodiacanthus perforatus* (Kozur), *H. permicus* (Kozur), *Parafollicucullus sakmarensis* Kozur, *P. nazarovi* Kozur, *Albaillella permica* (Kozur), *Helioentactinia ikka* Nazarov and Ormiston. Outside the stratotype district, its distribution is traced by us into more northern areas, for example in the Sim reference section and the Krasnousolsky reference section (Bashkiria).

Layers and complex with Entactinia pycnoclada – Tormentum circumfusum

The complex is singled out by B. Nazarov in the lower and middle parts of the Maloiksk Suites of the Orenburg-Aktyubinsk Preduralie. According to our data this interval of the Maloiksk Suites (interbedded sandstone, argillite and aleurolites with thin

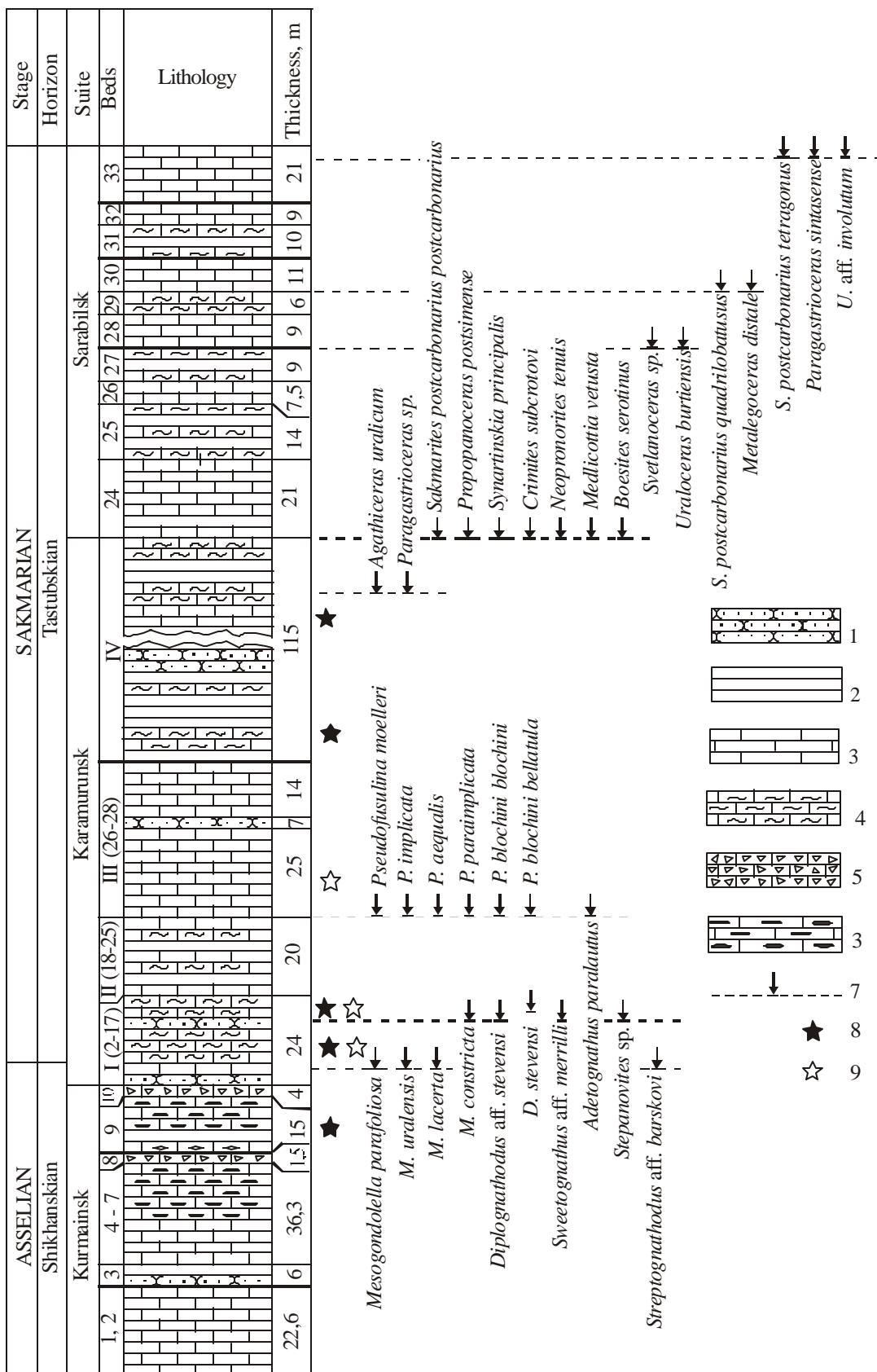


Fig. 3. Stratigraphic schematic of Asselian-Sakmarian part of Kondurovsky reference section.

1 – sandstone; 2 – argillite; 3 – limestone; 4 – marlstone; 5 – brecciated lamellar limestone; 6 – limestone with chert concretions; 7 – levels of first appearance of conodonts, fusulinids, ammonoids; 8 – level with radiolarians of *Copicyntra* sp. complex; 9 – level with radiolarians of *Tetragregnon vimineum* – *Copiellintra diploacantha* complex. After Chuvashov *et al.*, 2002, with additions.

layers of breccia and lenses of organogenic-detrital limestone) corresponds to the lower part of the Sterlitamakskian horizon of the Sakmarian Stage and is equivalent to part of the fusulinid zone *Parafusulina urdalensis*, and part of the conodont zone *Mesogondolella bisselli – Mesogondolella visibilis* (Chernykh, 2002; Chuvashov *et al.*, 2002).

Diagnostic species of the complex are (plate II) *Entactinia pycnoclada* Nazarov and Ormiston, *Tormentum circumfusum* Nazarov and Ormiston, *Latentibifistula triacanthophora* Nazarov and Ormiston, and *L. valdeinepta* Nazarov and Ormiston. Outside of the stratotype district, its distribution is traced by us into more northern areas with facies of thin flysch and pre-flysch in the Ishtuganovo, Krasnousolsky, and Sim sections.

The data on distribution of the radiolarian complexes *Copicyntra* sp., *Helioentactinia ikka – Haplodiacanthus perforatus* and *Entactinia pycnoclada – Tormentum circumfusum* in the Krasnousolsky reference section in Bashkiria are of significant interest. The generalized Krasnousolsky section is composed of two closely located and complementary outcrops: Usolka and Tyulkas. Here the Asselian-Sakmarian interval has the following structure and character of radiolarian distribution (from bottom to top and generalized) (Chuvashov *et al.*, 1990; Amon, 1999):

- **Asselian Stage, Shikhansky horizon.** It is represented mainly by bedded grey carbonate mudstone with thickness of beds around 5–25 cm. Small-debris carbonate breccia is also present. Limestone units are divided by interbeds of argillite and marlstone with thicknesses up to 10–25 cm. The thickest layers contain detrital material including small foramns, fusulinids, debris of bryozoa, porifera, brachiopods, and algae. Thin beds of aphanitic limestone in the upper part of this interval occasionally contain recrystallized radiolarians of the *Copicyntra* sp. complex (reference section Usolka) and sponge spicules. The foram *Sphaeroschwagerina sphaerica* Zone is established here. Horizon thickness is 14 m.
- **Sakmarian Stage, Tastubskian horizon.** It is composed mainly of brownish-grey, frequently microlayered marlstones, which contain grey pelitic limestone interbeds (up to 5–10 cm). In the upper part of the horizon there are limestones with gradational lamination that contain fusulinids, bryozoans, and crinoids. In marlstones there are numerous radiolarians relating to the *Helioentactinia ikka – Haplodiacanthus perforatus* complex (reference section Usolka). The foramns of the *Pseudofusulina verneuili – Eoparafusulina tschernyschcevi* Zone are established here. Horizon thickness is 10 m.
- **Sakmarian Stage, Sterlitamakskian horizon.** It is also composed mainly of brownish-grey, microlayered marlstone and grey pelitic limestone. Many interlayers of marl are actually radiolarites. Numerous radiolarian skeletons are usually strongly re-crystallized and calcitic, but well-preserved specimens also occur. Radiolarians related to the *Entactinia pycnoclada – Tormentum circumfusum* complex (reference section Tyulkas). The foramns of the *Parafusulina urdalensis*

Zone are established here. Horizon thickness is up to 38 m.

The data received at Krasnousolsky show first, that the lower part of the stratigraphic interval, characterized by the *Copicyntra* sp. complex can be dated by foramns *Sphaeroschwagerina sphaerica* Zone, and second that the boundary between the *Helioentactinia ikka – Haplodiacanthus perforatus* and *Entactinia pycnoclada – Tormentum circumfusum* complexes can be confidently correlated with the boundary between the *Pseudofusulina verneuili – Eoparafusulina tschernyschcevi* and *Parafusulina urdalensis* fusulinid zones. Thus one of the important boundaries within the Sakmarian Stage, namely, the boundary between the upper and lower substages (in other words, the boundary between the Tastubskian and Sterlitamakskian horizons), can be substantiated also on the basis of radiolarians.

Layers and complex with Camptoalatus monopterygius.

The complex was singled out by B. Nazarov at the highest levels of the Maloiksk Suites and in the Kondurovsk Suite; a formal stratotype has not been designated. Sediments from the above suites include a fusulinid association that allows recognition that this part of the section is an analogue for the *Pseudofusulina urdalensis* Zone (Nazarov, 1988). According to modern view on this stratigraphic interval, the Maloiksk and Kondurovsk limestone, marlstone, and argillite with interbeds of sandstone, correlate with the upper part of the Sterlitamakskian horizon of the Sakmarian Stage and is equivalent to part of the *Pseudofusulina urdalensis* Zone and part of the *Mesogondolella bisselli – Mesogondolella visibilis* Zone (Chernykh, 2002; Chuvashov *et al.*, 2002).

The primary diagnostic radiolarian species in this complex (plate II) include *Camptoalatus monopterygius* Nazarov and Rudenko, *Entactinosphaera strangulata* Nazarov and Ormiston, and *Ruzhencevispongs plumatus* Nazarov and Ormiston. The association with *Camptoalatus monopterygius* is distributed in Orenburg-Aktyubinsk Preduralie, in particular, in sections located on the Ural River near the Donskoy and Verkhneozerny villages, and also to the south from Aktyubinsk City, on the right bank of the Aktasty River. In more northern areas of Bashkirian Preduralie, its distribution has not been established by us. Additional study of the stratigraphic position of the complex is necessary.

Layers and complex with Rectotormentum fornicatum.

The association with *Rectotormentum fornicatum* was recognized by B. Nazarov in a section of Sakmarian-Artinskian sediments located on the right bank of the Ural River near Donskoy village. According to B. Nazarov, the change of the complex *Camptoalatus monopterygius* to the complex *Rectotormentum fornicatum*, and, then, to the complex *Entactinosphaera crassicalthrata – Quinqueremis arundinea* occurs in the upper part of section, which includes monotonous grey-coloured, thick, terrigenous rocks with interbeds and lenses of limestone and dolostone (about 190 m). Ammonoids, characteristic of the upper part of the Sakmarian Stage, and also, according to H. Kozur data, conodonts of the *Neogondolrella*

bisselli complex (Nazarov, 1988) in the lower part of this interval (47 m), are associated with radiolarians of the *Camptoalatus monopterygius* complex.

According to our new data based on accompanied fossils (Chuvashov *et al.*, 2002), it is clear that the stratigraphic range of the *Rectotomentum fornicateum* complex corresponds to part of the *Parafusulina urdalensis* fusulinid zone and to part of the *Mesogondolella bisselli* – *Mesogondolella visibilis* conodont zone.

Diagnostic species of this radiolarian complex include (plate II) *Rectotomentum fornicateum* Nazarov and Ormiston, *Tomentum pavlovi* (Kozur), *Tetratormentum narthecium* Nazarov and Ormiston, *Spinodeflandrella tetraspinosa* Kozur, and *Latentifistula* sp. Diagnostic species for the complex are (plate II) *Rectotomentum fornicateum* Nazarov and Ormiston, *Tomentum pavlovi* (Kozur), *Tetratormentum narthecium* Nazarov and Ormiston, *Spinodeflandrella tetraspinosa* Kozur, and *Latentifistula* sp.

The geographic distribution of layers with *Rectotomentum fornicateum* is traced into the stratotype area along the Ural River (Orenburg region) and on right bank of the Aktasty River in the Aktyubinsk region. In more northern areas of Bashkirian Preduralie its distribution has not been established by us.

Current knowledge of the features of stratigraphic distribution of the complexes *Camptoalatus monopterygius* and *Rectotomentum fornicateum* are limited and require additional study to reveal their true stratigraphic position. According to available data (Nazarov, 1988) both complexes originate in the same stratigraphic interval in the upper part of the *Parafusulina urdalensis* Zone and in the upper part of the *Mesogondolella bisselli* – *Mesogondolella visibilis* Zone, *i.e.* the position of complexes is actually the same and the question could be raised about the full stratigraphic equivalence of regarding complexes in the same area.

Concerning correlational possibilities and features of the radiolarian biozones described above, it is necessary to say that these Early Permian South Uralian radiolarian associations are unique, owing to their abundance, diversity of taxa, frequency of species occurrence, and their well-preserved nature. Similar richness and variety have not been previously recognized anywhere else in the world. Radiolarian communities from the Late Paleozoic South Uralian region can be attributed to faunas of Tethyan type (in Irenburg-Aktyubinsk Preduralie), or as mixed Boreal-Tethyan type (in the north of Bashkiria). Radiolarian associations lived in a rather shallow warm basin along the northern margin of the Tethys ocean, near the border with the cold Boreal realm. The abundance of nutrient-rich elements which are transported from the cold water areas to an area close to Uralian land, the comparative shoaliness of water areas, the cutting up of the coastline and the warm water conditions created maximum favourable conditions for radiolarian prosperity. The combination of these conditions created an effect, similar to that of modern upwelling. In other regions of the Northern hemisphere, Early Permian radiolarian variety and abundance is essentially lower than in the region considered herein. This circumstance creates some difficulties for correlation of the Uralian radiolarian associations with other regions of the world, where radiolarian complexes are essentially impoverished, or where they are absent, or where they are represented by preva-

lence of forms not characteristic for the Urals. It is necessary to state that the degree of study of Late Carboniferous – Early Permian age radiolarians remains low. Early Permian radiolarians are poorly investigated or are not investigated in territories Northeast of Russia, North America, Northern Africa, south of Europe, and Southwest Asia.

In contrast, Late Permian radiolarians are distributed more widely and have been investigated rather well; for example, they are established on the Far East of Russia, in Japan, China, in Oceania, the Mediterranean, and in North America. Unfortunately, Late Permian (higher than the Kungurian) sediments in the Ural and Preduralie regions are not found and in the Uralian sections radiolarians are not present. Thus, direct comparisons between Uralian Permian biozones and radiolarian associations known and described in the literature from other regions of the world are quite complicated, and it is possible that only indirect, or estimated comparisons can be made.

For example, in the dark layered Bone Springs Limestone (Leonardian Formation, Bone Springs, Bone Springs Canyon, Leonard Hills, Delaware Basin, Culbertson County, West Texas, point of observation – road cut on U.S. Highway 180, 31°40'45"N, 104°49'30"W) there is a radiolarian complex (Cornell, 1983; Nazarov, Ormiston, 1985, 1993). According to B. Nazarov's opinion, this complex is Early Permian (Artinskian). Based on ammonoids the limestones of upper part of Bone Springs section correlate with the Artinskian Stage. Based on fusulinids the lower part of Leonardian Stage in West Texas, including part of Bone Springs Limestone, corresponds to the Sakmarian Stage. The majority of radiolarian species from the above sites in the Southern Urals are not found, and Texas radiolarian complexes from Bone Springs Canyon can be provisionally compared to the Uralian biozones, namely, with *Rectotomentum fornicateum* and with *Quinqueremis arundinea* – *Entactinosphaera crassiclathrata*.

In rocks related to the lower part of the Leonardian Series in Texas, only single finds of radiolarian skeletons are known, and their composition, probably does not completely reflect the features of radiolarian associations typical for this region. All of these circumstances complicate the direct correlation between Urals and Texas. Therefore it is possible to compare only provisionally the Bone Springs Limestone as a whole to the upper part of the Sakmarian and the lower part of the Artinskian Stages of the Southern Urals. A Permian radiolarian complex was found in the Havallah reference section in Nevada (Upper Paleozoic Havallah sequence near Battle Mountain, Nevada; Murchey, 1990). Radiolarians of Early Guadalupian age are found in the Redding reference section in California (Permian-Triassic Redding Section, Eastern Klamath Mountains, California; Noble and Renne, 1990). Radiolarians of Wordian age are found in central Nevada (Quinn River Formation, Black Rock Terrane, north-central Nevada; Blome and Reed, 1995). These intervals of marine Upper Permian deposits on the North American continent have no radiolarian analogue in the Urals.

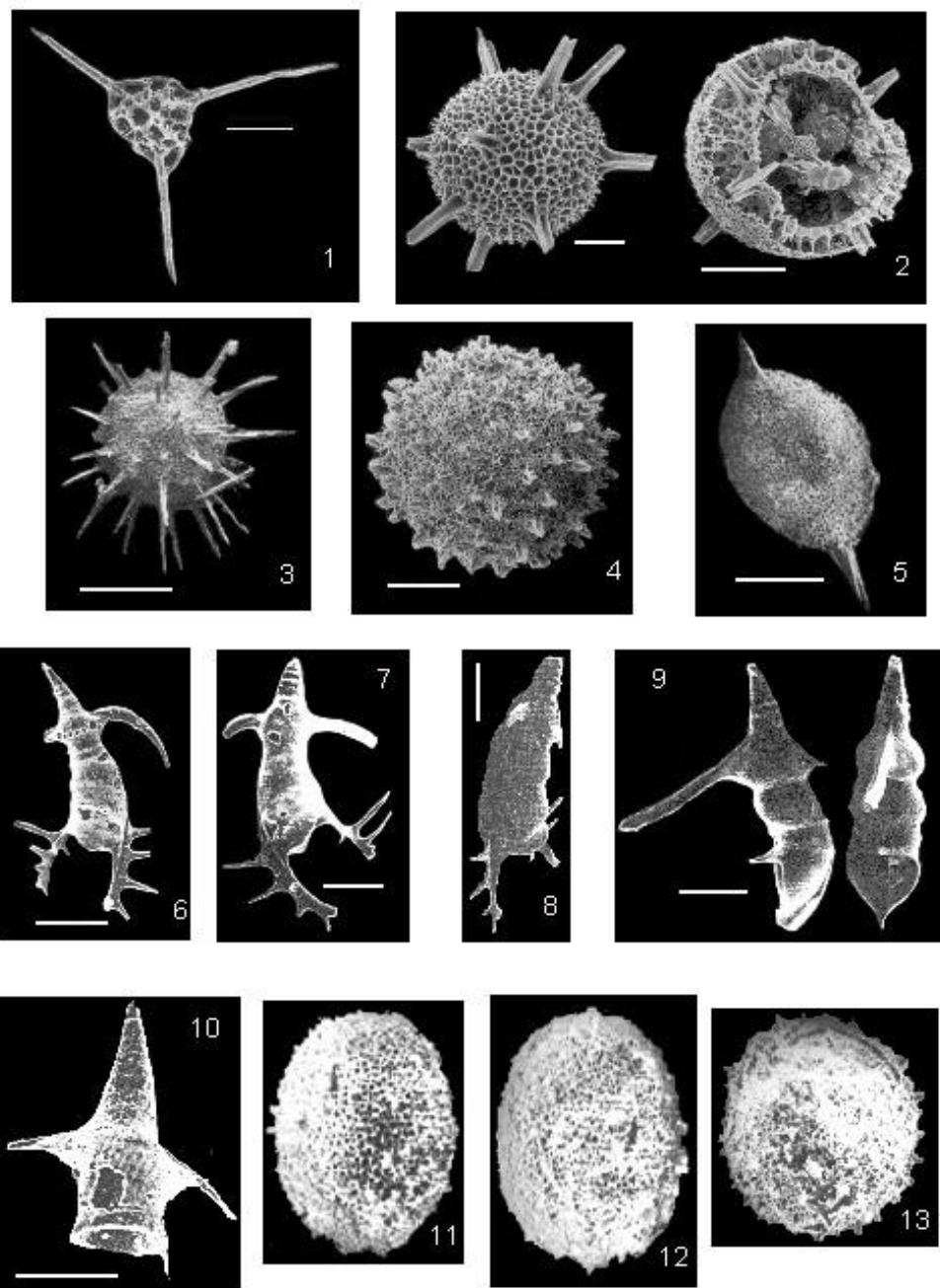


Plate I.

Fig. 1. *Tetragregnion vimineum* Amon and Braun. Lower Permian, Sakmarian and Artinskian Stages, Southern Urals. Adapted: Amon *et al.*, 1990.

Fig. 2. *Helioentactinia biexosphaera* Nazarov and Ormiston. Lower Permian, Sakmarian and Artinskian Stages, Southern Urals. Adapted: Amon *et al.*, 1990.

Fig. 3. *Copicyntra cuspidata* Nazarov and Ormiston. Lower Permian, Sakmarian and Artinskian Stages, Southern Urals. Adapted: Nazarov, Ormiston, 1985.

Fig. 4. *Copicyntra phymatodonta* Nazarov and Ormiston. Lower Permian, Sakmarian and Artinskian Stages, Southern Urals. Adapted: Amon *et al.*, 1990.

Fig. 5. *Copielintra diploacantha* Nazarov and Ormiston. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Nazarov, Ormiston, 1985.

Fig. 6. *Haplodiacanthus perforatus* (Kozur). Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Kozur, 1981.

Fig. 7, 8. *Haplodiacanthus permicus* (Kozur). Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Kozur, 1981.

Fig. 9. *Parafollicucullus sakmarensis* Kozur. Lower Permian, Sakmarian Stage, Southern Urals. Length of scale is 100 micrometres. Adapted: Kozur, 1981.

Fig. 10. *Parafollicucullus nazarovi* Kozur. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Kozur, 1981.

Fig. 11–13. *Copicyntra* sp. Lower Permian, Sakmarian Stage, Southern Urals. Photos from E.O. Amon's archive, magnification X 300.

Length of scale for figs. 1–10 is 100 micrometres.

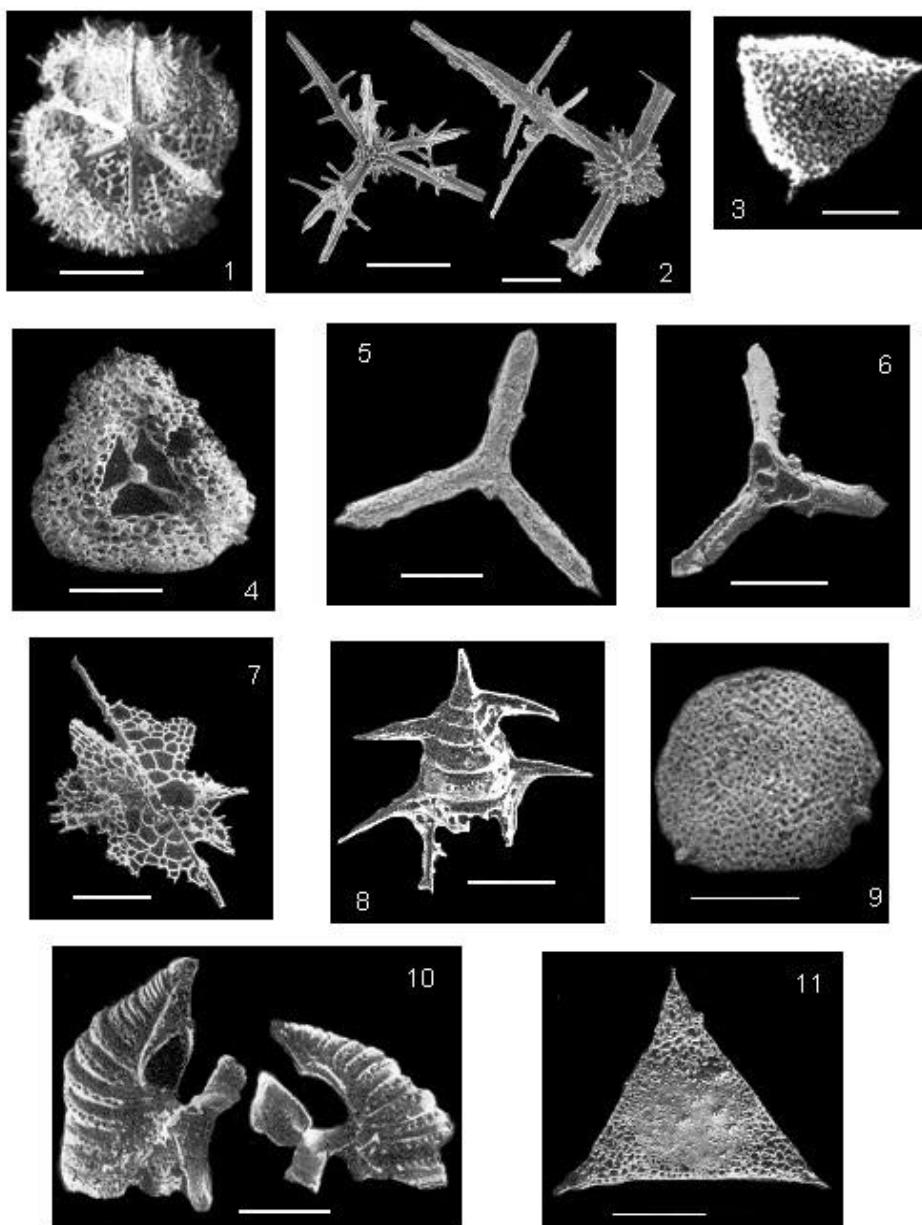


Plate II.

- Fig. 1. *Helioentactinia ikka* Nazarov and Ormiston. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Nazarov, Ormiston, 1993.
- Fig. 2. *Entactinia pycnoclada* Nazarov and Ormiston. Lower Permian, Sakmarian and Artinskian Stages, Southern Urals. Photo from E.O. Amon's archive.
- Fig. 3. *Tomentum pavlovi* (Kozur). Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Kozur, 1980.
- Fig. 4. *Tomentum circumfusum* Nazarov and Ormiston. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Nazarov, Ormiston, 1985.
- Fig. 5. *Latentibifistula triacanthophora* Nazarov and Ormiston. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Nazarov, Ormiston, 1985.
- Fig. 6. *Latentibifistula valdneipta* Nazarov and Ormiston. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Nazarov, Ormiston, 1985.
- Fig. 7. *Raphidociclicus huilcus* Nazarov and Rudenko. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Nazarov, Rudenko, 1981.
- Fig. 8. *Spinodeflandrella tetraspinosa* Kozur. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Kozur, 1981.
- Fig. 9. *Rectotormentum fornicatum* Nazarov and Ormiston. Lower Permian, Artinskian Stage, Southern Urals. Adapted: Nazarov, Ormiston, 1985.
- Fig. 10. *Campoalatus monopterygius* Nazarov and Rudenko. Lower Permian, Sakmarian Stage, Southern Urals. Adapted: Nazarov, Rudenko, 1981.
- Fig. 11. *Ruzhencevisponges plumatus* Nazarov and Ormiston. Lower Permian, Artinskian Stage, Southern Urals. Adapted: Nazarov, Ormiston, 1985. Length of scale for figs. 1-11 is 100 micrometres.

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Transitional Ufimian-Kazanian marine deposits in the southeastern seaboard of the Kanin Peninsula, Russia

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The Ufimian – Kazanian stratigraphic interval within the section of the Kanin Peninsula is composed of contiguous shallow-water marine facies. Biogeographically during the Late Permian this territory belonged to the Barentz Shelf Area. The section is located along the southwestern shore of Cheskaya Bay, between the estuary of the Nadtey River and the Cape of Jarneyssale (fig. 1A) along the tidal flat up to 4m height (fig. 2A). The Ufimian/Kazanian boundary was originally defined here by D. Stepanov (Stepanov *et al.*, 1975) based on brachiopod assemblages between the *Sowerbina* and *Licharewia* layers. Later this boundary was established between local zones *Sowerbina granulifera* and

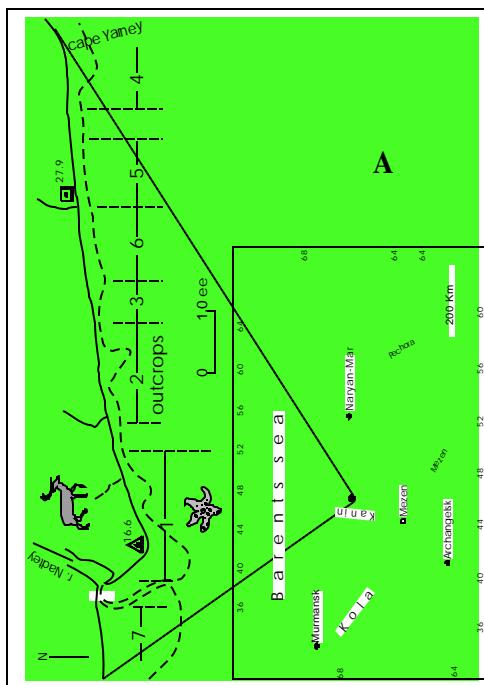


Figure 1A. Location map.

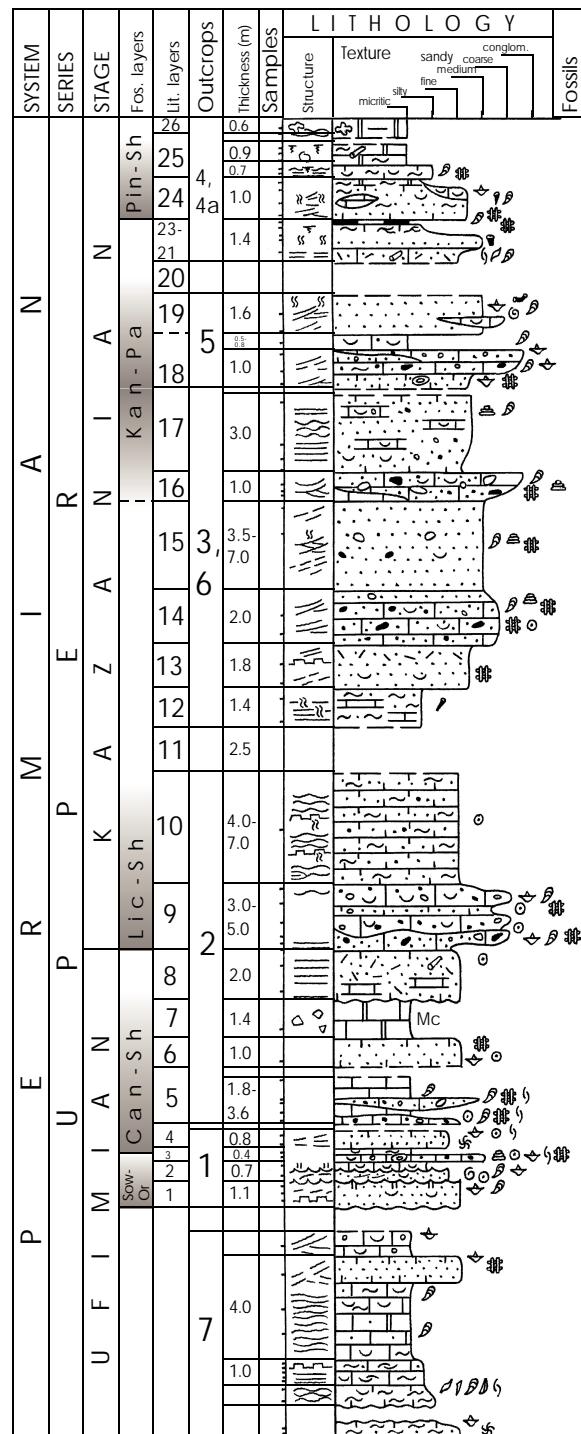
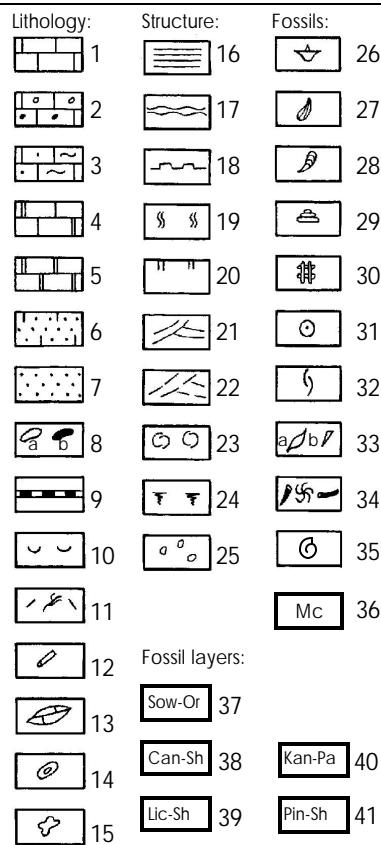


Fig. 1B. Stratigraphic column: Legend. 1-15 the rocks and inclusions: 1 – wackestone (micritic limestone), 2 – packstone and grainstone, 3 – silty and sandy limestone, 4 – dolomitic limestone, 5 – dolostone, 6 – mixed siliciclastic-carbonate rocks, 7 – sandstone, 8 – pebbles and gravel of (a) extraformational rocks, (b) intraformational rocks, 9 – coaly rocks, 10 – fossil remains (in general), 11 – plant remains and coaly detritus, 12 stems, 13 – carbonate lens and concretions, 14 – oolites, 15 – carbonate nodules; 16-25 structure: 16 – horizontal bedding, 17 – lenticular bedding, 18 – bioturbation, 19 – burrows, 20 – borings, 21 – bimodal cross bedding, 22 – unclear cross bedding, 23 – cloddy (destratified), 24 – rootlets, 25 – mottled; 26–36 – fossils: 26 – brachiopods (articulate), 27 – lingulas, 28 – bivalves, 29 – gastropods, 30 – bryozoans, 31 – crinoids, 32 – ostracods, 33 – fish remains (a) scales, (b) – teeth, 34 – ichnofossils, 35 – *Microcodium*; 36-40 fossil layers*: 36 – *Sowerbina ganulifera*–*Oriocrassatella komiorum*, 37 – *Cancriella cancrini*–*Schizodus rossicus*, 38 – *Licharewia schrenckii* – *Schizodus aff. rossicus*, 39 – *Kaninopsirifer borealis* – *Parallelodon licharewi*, 40 – *Pinegathyris alata* – *Schizodus subobscurus* *grey colour marks the distribution of fossil assemblages within the section.



Figure 2. Photographs: A – the view on the cape Nadtey; B – the rippled surface within the *Sowerbina ganulifera* – *Oriocrassatella komiorum* layers (layer 2); C – crossbedding in sandy packstone within *Licharewia schrenckii* – *Schizodus* aff. *rossicus* layers (layer 9).

Licharewia stuckenbergi (Molin *et al.*, 1983).

Detailed lithological description of the section and new collections of organic remains (brachiopods, bryozoans, bivalves, nautiloids, ostracods, and ichtyolites) were carried out in 2001. Based on the distribution of brachiopods and bivalves, a five-fold subdivision of the section is suggested (fig. 1B). New paleontological collections provide information on a more adequate dating of the layers described below.

Sowerbina ganulifera – *Oriocrassatella komiorum* layers

These layers are exposed near the cape of Nadtey. They are composed of interbedded greenish-grey, fine or medium grained, polymictic sandstone with gentle crossbedding and massive muschelkalks. Several surfaces with large scale wave ripples are typical for this part of the section (fig. 2B). Abundant brachiopods *Sowerbina granulifera* (Toula) and bivalves *Oriocrassatella komiorum* (Kanев) sometimes form minor banks. Rare bryozoans and the nautiloids *Uralothoceras* ex gr.

tzwetaevae Shimansky and ?*Simothoceras* sp. present as well. Observed thickness is up to 2m. The layers are assigned to the Solikamsk horizon of the Ufimian. This stratigraphic level corresponds to the middle and upper parts of the Kozhim Rudnik Formation within the section of the Kozhim River (Grunt *et al.*, 1998) and probably to the Voringen Member of the Kapp Starostin Formation in Central Spitsbergen (Nakamura *et al.*, 1978).

Cancrinella cancrini – *Schizodus rossicus* layers

These layers are of diverse lithologic composition differ from the subjacent and overlying rocks. The considered layers begin with coarse to gravel grainstones composed of well rounded, iron-stained bryozoan and crinoid fragments. They are overlain by micritic limestone with a terrigenous clastic admixture and oolites, replaced upward in the section by polymictic sandstone with abundant *Tounurus* burrows. Brachiopods include numerous *Cancrinella cancrini* (Verneuil) as well as singular *Svalbardia*

capitolina (Toula) and *Sowerbina granulifera* (Toula), bryozoans include *Retiporidra tuncheimensis* Morozova, *Polypora* sp., *Polyporellina* sp., *Retifenestella* sp., *Tabulipora* sp., *Stellahexaformis* sp., *Permafrenestella* sp., bivalves, crinoids and ostracods. Micritic dolomitic carbonate rocks with fragments of *Microcodium* and fine-grained horizontally laminated sandstone with abundant coaly plant detritus are present in the uppermost part. Thickness is up to 10m.

***Licharewia schrencki – Schizodus aff. rossicus* layers**

These layers are represented by interbedded sandy crossbedded packstones (fig. 2C) and grainstones with gravels and small pebbles of quartz and quartzite and some lens-like interbeds of conglomerate in the lower part. Numerous brachiopods are present, including *Licharewia schrenckii* (Keyserling), *L. stuckenbergi* (Netschajew), *L. kaninensis* Kulikov and Stepanov., bivalves, bryozoans and crinoids. The overlying part of the section is composed of mixed siliciclastic-carbonate rocks replaced by siltstones and fine- to medium-grained crossbedded sandstones containing packstone interbeds with abundant bivalves, bryozoans, gastropods and crinoids. Total thickness of the layer is up to 25m. The precise age is Lower Kazanian based on the abundant Licharewiinae characteristic of the Lower Kazanian within the reference sections of the Volga-Urals area. A Kazanian GSSP could be proposed within the lower part of these layers.

***Kaninospirifer borealis – Parallelodon licharewi* layers**

These layers are sandstone dominated. Two beds of coarse-grained to gravel grainstones with intra- and extraformational fragments of carbonate rock, quartz and quartzite occur in these layers. The sandstones are polymictic and crossbedded. The layers contain abundant brachiopods, including *Aulosteges wangenheimi* (Verneuil), *Craspedalosia pulchella* (Dunbar), *Kaninospirifer borealis* Kulikov and Stepanov, *Purdonella soderberghii* Dunbar, along with bryozoans *Parametelipora maculata* Morozova, *Stellahexaformis* sp., *Dyscritella* sp., bivalves, gastropods, nautioids *Uralothoceras verneuili* (Moller), *U. tzwetaevae* Shimansky, and *Metacoceras* sp. Sandy limestone and intensively burrowed sandstone with thin interbeds of coaly shale make up the uppermost part of the section. They contain abundant fish remains, mainly of the palaeoniscid *Kazanichys vjatkensis* Esin. The latter is a zonal form for the Upper Kazanian substage (Krasnovidovo horizon) within the reference sections of the Volga-Urals area. Thickness is up to 8m.

***Pinegathyris alata – Schizodus subobscurus* layers**

These layers, which are exposed at the Cape of Jarneisaale, terminate the uppermost marine part of the studied section. Formerly they were identified as the Upper Kazanian *Pinegathyris rossiana* Zone (Molin *et al.*, 1983). The layers are composed of calcareous, fine-grained sandstone penetrated by numerous subvertical burrows. The layers contain brachiopods, abundant *Pinegathyris alata* Grunt and rare *P. rossiana* (Keyserling), ramosc bryozoans *Rhombotrypella summa* Morozova, *Stellahexaformis* sp., *Anisotrypella borealis* Morozova, *Stenopora grandis* Morozova, *Dyscritella* sp.,

Permafrenestella probata Morozova, and *Laxifrenestella* sp., and throughout the entire layer, casts of bivalves close to lagoonal forms, and abundant plant debris. In the uppermost part, sandstone is replaced by calcareous-dolomitic siltstone and dolostone with stems and vertical rootlets. Thickness is up to 4m. A peculiar aspect to this assemblage is the presence of abundant ramosc bryozoan zoaria like *Stellahexaformis* Gilmour and Snyder. Formerly, this genus was known only from the Gerster Formation (Wordian) of the Nevada. Outside this region the genus is established for the first time.

Outcrop 7 (fig. 1B) is exposed to the west of the Nadtey River estuary along the tidal flat within the interfluvial of Nadtey and Krutaja. It is excluded from consideration because of some inconsistency between geological and paleontological data. Geological data suggests continuity of the section and the absence of any kind of unconformity between the *Sowerbina granulifera – Oriocrassatella komiorum* and underlying *Kaninospirifer kaninensis – Solenomorpha kogimica* layers. The latter contain brachiopods, including *Kaninospirifer kaninense* (Licharew), abundant *Baitugania kaninense* (Fredericks), and *?B. nielsi* (Dunbar), as well as the bryozoans *Parametelipora maculata* Morozova and *Pseudobatostomella decora* Morozova, ammonoids of the Family Pseudogastroticidae, bivalves *Solenomorpha kogimica* (Muromzeva), *Permophorus costatus* (Brown), *Aviculopesten orientalis* Fredericks, ichthyoliths *Boreolepis* (?) *jensenii* Aldinger, *Elonichthys contortus* Esin, *Acrolepis* sp., *Paleostrugia* (*Acrolepis*) *rhombifera* Eichw., “*Acentrophorus varians*” (Kirby), and shark teeth. Bivalves from this outcrop are characteristic for the lower part of the Kozhim Rudnuk Fm. (Grunt *et al.*, 1998). The lower part of the outcrop is a reference location for *Kaninospirifer kaninensis* (Licharew), which is very close in morphology to *Kaninospirifer striatoparadoxus* (Toula). The layers agree in age with the upper part of the Upper Marine Group (now known as Mallemuk Mountain Group) of North-east Greenland, traditionally referred to the Kungurian (Nakamura *et al.*, 1987). This faunal assemblage gives evidence of a Late Permian age for this part of the section (close to the Kazanian based on the brachiopods and fish remains). On the other hand, this assemblage has not been discovered within the main part of the section to the east of the Nadtey estuary.

Analysis of the section as a whole shows that sedimentation was in an open sea-basin close to, and influenced by, pre-beach and strictly intertidal (lower beach) incursions. Three levels of brief changing of sea-level are established. The main one is fixed between the *Sowerbina* and *Licharewia* layers. Each changing of sea-level is connected directly to the renewal of organic assemblages. In biogeographical aspect the Kanin Peninsula deposits occupy a position between the Late Permian basins of Central Europe and the basins of the Canadian Arctic. This section is important for detailed step-by-step correlation of Late Permian reference sections of the Volga-Urals area and the sections of the Guadalupian Series (North America) tying it to the middle part of the Permian International Chronostratigraphic Scale.

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Global Permian tetrapod footprint biostratigraphy and biochronology

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The global record of Permian tetrapod footprints encompasses localities in North America, South America, Europe, Russia and South Africa (Fig. 1). Permian tetrapod footprints have been assigned to two principal ichnofacies, an eolian ichnofacies and a red-bed ichnofacies. Various biostratigraphic schemes employing tetrapod footprints have been proposed, particularly for the red-bed ichnofacies, especially in Europe. For the purposes of a global Permian tetrapod footprint biostratigraphy, the operational taxonomic unit is the ichnogenus, as almost all ichnospecies are variants confined to a single locality and thus of little biostratigraphic value. Here, I rely on the ichnotaxonomy of Haubold (1996, 2000) and review briefly the biostratigraphic distribution of Permian tetrapod footprints to argue that on a global basis they only discriminate two intervals of Permian time.

North America

In North America, tetrapod footprints of Permian age are found primarily in the western United States in Arizona, New Mexico, Texas, Utah, Colorado and Oklahoma (Hunt *et al.*, 1995; Lucas, 2002b). The only notable Early Permian track record in eastern North America is from Lower Permian red beds on Prince Edward Island in Canada (Cotton *et al.*, 1995).

The eolian ichnofacies is best known from the Coconino Sandstone in Arizona, and some other Lower Permian eolianites also yield tracks in Arizona, Utah and Colorado. The Coconino Sandstone is of late Leonardian age—it is directly overlain by marine strata of the late Leonardian Kaibab Formation (Hopkins, 1990), and the Coconino is equivalent to the Glorieta Sandstone of New Mexico and the San Angelo Formation of Texas (Middleton *et al.*, 1990) (Fig. 2). The eolian trackmakers were probably the same animals as the red-bed trackmakers, and indeed one ichnogenus, *Dromopus*, is found in both ichnofacies. But, in general, the eolian

track assemblages are of low diversity and cannot be directly compared and correlated with the red bed tracks—the tracks of both ichnofacies are too different in morphology.

In North America, the red-bed ichnofacies is best understood in New Mexico, where numerous and extensive red-bed track assemblages of Early Permian age are known (see articles in Lucas and Heckert, 1995; Lucas *et al.*, 1998). These assemblages are from the Earp Formation (Big Hatchet Mountains), the Robledo Mountains Formation of the Hueco Group (Robledo, Doña Ana and San Andres Mountains), the Abo Formation (Caballo and Fra Cristobal Mountains, Joyita Hills, Abo Pass) and the Sangre de Cristo Formation (Villanueva). Relative abundances of the ichnotaxa vary between sites, but *Dromopus* and *Batrachichnus* dominate, and co-occur with *Amphisauropus*, *Varanopus*, *Dimetropus*, *Gilmoreichnus*, *Hyloidichnus*, *Ichniotherium* and *Limnopus* (e.g., Haubold, 2000; Haubold and Lucas, 2001a; Lucas *et al.*, 2001).

Tracksites in the Sangre de Cristo and Abo formations are of Wolfcampian age, but a more precise correlation and stratigraphic ordering of these sites has not yet been completed. Tracksites in the Robledo Mountains Formation in southern New Mexico are close in age to the Wolfcampian-Leonardian boundary. The New Mexican red-bed track record thus encompasses most or all of Wolfcampian time. Similar red-bed tracks from the Hermit Formation in Arizona are also of Wolfcampian age, but a more precise correlation is not now possible.

Much less is known of Leonardian-age tracks in North America. A single specimen of *Dimetropus* is known from the Leonardian Schnebly Hill Formation near Show Low in Arizona. A locality in the lower part of the Hennessey Formation at Oklahoma City yields *Amphisauropus* and possible *Dromopus* (Lucas and Suneson, 2002). The classic North American Leonardian tracksite is in the upper part of the Choza Formation at Castle Peak near Abilene, Texas. Haubold and Lucas (2001b) revised the ichnotaxonomy at Castle Peak, and it is dominated by *Amphisauropus*, *Varanopus* and *Dromopus*. A tracksite in the Arroyo Formation at Lake Kemp in Baylor County, Texas yields *Varanopus*, *Amphisauropus* and *Dromopus*. It is tempting to suggest that an abundance of *Amphisauropus* and *Varanopus* is characteristic of the Leonardian, but too few Leonardian age tracksites are known to confirm this. The differences now perceived between Wolfcampian and Leonardian tetrapod tracks may be due to collecting biases and/or facies differences and thus are not temporally significant.

The stratigraphically highest Permian tetrapod footprints from North America are in the San Angelo and Blaine formations at San Angelo, Tom Green County, Texas. Pittman *et al.* (1996) provided preliminary data on these tracks, which are evidently the tracks of a caseid pelycosaurs and rare examples of *Amphisauropus*. The San Angelo and Blaine are late Leonardian in age (Fig. 2), and these youngest North American Permian tracks mirror the abundance of caseid pelycosaurs seen in the San Angelo Formation body fossil fauna (e.g., Olson, 1962). It is also interesting that the common Coconino ichnogenus *Chelichnus* has been thought by some to be a caseid track, so this may provide a tiepoint between the eolian and the red-bed ichnofacies.

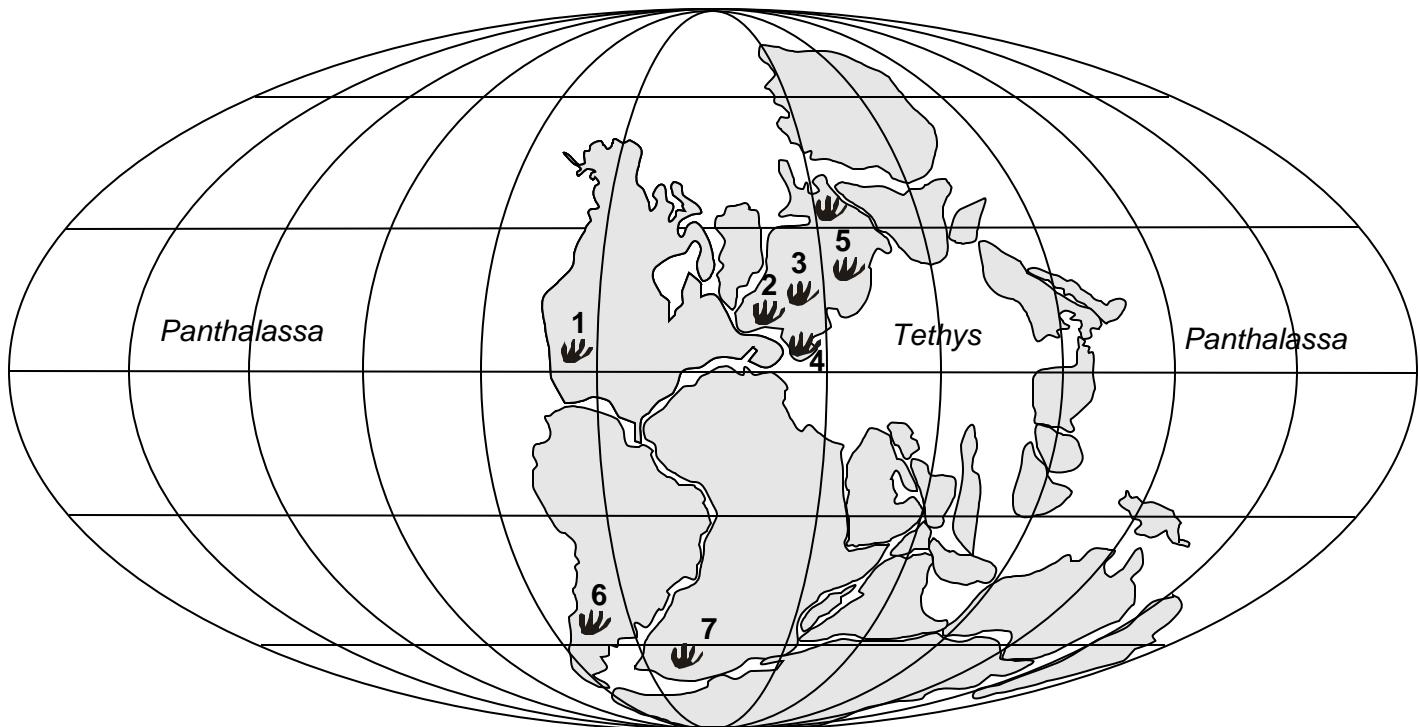


Figure 1. Distribution of principal Permian tetrapod tracksites on Permian Pangea. Locations are: 1 = western United States, 2 = France, 3 = Germany, 4 = Italy, 5 = Russia, 6 = Argentina, 7 = South Africa.

Europe

The European Permian tetrapod footprint record comes principally from three countries—Germany, France and Italy—though Lower Permian tracks are also known from the United Kingdom, Spain, Poland, and the Czech Republic (e.g., Haubold, 1973, 1984). The German tracks have the longest studied record, with published work going back to the 1800s.

In Germany, the most extensive records are from Thuringia and the Saar-Nahe basin, which Boy and Fichter (1988a,b) used as the principal basis for recognition of six successive tetrapod footprint zones that spanned the Permian. These are the (ascending order) *Protritrichnites lacertoides*, *Saurichnites incurvatus*, *Varanopus microdactylus*, *Anhomoiichnium*, *Harpagichnus* and *Rhynchosauroides* zones. Boy and Fichter (1988b, p. 882) claimed that “the biostratigraphic zonation of tetrapod tracks is not based on ecological and local climatic changes...but on large-scale faunal interchange across wide areas of Pangea.” Nevertheless, the biostratigraphic zonation of Boy and Fichter has been invalidated by taxonomic revision and further understanding of the stratigraphic distribution of Permian tetrapod footprint ichnogenera. Thus, their *Protoichnites* is *Dromopus*, and what they termed *Anomoiichnium* includes tracks now termed *Dromopus* and *Batrachichnus* (Haubold, 1996). *Saurichnites incurvatus* of Boy and Fichter also is *Batrachichnus* (Haubold, 1996). The zones are thus based on *Dromopus*, *Batrachichnus* and *Varanopus*, ichnogenera that routinely co-occur and have long stratigraphic ranges in the North American Lower Permian. Furthermore, “*Harpagichnus*” (= *Chelichnus*) is the dominant ichnogenus of the eolian ichnofacies and is found in Lower Permian eolianites regardless of their precise age. The only zone that may be of value is the *Rhynchosauroides* zone, a tetrapod ichnogenus that has its

lowest occurrence in the Upper Permian.

An extensive and well-studied Permian red-bed tetrapod footprint record is known from France, especially from the Autun, Saint Affrique and Lodève basins (e.g., Ellenberger, 1983a, b, 1984; Gand, 1987, 1993; Gand and Haubold, 1988). The Lower Permian strata in these basins produce track assemblages dominated by *Batrachichnus*, *Limnopus*, *Amphisauropus*, *Dromopus*, *Varanopus*, *Hyloidichnus* and *Dimetropus*. A stratigraphically much higher level in the Lodève basin at La Lieude yields apparent pareiasaur (“*Brontopus*”) and therapsid (“*Eocynodontripus*”) tracks, among others, and compares well with the Upper Permian ichnoassociation from Italy (see below).

Avanzini *et al.* (2001) presented the most recent stratigraphic review of the Italian Permian tetrapod footprint record. They identified two “ichnoassociations.” The Lower Permian “ichnoassociation” is dominated by the ichnogenera *Varanopus*, *Amphisauropus*, *Ichniotherium*, *Dromopus* and *Batrachichnus*. These are best known from the Collio Formation in Brescia, northern Italy. The Upper Permian “ichnoassociation” is best known from the Val Gardena and Bellerophon formations in the Bletterbach Gorge section in northern Italy (e.g., Conti *et al.*, 1977). The ichnogenera *Pachypes*, *Rhynchosauroides* and *Dicynodontipus* are characteristic. There is a substantial temporal gap between the two ichnoassociations, equal to at least the entire Guadalupian (e.g., Cassinis *et al.*, 2002).

Russia

Lucas *et al.* (1999) reported a handful of tetrapod footprints (assigned to cf. *Dromopus* and cf. *Dimetropus*) from Early Permian red beds of the Caucasus. Tverdokhlebov *et al.* (1997)

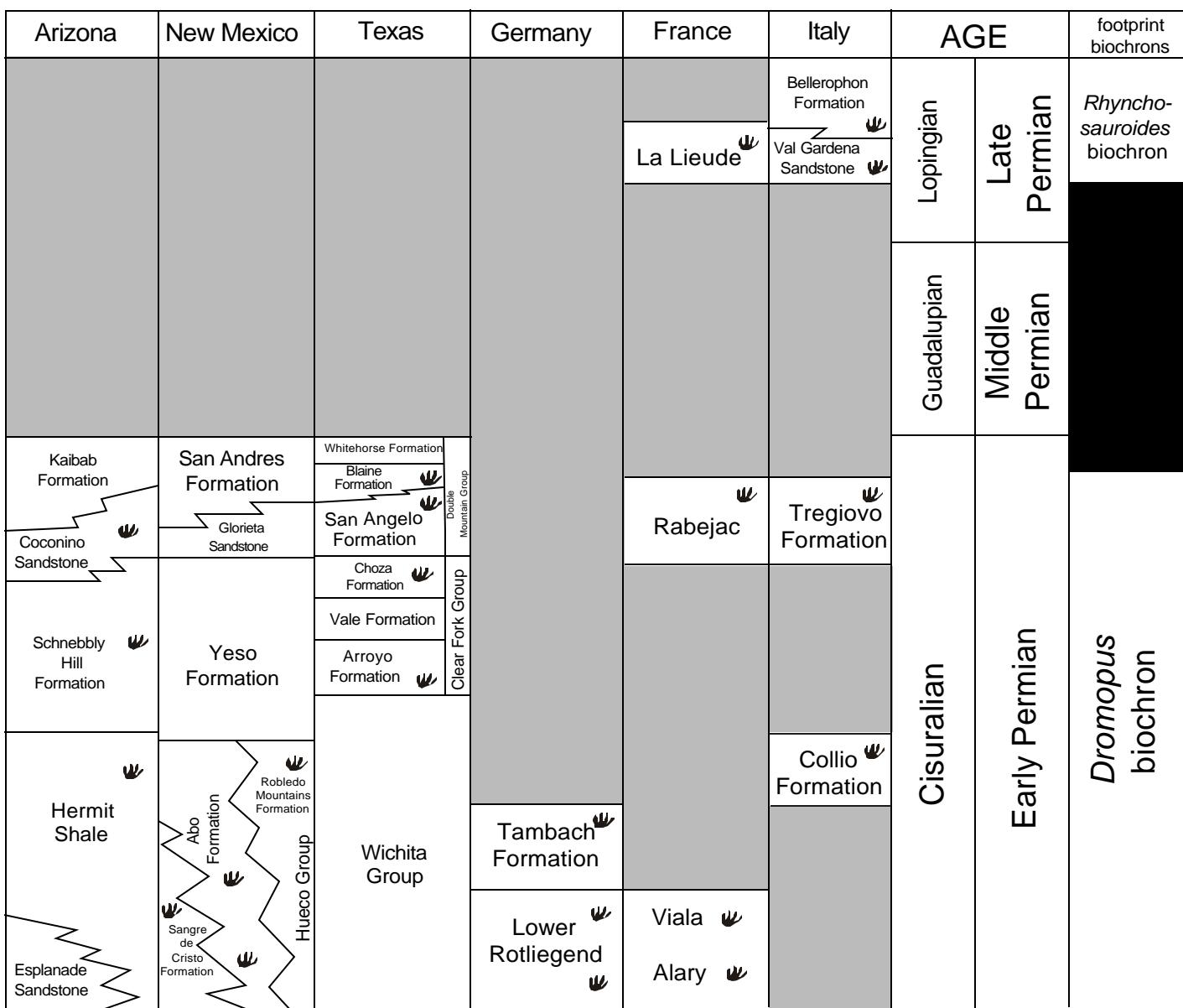


Figure 2. Global correlation of selected Permian tetrapod tracksites.

described red-bed tracks assigned to *Batrachichnus* (= *Anthichnium*) from the upper Tatarian of Russia, and Gubin *et al.* (2001) described apparent pareiasaur tracks, also from the upper Tatarian.

Argentina

Melchor (2001) described Permian tetrapod footprints from Argentina in the Carapacha basin (red-bed ichnofacies tracks assigned to *Batrachichnus*, *Hyloidichnus* and cf. *Gilmoreichnus*) and the eastern Permian basin (eolian ichnofacies tracks assigned to *Chelichnus*). Melchor (2001) suggested these records are of Late Permian age, but both records are more likely Early Permian. The Argentinian track record is significant because it suggests a global distribution during the Early Permian of the characteristic ichnogenera of the red-bed and eolian ichnofacies.

South Africa

A substantial record of tetrapod footprints is present in Upper Permian strata in the Karoo Basin of South Africa (Seeley, 1904; Smith, 1993). These are primarily tracks of pareiasaurs and dicynodonts and should be further documented and compared to the Upper Permian tracks from northern Italy, which they resemble.

Biostratigraphy and Biochronology

The above review makes the following points clear:

1. The Permian eolian ichnofacies is dominated by *Chelichnus* and is of the same composition at all sites. The fact that Permian units such as the Coconino, DeChelly and Supai formations in the USA, the Corockle and Lochabriggs sandstones in Scotland and the Cornberger Sandstein in

Germany have similar tetrapod ichnofossils (e.g., McKeever and Haubold, 1996) is more a reflection of shared lithofacies than of precise age equivalence. Tetrapod footprints of the eolian ichnofacies are of little biostratigraphic value.

2. Tetrapod footprints of the Early Permian red-bed ichnofacies are similarly of broad, uniform composition. The following ichnogenera dominate: *Batrachichnus*, *Limnopus*, *Amphisauropous*, *Dromopus*, *Varanopus*, *Hyloidichnus*, *Ichnotherium*, *Dimetropus* and *Gilmoreichnus*. This assemblage is mostly the tracks of temnospondyls, diadectomorphs, seymouriamorphs, procolophonids and pelycosaurs. The North American record demonstrates that most (if not all) of these ichnogenera have long stratigraphic ranges through most or all of Wolfcampian and Leonardian time (Haubold and Lucas, 2001a, b; Lucas, 2002b). Furthermore, at the Robledo Mountains megatracksite in southern New Mexico, almost all of these ichnogenera co-occur in a single, narrow stratigraphic interval. This suggests that local biostratigraphic zonations based on these ichnotaxa, especially those proposed in Germany and France, are not of global applicability, and may also be of questionable local or regional utility. Thus, the Early Permian red-bed ichnofacies yields a single biostratigraphic assemblage of tetrapod footprints found in the United States, Canada, Argentina, Germany, France, Italy, Russia and some other places in Europe.

3. The Late Permian record of tetrapod footprints is less extensive than but shows significant differences from the Early Permian record. *Pachypes*, *Dicynodontipus* and *Rhynchosauroides* are characteristic. This is a record dominated by the tracks of pareiasaurs and dicynodont therapsids. It is best known from northern Italy, but French, South African and Russian records demonstrate a broad distribution of this biostratigraphic assemblage.

4. There is a substantial stratigraphic gap in the global Permian tetrapod footprint record. This is the gap between the youngest Early Permian track records, which are as young as Kungurian, and the oldest Late Permian records, which are no older than Wuchiapingian. This gap, approximately equivalent to the Guadalupian, is longer and more profound than the corresponding mid-Permian gap in the tetrapod body fossil record, which approximately equals Roadian time (Lucas, 2001, 2002c).

If we construct a global biochronology based on red-bed ichnofacies tetrapod footprints, it contains only two time intervals (Fig. 2). I term these the *Dromopus* and *Rhynchosauroides* biochrons, and note that *Dromopus* has a temporal range of Pennsylvanian through Early Permian, and *Rhynchosauroides* has a temporal range of Late Permian through Late Triassic. In contrast, tetrapod body fossils can be used to discriminate about 10 intervals of Permian time (Lucas, 2002a). Therefore, the tetrapod track record only resolves Permian time about 20% as well as does the tetrapod body fossil record. It thus represents an excellent example of the low biochronological resolution provided by tetrapod footprints (Lucas, 1998).

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Permian-Triassic boundary conodonts from Jolfa-Abadeh Belt along Northwest and Central Iran

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Abstract

The Permian-Triassic boundary beds of the Jolfa and Abadeh belt, in northwest and central Iran, have been previously interpreted to be disconformable. Recent consideration upon conodont examination of *Paratirolites* beds of uppermost Permian boundary from the Jolfa-Abadeh belt, yielded the *Clarkina changxingensis* (Wang and Wang) Zone, indicating a late Dorashamian or Changhsingian age and the samples of the Lower Triassic sequence immediately above the *Paratirolites* beds included in ascending order: *Hindeodus minutus* (Ellison), *Hindeodus typicalis* (Sweet), *Hindeodus parvus* (Kozur and Pjatakova), *Isarcicella isarcica* (Huckriede) zones, indicating an early Griesbachian age and a transitional and continuous sedimentary record through the Permian-Triassic boundary.

Introduction

The greatest biological catastrophe in Earth's history occurred in the Late Permian just over 250 million years before present. The significant intensity of life, during the terminal Permian interval and the turnover of invertebrate faunas at the stratigraphic level of the Lower Triassic have long been important problems in earth history.

Permian-Triassic boundary conodonts in Iran were reported for the first time in the Alibashi section by Walter Sweet. He made a suggestion of continuous sedimentation between the Permian-Triassic strata, based on the existence of *Anchignathodus typicalis*

Zone below the *Anchignathodus parvus* Zone (Sweet, 1973) in strata with *Ophiceras* in Jolfa area, northwest Iran.

On the other hand, Taraz and the Japanese Group in their treatise of 1981 claim that the lower *Otoceras woodwardi* Zone, means *Anchignathodus typicalis* Zone is missing through the Early Triassic (lower Elika Formation) indicating a paraconformity between the Permian and Triassic.

The Permian-Triassic boundary beds in Alibashi, Shahreza and Hambast sections were reexamined for conodonts in 1995. The late Dorashamian and early Griesbachian conodonts from the "Jolfa-Abadeh belt" were described by M. Lesani and M. Musa Ahmadi, paleontologist of the Geological Survey of Iran. The appearance of *Clarkina changxingensis* from the uppermost *Paratirolites* beds of the three above-mentioned sections indicates a late Dorashamian or Changhsingian age. Lower Triassic, Griesbachian, conodonts *Hindeodus minutus* (Ellison), *Hindeodus typicalis* (Sweet), *Hindeodus parvus* (Kozur and Pjatakova), and *Isarcicella isarcica* (Huckriede) represent the lowermost Griesbachian stage, so that here is a place in the world in which a continuous marine section in the Tethys realm is preserved through the Permian-Triassic transition.

Consequently during the formation of Pangea, that culminated in the closing of the Tethys sea, a trough of the sea remained through the Jolfa-Abadeh belt allowing for sedimentation to continue through Permian-Triassic boundary time.

Historical geology

The geological map of Iran, 1:2,500,000, published by the National Iranian Oil Company in 1959, shows only Triassic, no Permian rocks in this area, and also no information on the geology of this part of

Iran was available in the Geological Survey of Iran. Bonnet's map and their descriptions, published in 1947, suggested to Teichert the possibility that Permian rocks might be present on the Iranian side of the Aras River.

Teichert explained his general interest in problems of the Permian-Triassic boundary on a worldwide basis and inquired about the possibility of a reconnaissance visit to this area with logistic support from the Geological Survey of Iran, after getting authorization from Mr. Khadem (Director of GSI). Tiechert, Flugetl, and Stepanov met in Tabriz on 6 October, 1966, where they were joined by W. Graf and Mehrnush of the Geological Survey of Iran.

Kuh-e-Ali Bashi was visited by the party on 7 October and it was apparent that rocks of Permian age occupied a considerable area in that range. The presence of Triassic rocks was also confirmed. The locality of Ali Bashi section was situated about 8 km west of Julfa.

The Geological Survey of Iran developed this project by Stepanov, Golshani, and Stocklin (1969). These authors describe Permian and Triassic sections from Keh-e-Ali Bashi. Stepanov *et al.* indicated the Gnishik and Khachik beds as Guadalupian and the age of the Julfa beds as Dzhulfian. In the latter stage they also included the lowermost unit (*Phisonites-Comelicanina* Assemblage zone) of their "Permo-Triassic transition beds" without stating specific reasons. In the zonation of the upper part of the "transition beds" by ammonoid genera, Stepanov *et al.*, adopted the scheme proposed by Shevyrev (in Ruzhentsev and Sarycheva,

1965), but their conclusions were based on extremely limited material, not on critical paleontological studies.

Teichert and Kummel, after examining their large fossil collection, concluded that the "Permian-Eotriassic transition beds" of Stepanov *et al.* (1969) were in fact of Late Permian age and, indeed, the Permian-Triassic boundary should be placed at the top of the *Paratirolites* beds. They also proposed the name Ali Bashi Formation for the lithologic unit that lies between the top of the Julfa beds and the base of the thin bedded medium grey limestone containing *Claraia* that can be correlated with the Elika Formation, including the *Phisonites* Zone as well as the *Paratirolites* limestone.

Stratigraphy of the Jolfa Formation

The writer visited Kuh-e-Ali Bashi in June, 1992, spending one month on field studies. After one day reconnaissance a suitable locality was chosen on the western flank of the Kuh-e-Ali Bashi, just north of the Selgord village. Detailed measurement and sample collection carried out carefully throughout the type section. The basal part of the section at Kuh-e-Ali Bashi is faulted.

The result of the investigation of the microfauna of the "Gnishik and Khachik beds" indicated an Early Dzhulfian age, thus the age of the Gnishik and Khachik beds are time equivalent to the Nessen Formation (Glaus, 1964) in the Alborz Range, and correlate with the Abadeh Formation (H. Taraz, 1974).

As the stratigraphic section (fig. 3) shows, owing to the rules of the International Stratigraphic Guide, the names of Gnishik and Khachik beds are omitted and instead the Selgord (Gnishik) and Shammar (Khachik) members are proposed. The names of Selgord and Shammar are derived from the Selgord and Shammar villages near the Ali Bashi type section. The

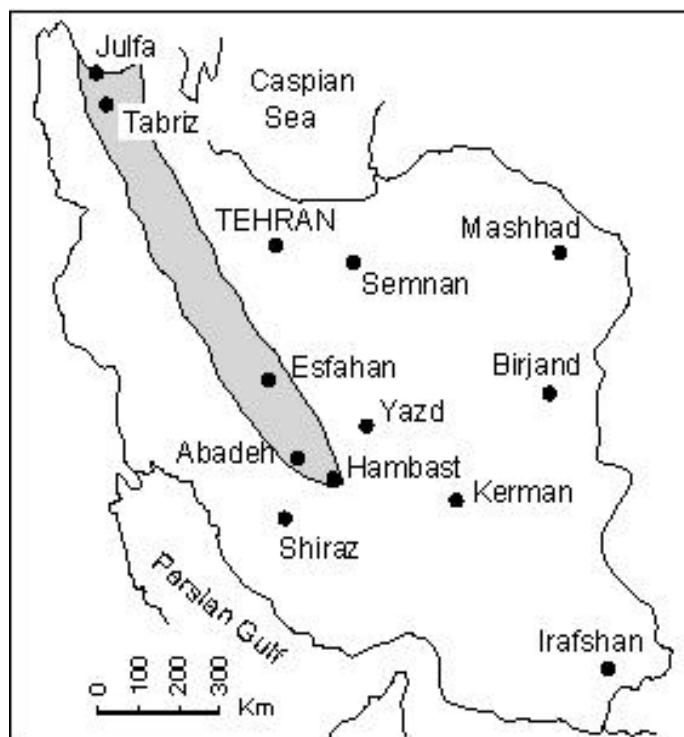


Figure 1. Index map showing the Julf-Hambast Trough Belt.

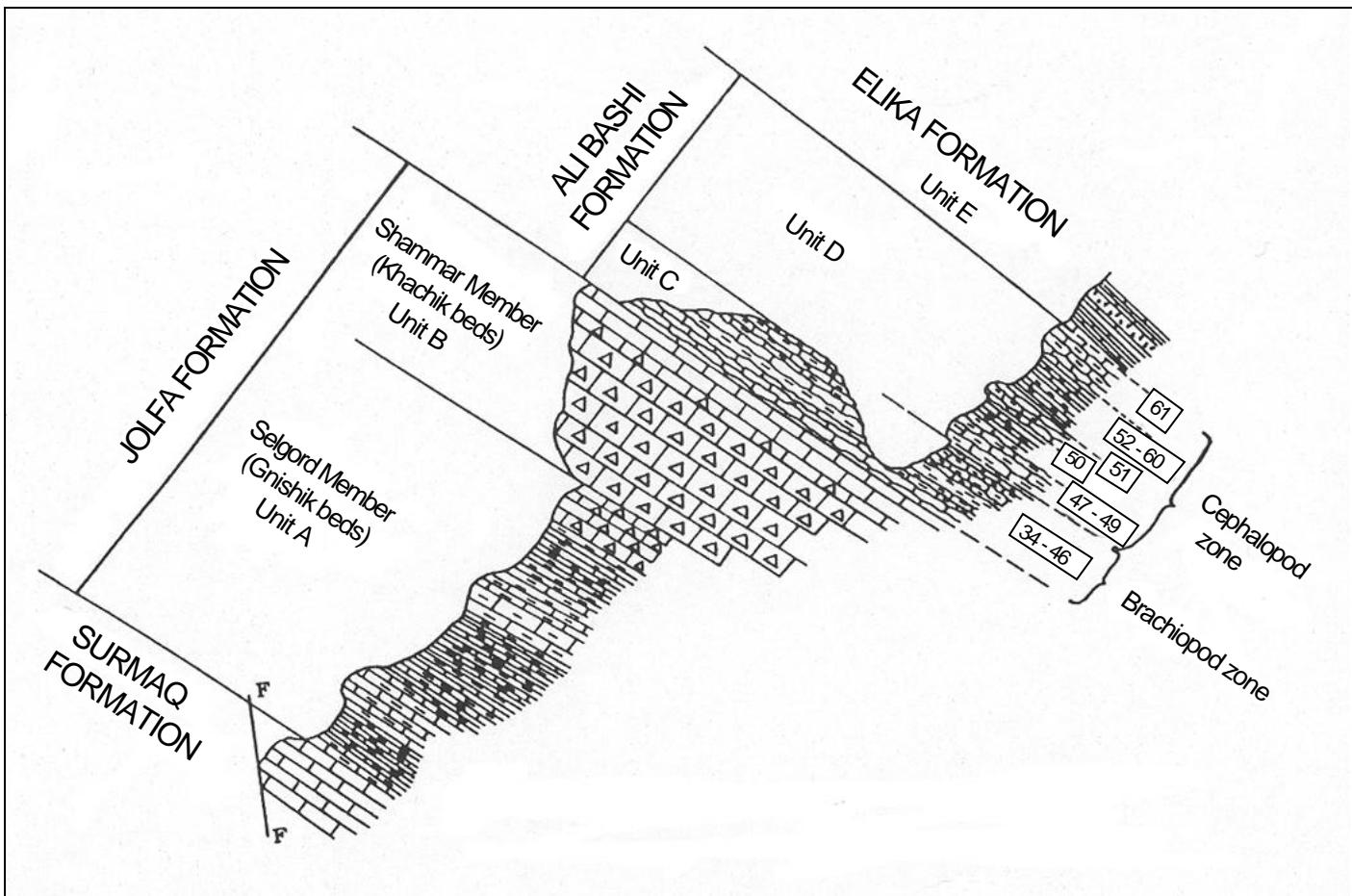


Figure 2. Schematic of Permian-Triassic sediments at Kuh-e-Ali Basi west of Jolfa region.

Jolfa Formation is proposed for the lithologic units of Selgord and Shammar Members, and were accepted by the National Stratigraphic Commission of Iran (NCSI) in 1995.

Lithology

The sequence from bottom to the base of the Jolfa Formation (fig. 3) consists of a 32 m, grey to cream weathering, medium bedded, rubbly, dominantly carbonate sequence, equivalent to the uppermost part of the Surmagh Formation (Taraz, 1973) in the Abadeh region (Central Iran). The Jolfa Formation includes two units, unit A or the Selgord Member (Gnishik beds, Arakelian, 1964) and unit B or the Shammar Member (Khachik beds, Arakelian, 1964).

Unit A, or Selgord Member, consists of 153 m of grey to dark grey, recessive, alternating marl and shale with subordinate fine-grained, medium to thin bedded fossiliferous limestone. A conspicuous dark grey medium bedded cherty dolomitic limestone forms the top of the unit.

Unit B, or Shammar Member, consists of a 120 m of grey, thick bedded, in part, massive, reddish weathering, with nodular chert parallel to the bedding plane, cliff-forming limestone.

Thus, the thickness of the Jolfa Formation according to the measurement is about 272 m at the type locality. Both the lower contact with the faulted layers of the Surmagh and the upper contact with the Ali Bashi are gradational.

Fossils and Age

The Jolfa Formation contains a diagnostic microfauna as follows: *Codonofusiella nana* Erk., *Cribrogenerina sumatrana* (Volz), *Dagmarita chanakchiensis* Reitlinger, *Frondina permica* de Civri. and Dess., *Baisalina pulchra* Reitlinger, *Paraglobivalvulinamira* Reitlinger, and *Mizzia velbitana* (Schubert). An early Dzhulfian age has been assigned to the Jolfa Formation on the basis of the above microbenthic index fauna. A close correlation exists between the microfauna of the Jolfa, Nessen, and Abadeh formations, including a similar benthic fauna from Dzhulfian of Nessen and Abadeh Formation in Alborz and Hambast Ranges.

Stratigraphy of the Ali Bashi Formation

The examination of microfacies and macrofossil samples has led the writer to conclude that the homogeneous texture of the Julfa beds (Stepanov *et al.*, 1969) with Ali Bashi Formation (transition beds and *Paratirolites* limestone, Teichert *et al.*, 1973), includes beds 34-61 of the stratigraphic section published by Stepanov *et al.*, 1966, containing the *Araxilevis* Zone as well as the *Paratirolites* limestone, must be combined into one rock unit. Thus, the extension of chronostratigraphy and geochronology of the Ali Bashi Formation is proposed from the top of the Shammar Member (Khachik beds) and the base of the grey to reddish thin bedded, slaty limestone, containing *Claraia* and vermicular limestone, equivalent to the Lika Formation (Glaus, 1964) of the Albroz Range, so that the Ali Bashi Formation is absolutely equivalent to the Hambast Formation (Iranian-Japanese Research Group, 1980) in the Abadeh region.

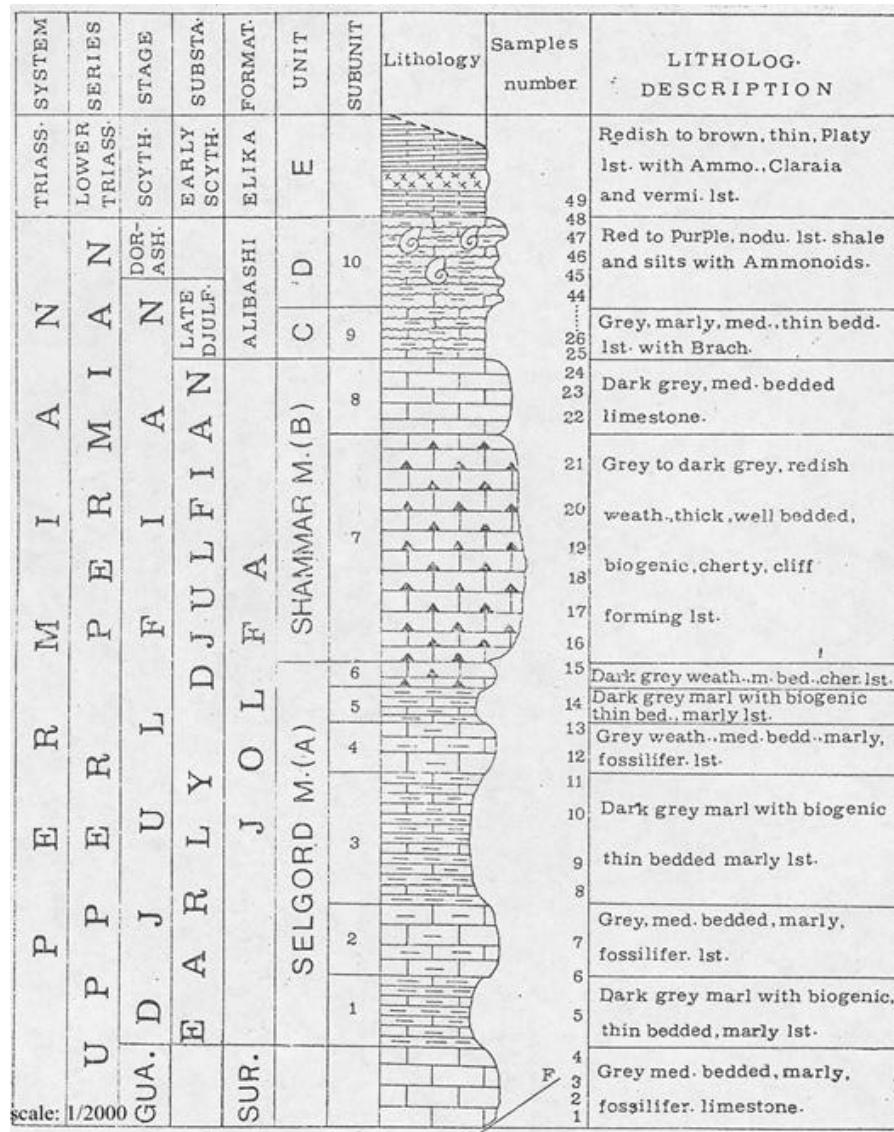


Figure 3. Stratigraphic section of Upper Permian and Permian-Triassuc boundary at Kuh-e-Ali Bashi, west Jolfa.

Lithology

The sequence of the Ali Bashi Formation is divided into two units, unit C and unit D. Unit C consists of pale grey, wavy, nodular, medium bedded marly limestone, intercalated with grey, anhydritic marl with abundant brachiopods, so that it is called the “brachiopod zone”; the name is derived from the profusion of brachiopods, which characterize this unit. This unit includes beds 34-46 of Julfa beds published by Stepanov *et al.*, 1969. The thickness of this unit is about 20-25m. Unit C conformably overlies the Shammar Member (Khachik beds); the top contact with Unit D is conformable and gradational and Unit D consists of red to purple, nodular limestone and alternating silty shale with abundant cephalopods, so that it is called the “cephalopod zone”. Its bottom part is made up of reddish, medium bedded wavy limestone, containing *Vedioceras*, includes beds 47-49 of Julfa bed (Stepanov *et al.*, 1969). The middle part is interbedded red to purple. Recessive shale and thin bedded wavy limestone, containing *Phisonites* up to *Bernhardites*, comprises beds 50-60

of the transition beds (Stepanov *et al.*, 1969). The top part is a reddish, medium to thick bedded, cliff forming limestone, containing *Paratirolites*, includes bed 61 of *Paratirolites* limestone (Stepanov *et al.*, 1969); this interval is called the *Paratirolites* Limestone Member and forms an important unit within the Ali Bashi Formation. The thickness of unit D is 30 m. The top contact with the Lower Triassic beds is gradational (by result of conodonts) and conformable. The thickness of the Ali Bashi is 55m (fig. 3).

Fossils and age

Due to lack of microfauna throughout the Ali Bashi Formation, the writer applied the eight megafossil biozones which Stepanov described and established for the Ali Bashi Formation (Julfa beds, transition beds, and *Paratirolites* limestone), in descending order: *Paratirolites* zone, *Bernhardites* zone, *Dzhulites* zone, *Tompophiceras* zone, *Phisonites-Comelicania* assemblage zone, *Haydenella-Pseudowellerella* assemblage zone, and *Araxilevis-Orthotetina* assemblage zone. The Julfa beds embrace beds 34-51 of Stepanov *et al.*, 1969, contain the *Araxilevis* up to *Haydenella* assemblage zones, indicating a post early Dzhulfian age (fig. 5), because the Julfa beds were formed in the Tethys trough (Jolfa-Abadeh belt) after Hersynian movement; therefore, it should be noted, that the Julfa beds which are definitely post early Dzhulfian in age, must be late Dzhulfian in age. The Dorashamian Stage ranges from the first appearance of the *Phisonites* Zone up to the end of the *Paratirolites* limestone.

Conodonts

Conodont rock samples were collected from the Permian-Triassic boundary strata at Kuh-e-Ali Bashi, E. Shah-Resa, and Kuh-e-Hambast. The conodont examination of the uppermost Permian boundary (*Paratirolites* beds) from the “Ali Bashi-Hambast belt” contains *Clarkina changxingensis* (Wang and Wang) Zone, indicating a late Dorashamian or Changhsingian age. Conodont samples from the above area, from the Lower Triassic sequence immediately above the *Paratirolites* beds, include in descending order: *Isarcicella isarcica* (Huckriede) zone, *Hindeodus parvus* (Kozur and Pjatakova), *Hindeodus typicalis* (Sweet), and *Hindeodus minutus* (Ellison). These conodonts are Early Griesbachian in age and show a transitional and continuous sedimentary record for the Permian-Triassic boundary in this trough.

Conclusion

As the stratigraphic section (fig. 3) shows, owing to the rules

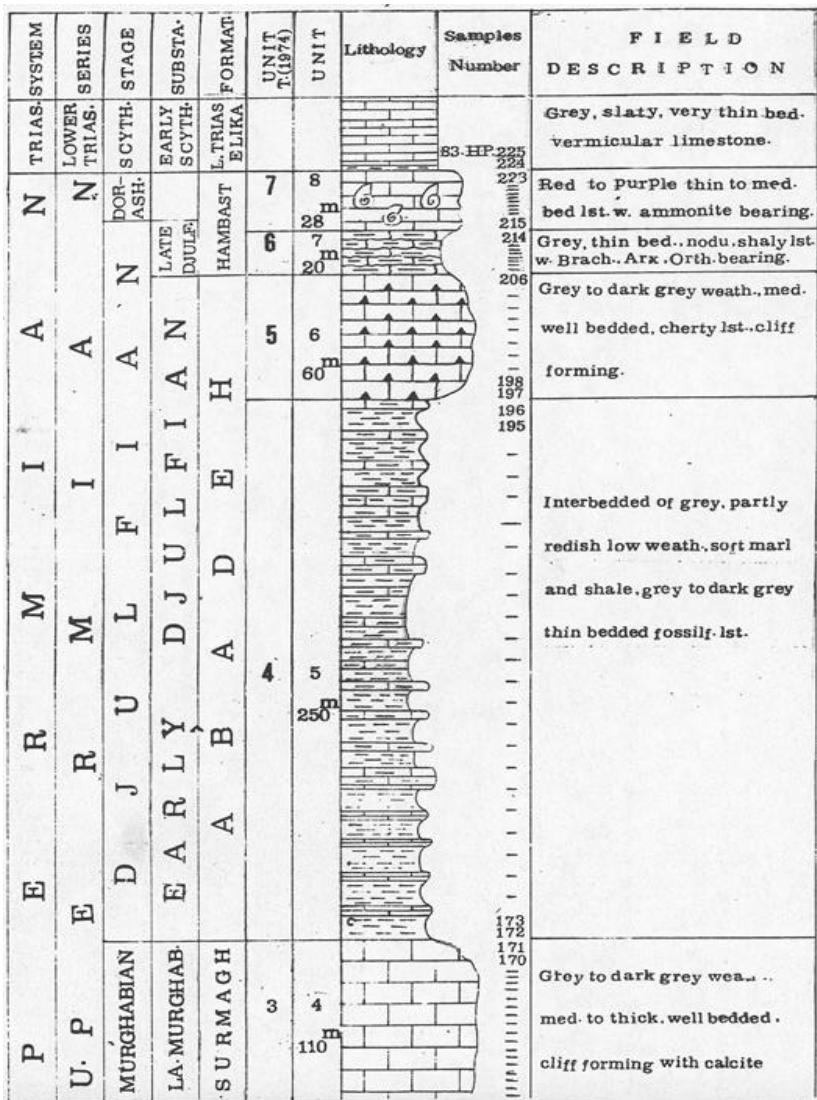


Figure 4. Stratigraphic section of Permian sequence at Kuh-e-Hambast and Abadeh region, Central Iran.

of the International Stratigraphic Commission, the names Gnishik and Khachik beds are omitted and the Selgord and Shammar Members are proposed in their place, as members of the Jolfa Formation. The Jolfa Formation was introduced and accepted by the National Stratigraphic Commission of Iran and an early Dzhulfian age has been assigned to the Jolfa Formation. The Jolfa Formation correlates with and is equivalent to the Nessen Formation (Glaus, 1964) in the Alborz Range and the Abadeh Formation (Taraz, 1974) in Central Iran.

The Ali Bashi Formation includes the Julfa beds, transition beds, and *Paratirolites* limestone of Stepanov *et al.* (1969). The Ali Bashi Formation is equivalent to the Hambast Formation. The Permian-Triassic boundary in the Ali Bashi section, west Jolfa region, in Esfeh, northeast of Shah Reza, and in the Hambast Range (Central Iran) are transitional and conformable.

The most important conclusion is that consequently during the Hersynian movement and the formation of Pangea, which was culminated by the closing of the Tethys sea, a trough of the Tethys sea remained open through the Jolfa-Abadeh belt and sedimentation was continuous there during the Permian-Triassic boundary.

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RUSSIAN JULFA RZHENTSEV & SARYCHEVA, 1964				I R A N I A N J U L F A							
				STEPANOV et al. 1969		TEIOH-KUM- & SWE.. 1973		PARTOAZAR, 1992			
SERIES	STAGE	ZONE	ZONE	ROCK UNIT	STAGE	ROCK UNIT	STAGE	ROCK UNIT	UNIT	STAGE	SERIES
UPPER PERMIAN GUADALUPIAN D Z H U L F I A N	LOWER TRIASSIC INDUAN	Claraia	Claraia	Claraia Beds	Ali Bashi	LOWER ELIKA	SCYTHIAN	LOWER ELIKA	E	SCYTHIAN	TRIAS.
		Paratirolites	Paratirolites	Paratirolit- lst.		Trasition Beds		Ali Bashi	SCYTHIAN		
		Bernhardites	Bernhardites								
		Dzhulfites	Dzhulfites								
		Tampophiceras	Tampophiceras								
	Dzhulfian	Phisonites— Comelicania	Phisonites— Comelicania		Upper Julfa Beds	Upper Julfa Beds	DORASHAMIAN		D	DORASHAMIAN	SCYTHIAN
		Vedioceras— Haydenella	Haydenella— pseudowellerella								
		Araxoceras— Oldhamina	Pseudogastric- Permophericodo-			Lower Julfa Beds					
		Araxilevis	Araxilevis— Orthotetina								
		Codonofusiella— Reichelina	Codonofusiella— Reichelina	Khachik Beds		Khachik Beds					
UPPER PERMIAN GUADALUPIAN D Z H U L F I A N	Khachik Horizon				GUA DALUPIAN DZHULFIAN		Jolfa Form. (Nessen Eqv.)	A l i B a s h i		DORASHAMIAN	SCYTHIAN
		Gnishik Horizon		Gnishik Beds		Gnishik Beds					
				Selgord Shammard U.A. U.B.	C						
				D Z H U L F I A N EARLY	LATE			DORASHAMIAN			
				UPPER PERMIAN	PERMIAN						

Figure 5. Correlation chart of the Permian-Lower Triassic biozones and rock unit between Russian Jolfa and Iranian Jolfa.

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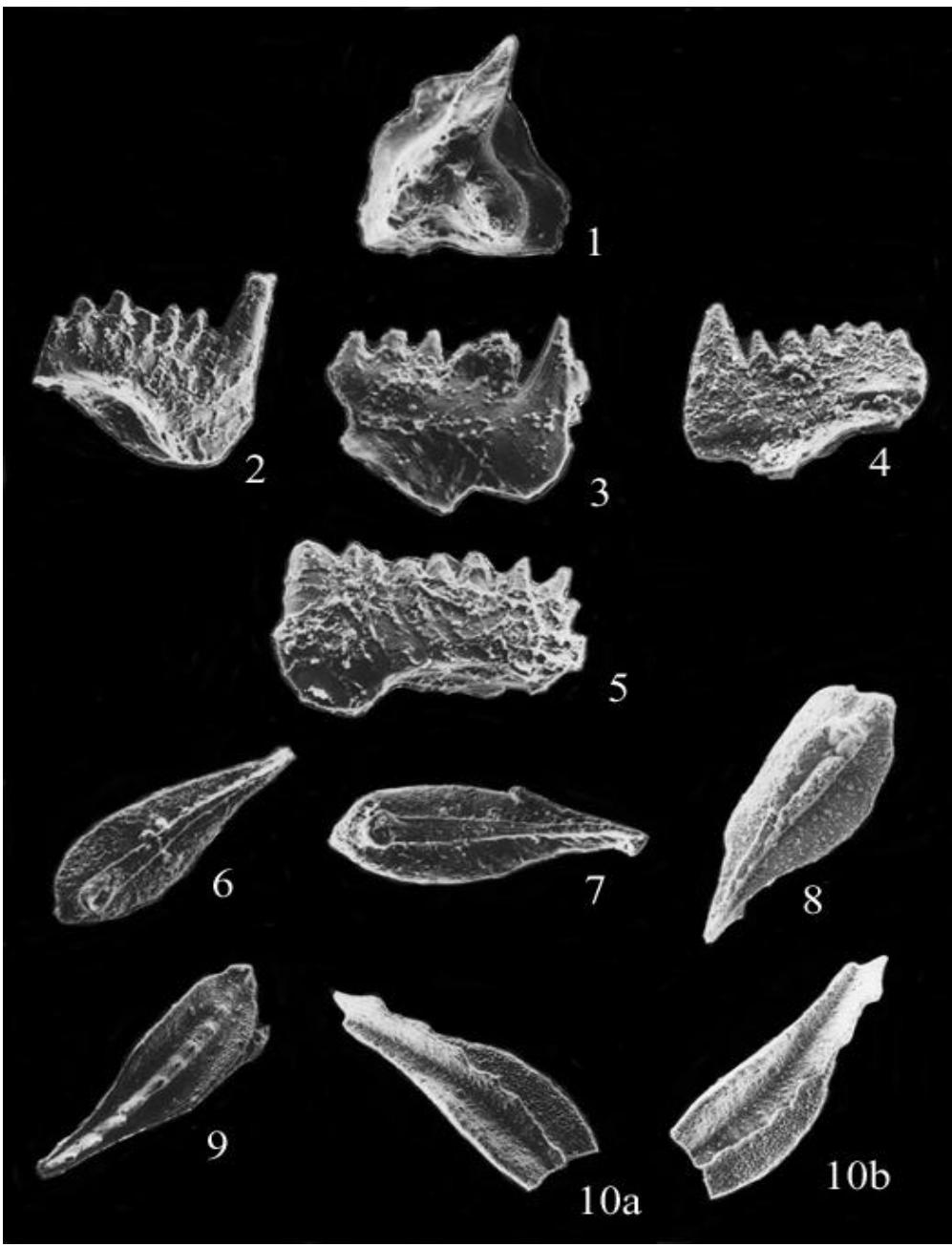


Plate 1.

Figure 1. *Isarcicella isarcica* (Huckriede, 1958) Julfa outcrop section, sample no. 92.P.T.1, Early Triassic, uppermost part of the *Hindeodus parvus* zone.

Figures 2-4. *Hindeodus parvus* (Kozur and Pjatakova, 1975) Hambast outcrop section, sample no. 95.P.T.4, Early Triassic (Early Griesbachian).

Figure 5. *Hindeodus minutus* (Ellison, 1941) Hambast outcrop section, sample no. 95.P.T.4, Early Triassic (Early Griesbachian).

Figures 6-11. *Clarkina changxingensis* (Wang and Wang, 1981) Hambast outcrop section, sample 95.TS.1, Late Permian (Dorashamian)

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Definition of the Lopingian base with the FAD of *Clarkina postbitteri postbitteri*

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Since the discrimination of *Clarkina postbitteri* by Mei and Wardlaw, 1994, the first appearance of this species in the Penglaitan section was chosen as the base of the Lopingian Series. This view was well discussed by Jin Yukan *et al.* (1998) and Mei *et al.* (1998). The holotype of *C. postbitteri* is derived from sample LD 115 which is shown by MEI *et al.* (1998) to be derived from the thin bed 6j between the thicker beds 6i and the much thicker bed 6k. From bed 6k to this time only the upper part was sampled in sample 114.6. This clear position for the stratum typicum of *C. postbitteri* cannot be misinterpreted in any careful scientific paper, the more as the thin bed 6j between the much thicker beds 6i and 6k has a lithology different from these two beds. The holotype is an adult Pa element, a slender form with rounded posterior end, densely spaced denticles and gradually tapering anterior platform; on one side the anteriomost platform is seemingly damaged at a crack which is also to seen on the other side. It is re-figured in Fig. 1 d. Two juvenile forms illustrated by Mei *et al.* (1994, Pl. 1, Figs. 3, 4) show widely separated denticles (a feature which occurs even in juveniles of the forerunner, *M. stampflii*, see Fig. 2 d) and partly a more abrupt narrowing of the anterior platform. A subadult form illustrated by Mei *et al.* (1994, Pl. 1, Fig. 5) is in its features transitional between the adult holotype and the juvenile forms. As a whole, *C. postbitteri* was well defined in form taxonomy for a *Clarkina* Pa element. The FAD of *C. postbitteri* and therefore the base of the Lopingian was indicated in Mei *et al.* (1998) and in later publications (e.g. Jin Yukan, 2000) in the upper part of bed 6i. All important contributions of Jin Yukan and co-workers about the base of the Lopingian were focussed to this boundary. The proposal to define the base of the Lopingian with the upper part of bed 6i by the FAD of *C. postbitteri* was repeated until 2001 (Jin Yukan *et al.*, 2001a).

During the International Congress Geology of Oman, I have sampled the entire Wadi Wasit section in the Hawasina nappes. Red ammonoid-bearing limestones in the lowermost part yielded *Waagenoceras* and other Wordian ammonoids (Blendinger *et al.*, 1992, Pillevuit, 1993) and *Timorites* (material and determination L. Krystyn, Vienna). The conodonts consists mainly of *M. siciliensis* (Kozur) and dominating *Mesogondolella omanensis* Kozur and Wardlaw which was erroneously assigned to the Kungurian *M. idahoensis lamberti* by Mei and Henderson (2002) to "prove" their preconception of a Kungurian age for these beds. Above this level, *M. siciliensis* becomes very rare, the last typical forms occur 7.1 m above the ammonoid-bearing horizon, where also *M. stampflii* and *Iranognathus erwini* and other *Iranognathus* species appear. *M. omanensis* is dominant until 8.7m above the ammonoid horizon. Until 16m above the ammonoid horizon both *M. omanensis* and *M. stampflii* are common, then *M. stampflii* dominates and the last rare *M. omanensis* occurs 26.8 m above the ammonoid horizon. *C. postbitteri* begins 31.7 m above the ammonoid horizon. Very interesting faunas across the Guadalupian-Lopingian boundary occur in Batain (Oman), which will be described by Kozur, Baud and Richoz (in prep.) They allow exact correlation of the conodont zonation with the radiolarian zonation which is much better suitable for cor-

relation than the conodont zonation because the radiolarians occur with the same species in intraplatform and open sea deposits of the warm water belt, whereas the conodonts show very strong provincialism within the warm water belt. Conodont faunas dominated by *M. stampflii* occur in the *Parafollicuculus convexus-F. porrectus* Zone and in the *F. ventricosus-I. scholasticus* Zone. The first zone occurs in the Delaware Basin in the *M. shannoni* Zone, the latter zone begins in the Delaware basin at the base of the *M. altudaensis-C. crofti* Zone in the topmost centimetres of the Lamar Limestone and ranges up to the top of the Capitanian. The *C. postbitteri* Zone corresponds to the *Cariver orthogonus-Ishigaconus hamatus* Zone, a very typical Lopingian fauna. *M. stampflii* and *C. postbitteri* occur also in Sicily, but in blocks and not in superposition. Most important is the fact that the endemic *C. postbitteri* "postbitteri" sensu Mei and Henderson (2001) does not occur in the Tethys and in any other region outside its occurrence in three sections in South China. Such an endemic form is absolutely unsuitable for definition of the Lopingian series, the more as the typical Lopingian radiolarian and holothurian fauna begins at the base of the *C. postbitteri* fauna and not in its upper part.

The transition from *M. stampflii* to *C. postbitteri* is gradual. Both species show intraspecific variations of the anterior platform which partly gradually tapers, partly it narrows more abruptly, but the denticulation is rather constant. Adult forms have densely spaced, sometimes fused denticles, whereas juvenile forms have widely spaced denticles. The posterior end is rounded or obliquely rounded in *M. stampflii* and in primitive *C. postbitteri*, whereas in the upper range of *C. postbitteri* first forms with bluntly rounded posterior end occur which are transitional to *C. dukouensis*.

The interval with transition forms between *M. stampflii* and *C. postbitteri* and the interval with primitive *C. postbitteri* which are exclusively represented by forms with round posterior end and narrowly spaced denticles is in Oman several metres thick, which represent rather much time because the sections show a low sedimentation rate. This interval is absent in the Penglaitan section and in all other South Chinese intraplatform basin sections indicating a distinct gap and interval without gondolellids in all South Chinese intraplatform basin sections. Any gap or shallowing close to the Guadalupian-Lopingian boundary cannot be observed in the pelagic sections of Oman indicating that the water depth was distinctly deeper than the maximum sea level drop close to the Guadalupian-Lopingian boundary.

Primitive *C. postbitteri* with rounded or obliquely rounded posterior end and narrowly spaced denticles are also present in the Apache Mts. of the Delaware Basin (Wardlaw *et al.*, 2001). As in Oman, the development of the anterior platform is very variable in primitive *C. postbitteri*. There are forms in which the anterior platform tapers gradually and other forms in which the anterior platform narrows abruptly (as also shown in the illustrated specimen by Wardlaw *et al.*, 2001, Fig. 1). This feature can be therefore not used as an important feature for discriminating of subspecies within *C. postbitteri*. I have re-sampled the pre-Castile beds of the Apache Mts. for studying the changes in radiolarian and ostracod faunas around the FAD of *C. postbitteri*. The conodont data by Wardlaw *et al.* (2001) were confirmed. The beginning of the hypersaline Castile Formation was either distinctly later than the gap in the Penglaitan section between the Guadalupian and

Lopingian or the gap in Penglaitan was much longer than assumed. If it was inside the *C. postbitteri* Zone and caused by a sea-level drop in this level (within the *C. postbitteri* Zone of early Lopingian), then by this gap both the lower and middle *C. postbitteri* Zone and the part with transitional forms between *M. stampflii* and *C. postbitteri* (uppermost Capitanian) can be removed. This would explain the contradiction that in South China the *C. postbitteri* Zone begins above the world-wide sea-level drop, in the Delaware Basin below it.

The data from Oman and from the Apache Mts. clearly show that the original proposal for the base of the Lopingian with the FAD of *C. postbitteri* (e.g. Jin Yugan *et al.*, 1998) is a good and acceptable boundary, which can be traced in the Tethys and in North America. Any higher boundary (FAD of *C. dukouensis* or advanced *C. postbitteri*) would leave a substantial part of the Lopingian fauna (at least one major radiolarian zone with a typical Lopingian radiolarian fauna) within the Capitanian. On the other hand, the data from Oman and Apache Mts. show that the Penglaitan section is unsuitable for defining the base of the Lopingian because of a gap and a gondolellid-free part in the lower and middle *C. postbitteri* Zone.

Henderson (in Jin Yugan, 2000) tried to solve this problem and use both the good boundary with the FAD of *C. postbitteri* and the unsuitable Penglaitan section for definition of the base of the Lopingian. He regarded *M. granti* Mei and Wardlaw as the fore-runner of *C. postbitteri* because it is the youngest species below the first appearance of *C. postbitteri*. Otherwise, the two species are quite different and have no range-overlap. This was explained by punctuated evolution. However, this explanation is very improbable. Close to the Guadalupian-Lopingian boundary all gondolellid conodonts disappeared in the South Chinese intraplatform basins of the Ouachita-Cathaysia faunal province which is characterised during the Guadalupian by the exclusive occurrence of serrated *Mesogondolella*. The new invasion of conodonts with the early Lopingian transgression brought Tethyan faunas (where in the Capitanian only smooth gondolellids are present) into the South Chinese intraplatform basins, among them *C. postbitteri*, but only advanced forms as clearly seen by comparison of the Chinese forms with the Tethyan and North American ones. *C. postbitteri* has evolved in the Tethys from the upper Capitanian smooth *M. stampflii* (Fig. 2), from which it is mainly distinguished by the plane attachment surface. Even such a feature as the widely separated denticles in juvenile forms and the closely spaced and partly fused denticles in adult forms are present at the *M. stampflii* (Fig. 2d).

Henderson *et al.* (2001) changed their mind and proposed the base of the Lopingian higher, at the base of bed 6k in Penglaitan with the FAD of *C. postbitteri postbitteri* n. subsp. (sic!) Henderson and Mei, 2001. Below this level only *C. postbitteri hongshuiensis* n. subsp. Henderson and Mei, 2001 should occur. They referred to a paper Henderson and Mei (2001), which really appeared in April 2002 and in the last moment Wardlaw was added as co-author to this then Henderson *et al.* (2002) paper. As pointed out by Kozur and Wang Cheng-yuan (2002), the taxonomic subdivision of *C. postbitteri* by Henderson *et al.* (2001) contains two very serious violations of the International Code of Zoological Nomenclature (ICZN). (1) The nominate subspecies cannot be a new subspecies but as its holotype is the holotype of the species, this new subspecies is an objective junior synonym of *C. postbitteri* and must be

correctly assigned to *C. postbitteri postbitteri* Mei and Wardlaw, 1994. (2) As the nominate subspecies has the same holotype as the species, it must be related to this holotype. But the holotype of *C. postbitteri hongshuiensis* perfectly corresponds to the holotype of *C. postbitteri* and, therefore *C. postbitteri hongshuiensis* is a junior synonym of *C. postbitteri postbitteri*. The adults of *C. postbitteri postbitteri* sensu Henderson *et al.* (2001, 2002) are quite different from the holotype of *C. postbitteri* and are the real new subspecies, which is herein discriminated as *C. postbitteri sinensis* n. subsp. As Wardlaw was added in the last moment as co-author to the Henderson and MEI paper (2001) paper to which was referred by Henderson *et al.* (2001) for discrimination of the two subspecies of *C. postbitteri* (Henderson *et al.*, 2001), he obviously removed the first mentioned violation of the ICZN and in Henderson *et al.* (2002) *C. postbitteri postbitteri* is correctly assigned to Mei *et al.* (1994). But the second violation of the ICZN, which is connected with the first one, remained. As Henderson *et al.* (2001) originally regarded *C. postbitteri postbitteri* as a new subspecies, they did not take care that this nominate subspecies corresponds to the holotype of the species. Thus, the forms that they assigned to *C. postbitteri postbitteri* do not correspond to the holotype of this species, whereas the holotype of *C. postbitteri hongshuiensis* fits very well to the holotype of *C. postbitteri* (see above, compare Fig. 1d with Figs. 1e and c).

Immediately after the new taxonomic subdivision into *C. postbitteri postbitteri* and *C. postbitteri hongshuiensis*, it was proposed to take the FAD of *C. postbitteri "postbitteri"* in Bed 6k of the Penglaitan section as base of the Lopingian before any discussion to the taxonomy of these two subspecies and the quality of the new definition could be made. At first two options, the original base with the FAD of *C. postbitteri*, and the FAD of *C. postbitteri "postbitteri"* were presented to the Lopingian working group for voting. None of these proposals got a majority. Then, without any reason from the previous voting, only the latter variant was sent to the Lopingian working group for voting and this proposal got 92 % agreement from the 19 members of the working group. The same results or more (Kozur had voted with yes) also the first variant had got, if presented alone. Without any scientific discussion of the new proposal, the decision should be made simply by different voting, so long, until a majority is present. The 92 % yes-votes among 19 members of the Working Group is a funny number, as it means 1.5 members had rejected the proposal. Wang Cheng-yuan was taken as having 50 % approved despite the fact that he had rejected the proposal. He wishes the definition with the FAD of *C. dukouensis*, which he believes to begin in bed 6k, but it begins higher. This makes a rejection to a half approval.

The first scientific discussion of the proposal to use the FAD of *C. postbitteri "postbitteri"* as base of the Lopingian was made by Kozur and Wang Cheng-yuan (2002) after the voting (there was absolute no time to publish it before the voting). The two answers by Henderson and Mei and Wardlaw and Henderson in the same issue contain a lot of polemic but no answer to the most important questions. The main arguments by Kozur and Wang Cheng-yuan against the use of the FAD of *C. postbitteri "postbitteri"* were: 1.) The subdivision of the *C. postbitteri* is taxonomically not well founded. 2.) *C. postbitteri "postbitteri"* is independent of its taxonomic status an endemic form which is only known from South China where it was reported from three sections. Neither in North America nor in the Tethys, is this taxon

present. In contrast, *C. postbitteri* "hongshuiensis" (=*C. postbitteri* s.s. according to the holotypes) is present in South China, in the Tethys and in the Delaware Basin. Additionally was written that in the original paper until Mei *et al.* (1998) the stratum typicum of *C. postbitteri* (sample LPD 115) was indicated to be derived from bed 6j in which according to Henderson *et al.* (2001, 2002) only *C. postbitteri* "hongshuiensis" is present.

The latter, less important point was the only to which we got an answer by Wardlaw and Henderson (2002). They wrote that according to Zhu Zili sample LPD 115 does not correspond to bed 6j as always indicated, but to bed 6k, a bed of totally different thickness and different lithology. The answer is not too much convincing. The quoted remarks of Jin Yukan rather strengthen the doubt about the exact position of the samples in Penglaitan section than to remove the doubts. It was presented an information of Dr. Jin Yukan that it is clearly indicated that LPD 115' corresponds to bed 6j and LPD 115 to bed 6k. However, in Jin Yukan *et al.* (2003) was shown that sample LPD 115' is derived from the base of bed 6i. Furthermore was stated by Jin Yukan in Wardlaw and Henderson (2002) that in 1993 he and Zhu Zhili collected "a sample from each single bed of Bed 18". This statement is confirmed by the data in Mei *et al.* (1998) indicating one sample (LPD 115') in Bed 6i, one sample (LPD 115) in bed 6j, and one sample (LPD 114.6) in the upper part of bed 6k. When now is pointed out that sample LPD 115 is from bed 6k, then this is in contradiction to the statement that from every bed a sample was taken, instead in this case no sample was taken from bed 6j and two samples were taken from bed 6k. Which statement in Wardlaw and Henderson (2002) is correct? If samples were taken from every bed, then sample LPD 115 must be from bed 6j as indicated in Mei *et al.* (1998) or sample LPD 115 is from bed 6k and then bed 6j was not sampled and two samples have been derived from bed 6k. Is sample LPD 115' from bed 6j, as "clearly indicated" by Wardlaw and Henderson (2002) or from bed 6i as indicated in all other papers? When sample 115' has been derived from bed 6i, then no sample was present until Jin Yukan *et al.* (1998) from bed 6i. How could be then shown in Mei *et al.* (1998) that *C. postbitteri* begins in bed 6i? And why was sample LPD 115' indicated both in Mei *et al.* (1998) and in Jin Yukan *et al.* (2003) in bed 6i? Thus the "upward-shift" of samples LPD 115' from bed 6i to bed 6j and LPD 115 from bed 6j to bed 6k brings more problems with the real position of the samples in the Penglaitan section than it solves. In such situation it is irresponsible to made now the voting about the base of the Lopingian instead to resample the critical interval from bed 6i to bed 6k by an international group (not only consisting of representatives of one view), and to postpone the voting until results are present. Moreover, our material from bed 6j exactly corresponds to the type series figured by Mei *et al.* (1994) and the holotype of *C. postbitteri* perfectly corresponds to *C. postbitteri* "hongshuiensis" which should not more occur in bed 6k according to Jin *et al.* (2003)! Moreover, it is interesting that the change of the stratum typicum was published just in that moment, when the derivation of sample LPD 115 was favourable for the attempt to change the stratum typicum to the base of bed 6k.

Henderson and Mei (2002) starts their replay with contentless polemics that detailed stratigraphic sections and illustrations had to be published by Kozur and Wang (2002) before they can react to "unsubstantiated negative claims of others". How we could publish sections and illustrations to prove that the taxonomic sub-

division of the two subspecies are superficial and violate the ICZN, three month after the subdivision of *C. postbitteri* into two subspecies? What we could do, and what we have done, is to show that there are contradictions in the originally and later shown stratum typicum for *C. postbitteri*, that the subdivision of *C. postbitteri* was taxonomically superficial and violates the ICZN, and that *C. postbitteri postbitteri* sensu Henderson *et al.* is an endemic taxon known only in three section in South China. Why the base of the Lopingian should be defined by a taxon which is restricted to a small part of South China, when its forerunner, *C. postbitteri* "hongshuiensis" has a wide distribution from South China through the Tethys to North America and was originally used to define the base of the Lopingian with arguments that are also today acceptable (funny enough by the same authors)? They could reject our view about the endemic character of *C. postbitteri postbitteri* sensu Henderson *et al.* by presenting a section outside South China, which contains adult specimens of *C. postbitteri* "postbitteri", but this was not done because this taxon is not present outside a small area of South China. What is not present, we cannot illustrate, even not, if we had enough time to do it. But Wardlaw and Henderson polemically rejected the view that *C. postbitteri* "postbitteri" is an endemic form without presenting any section outside South China, which contains this taxon. Instead they wrote: "The material from the Delaware Basin is badly misinterpreted. Please refer to the soon to be published article by Lambert *et al.* (2002) for the correct distribution of conodonts from the upper part of the Guadalupian in its type area. Of important note here, is that the Chinese succession documented at Penglaitan is presented there including the first occurrence of *Clarkina postbitteri hongshuiensis* and that Lambert *et al.* correlate the Delaware Basin sections bed for bed with those at Penglaitan. If this endemic, then certainly we can live with this kind of endemism in global correlation." We cannot live for global correlation with such endemism because we have written about endemism of *C. postbitteri* "postbitteri" and not about endemism of *C. postbitteri* "hongshuiensis". In contrast, we have written that this taxon occurs not only in South China, but also in the Tethys and in the Delaware Basin immediately below the Castile beds. Moreover, the this was the only remark about conodont distribution in the Delaware Basin, first published by Wardlaw *et al.* (2001), confirmed by my own sampling of this section for radiolarians and ostracods (conodonts as "by-product") and confirmed again by the above reference in Wardlaw and Henderson (2002). Where is there the "bad misinterpretation" of the conodont distribution in the uppermost Guadalupian by Kozur and Wang Cheng-yuan (2002)? Pure polemic without scientific background to replace a scientific answer which can not be given because *C. postbitteri* "postbitteri" is not known from any section outside South China. The bed-by-bed correlation of Penglaitan with the Delaware Basin is an unrealistic dream. How do correlate the gondolellid-free beds in the Penglaitan section at the Guadalupian-Lopingian boundary with the Delaware Basin? With the upper *M. granti* fauna or with the lower or middle *C. postbitteri* Zone? How do correlate with the Delaware basin the rather thick beds 3a, 3 b and most of 3 c of Penglaitan with only *Hindeodus* sp. or without conodonts? Sometimes we even do not know exactly from where are derived the samples in the Penglaitan section. Sample LPD 115' may be derived "clearly" from bed 6j (Wardlaw and Henderson, 2002), from the middle part of bed 6i (Mei *et al.*,

1998) or from basal part of 6i (Jin Jugan et al., 2003). In the Penglaitan section *M. altudaensis*, *M. praexuanhanensis* and *M. xuanhanensis* follow over each other without overlap (Mei et al., 1998), in the Delaware Basin they largely overlap each other (Wardlaw, 1996 and own data). The Guadalupian of intraplatform basins in the Ouachita-Cathaysia conodont province is well correlatable between South China and the Delaware Basin by serrated *Mesogondolella* (but, of course, not bed by bed), but the Capitanian of the Tethys has only smooth *Mesogondolella* and in the Wordian serrated *Mesogondolella* are rare and occur only under exceptional facies (e.g. in inner atoll seas with similar bottom water conditions as in intraplatform basins). The correlation of the type Guadalupian with the Tethys is, therefore, difficult, and for people without experience in Tethyan stratigraphy obviously impossible as shown by the numerous papers of Mei and Henderson (e.g., 2001, 2002), see below.

To the taxonomic problems which Kozur and Wang Cheng-yuan (2002) have discussed, Wardlaw and Henderson wrote: "that they cannot discriminate the differences between *Clarkina postbitteri hongshuiensis*, *C. postbitteri postbitteri* and *C. dukouensis*" and that *C. postbitteri* and *C. dukouensis* "can be consistently differentiated by apparently everyone except Kozur and Wang !" For explanation everyone means Henderson, Mei and Wardlaw, the only 3 authors, which have discussed except us the separation of these taxa. The "discussion" by Wardlaw and Henderson are personal polemic without any scientific background from the Kozur and Wang Cheng-yuan (2002) paper or any other of our papers. We have not written that *C. postbitteri "hongshuiensis"*, *C. postbitteri postbitteri* and *C. dukouensis* cannot be discriminated. We even have written that *C. postbitteri "postbitteri"* may be even an independent species! I had never problems with the separation of *C. postbitteri* and *C. dukouensis* and I have never written any word about this. My separation of these two species was consistently identical with the original separation based on the holotypes and type series of the two species. Only Henderson, MEI and Wardlawt were inconsistent in separation of these two species. Mei et al. (1994) wrote that the main (and firstly mentioned) difference between *C. postbitteri* and *C. dukouensis* is that *C. postbitteri* has a round rather than a bluntly rounded posterior termination of the platform. I agree despite of the fact that some highly advanced *C. postbitteri* have a bluntly rounded posterior end. Henderson et al. (2002) regarded the "shape and outline of the platform as not particularly diagnostic" a view, which is certainly incorrect because in many cases (not always) the platform shape and outline is very diagnostic as all conodont workers know. Wardlaw and Henderson (2002) regard (correctly) again the blunt posterior end in *C. dukouensis* as the most important and firstly mentioned difference. With this, they are again back to their original differentiation between *C. postbitteri* and *C. dukouensis* and therefore again in full agreement with my separation which has never changed. If somebody could be critisized for giving inconsistent criteria for separation of *C. postbitteri* and *C. dukouensis*, then Henderson, Mei and Wardlaw!

With respect to the taxonomic separation of *C. postbitteri "hongshuiensis"* and *C. postbitteri "postbitteri"*, Kozur and Wang Cheng-yuan (2002) wrote that the ad hoc subdivision was superficial and violated basic principles of the rules of the ICZN. This is well documented even in the papers of Henderson et al. (2001, 2002) and Wardlaw and Henderson (2002). Within a few months,

the diagnosis of the assumed new subspecies *C. postbitteri hongshuiensis* was changed three times and the last revised diagnosis in Wardlaw and Henderson (2002) is very different from the first diagnosis. But this is even not the main problem. As seen in Fig. 1 the holotypes of *C. postbitteri* and *C. postbitteri hongshuiensis* belong to the same taxon, whereas *C. postbitteri "postbitteri"* comprises forms which do not correspond to the holotype of *C. postbitteri* what is according to the rules of the ICZN not possible. The holotypes of both *C. postbitteri* and of *C. postbitteri hongshuiensis* have no abrupt sharp narrowing in the anterior platform, and the platform immediately behind the anterior narrowing is identical developed in the holotype of *C. postbitteri* and in *C. postbitteri hongshuiensis*. In the contrast, forms illustrated as *C. postbitteri "postbitteri"* have all an abrupt sharp anterior narrowing of the platform and a highly flared platform just posterior to the sharp anterior narrowing of the platform. As shown in Fig. 1, the carinal denticles in the holotype of *C. postbitteri postbitteri* are even more densely spaced than in the holotype of *C. postbitteri hongshuiensis*. Again, in the contrast, all illustrated adults of *C. postbitteri "postbitteri"* have widely separated denticles, quite different from the adult holotype of *C. postbitteri*. Differences in the micro-reticulation mentioned in Wardlaw and Henderson (2002) are a very unimportant feature in gondolellid conodonts. They are directly related to marco-morphologic features. In forms with abrupt and sharp narrowing of the anterior platform this narrow anterior platform loses the micro-ornamentation, equal, in which gondolellid species or genus this is the case. As seen in Fig. 1 and from the above discussion (see also Kozur and Wang Cheng-yuan, 2002), the forms named as *C. postbitteri hongshuiensis* and *C. postbitteri postbitteri* can be separated from each other. However, the holotype of *C. postbitteri hongshuiensis* shows perfectly the same characters as the holotype of *C. postbitteri* which is, according to the rules of the ICZN, also the holotype of the nominate subspecies *C. postbitteri postbitteri*. Therefore, as pointed out in Kozur and Wang Cheng-yuan (2002), *C. postbitteri hongshuiensis* is a junior synonym of *C. postbitteri (postbitteri)*. In the contrast, the elements assigned to *C. postbitteri postbitteri* do not correspond to the holotype of the *C. postbitteri*. This is a serious violation of the rules of the ICZN. We have not get an answer to this point in Henderson and Mei (2002) and Wardlaw and Henderson (2002).

The endemic character of *C. postbitteri "postbitteri"* to the South Chinese intraplatform basin is a common feature of Permian and Triassic gondolellid faunas form intraplatform basins which are invaded by open sea gondolellid faunas after a gap or conodont- (gondolellid-) free interval. In the Germanic Basin all Anisian conodonts of the Lower Muschelkalk died out during the hypersaline Middle Muschelkalk. During the upper Illyrian, marine faunas invaded the Muschelkalk Basin in a new transgression, among them *Neogondolella mombergensis*. Under the ecological stress of the intraplatform Germanic Basin the open sea gondolellids underwent a rapid evolution *N. mombergensis*-*N. media*-*N. haslachensis*-*Celsigondolella watznaueri praecursor*-*C. watznaueri watznaueri*. Most characteristic for this evolution is that the successor species always retains the main characters of the juvenile forms of the ancestor species. In the open sea Tethys this Germanic development cannot be observed. Despite the fact that this evolution is well known and much faster then the contemporaneous conodont evolution in the open Tethyan sea, it would

be irresponsible to take this phylomorphogenetic cline for definition of the Anisian-Ladinian or Fassanian-Longobardian boundary, even under consideration of the fact that the Germanic Basin is the type area of the Triassic and this development can be found in numerous sections in the entire Germanic Basin. Still more irresponsible is to define the base of the Lopingian Series with a taxon which is only known from three sections in South China, even if its taxonomy would be without problems, what is not the case.

Henderson and Mei (2002) gave another argument for their taxonomy. They use population taxonomy. As "evidence" for the superiority of this taxonomy they wrote: "...population approach. This approach has proven very valuable for establishing high-resolution and reliable global conodont zonation and led us to recognize profound Permian provincialism and geographic clines." As an example for this success the correlations of the Tethyan Guadalupian with the type Guadalupian are presented in the quoted references. To this belongs the assignment to the lower, middle or upper Kungurian of the stratum typicum of the type species of *Waagenoceras*, Rupe del Passo di Burgio in Sicily, with the richest Wordian ammonoid fauna in the world and lower Midian fusulinids and small foraminifers, of the Rustaq (Oman) fauna with rich upper Wordian ammonoid and conodont faunas and in a parallel section with upper Wordian conodont and radiolarian faunas and the Wadi Wasit (Oman) fauna with *Waagenoceras*, *Timorites* and Midian fusulinids and small foraminifers. This would mean that the Illawarra reversal is within the Kungurian because it lies at the base of the type Midian (Zakharov and Sokarev, 1991). In the type area of the Kungurian (and Permian System) is clearly to seen that the Kungurian is within the reverse Kiaman interval, and also the overlying Ufimian, Kazanian and lower Tatarian strata belong to this interval. The Tethyan miscorrelations of Mei and Henderson very much harm the Permian stratigraphy, not only for correlation of the Tethyan successions but through the palaeomagnetic also the correlation of the marine and continental Permian. This shows that the "population taxonomy" of Mei and Henderson is only a tool for supporting wrong correlations without regarding any evidences from other fossil groups, palaeomagnetic and stable isotope investigations. By this, conodont results become contraproductive and lead to the "terror of conodonts" by suppressing all other evidences. *Waagenoceras* was said to have its FAD within the Kungurian, although even its forerunner *Demarezites* starts only within the Roadian. Upper Roadian representatives of *Waagenoceras*, the most primitive *Waagenoceras* and oldest occurrence of this genus are declared as advanced *Waagenoceras* despite the fact that they are often difficult to separate from the forerunner *Demarezites*. Even the *Waagenoceras-Timorites* fauna from the Wadi Wasit ammonoid limestone was assigned by Mei and Henderson (2002) into the Kungurian. The FAD of *Timorites* is, also in the Guadalupian type area, within the upper Wordian s.s. and its main occurrence in the Tethys is in the Capitanian. The lower Midian fusulinids in the level of the lowermost occurrence of *Yabeina* is by no means Kungurian in age, not only because of the fact the lower Midian is above the Illawarra reversal, but also by all palaeontologic data. In the Guadalupian type area *Yabeina* is Capitanian, the total range of the genus is upper Wordian to Capitanian, in no case Roadian or lower Wordian or even Kungurian as indicated by the correlation of lower Midian fusulinid faunas into the lower or upper Kungurian in numerous papers by Mei and Henderson. The small foraminifer fauna of the lower Midian Rupe

del Passo di Burgio section contain taxa which begin in the type Guadalupian not earlier than upper Wordian (pers. comm. M. Nestell) and the level with *M. siciliensis* and *M. omanensis* in Oman contains *Parafollicucullus fusiformis* (Cordey, 2001 and own material), a species which occurs in the western hemisphere, including the type Guadalupian, within the upper Wordian and lower Capitanian. As the correlation by Mei and Henderson (2002) cannot be confirmed by any palaeontologic data and also not by palaeomagnetic data which all show that the correlation is basically wrong, they "proved" the upper Kungurian correlation by the occurrence of the upper Kungurian *M. idahoensis lamberti* in the Oman sections with upper Wordian ammonoids (e.g. advanced *Waagenoceras* and *Timorites*), upper Wordian to lower Capitanian *Parafollicucullus fusiformis*, lower Midian fusulinids and small foraminifers. On the base of such a population taxonomy they disregard their own Kungurian holotype of this taxon from the Delaware basin and assign an advanced *Mesogondolella*, *M. omanensis* Kozur and Wardlaw with development of a true keel on the anterior attachment surface to the Kungurian *M. idahoensis lamberti* and by this also the taxonomy becomes disastrous, not only the correlation. *M. omanensis* evolved from *M. siciliensis*, but *M. idahoensis* surely does not evolve from *M. siciliensis*, which is restricted to the Tethys and begins after the extinction of *M. idahoensis*. Thus, the population taxonomy lead to a taxonomy, in which one species evolved from two different ancestor species. In the inner atoll lake sequence of Rustaq even *M. aserrata* is present, but in the population taxonomy it is assigned to *M. idahoensis lamberti* (serrated forms, Mei and Henderson, 2002, Pl. 7, Figs. 6, 7) and *M. rustaquensis* Mei and Henderson (unserrated forms, junior synonym of *M. aserrata*). Also these forms have a distinct true keel in the anterior half of the attachment surface, a feature which is never present in Kungurian *M. idahoensis lamberti*, also not in transitions forms to the Roadian *M. nankingensis*, and it starts only in some specimens of *M. nankingensis* but only in the anteriormost part of this Pa element. Thus, the population taxonomy, which is praised for the *C. postbitteri* taxonomy has partly the aim not to look for the holotype and the real phylogenetic clines and to put morphologically superficially similar forms in an unrelated taxon to "prove" any preconception. The preconception in the Guadalupian case is that the Tethyan Guadalupian consists exclusively of serrated *Mesogondolella* ("Jinogondolella"), a view which was established before Mei and Henderson had studied any Tethyan open sea conodont fauna! In the contrast, the Tethyan Guadalupian conodont fauna consists almost exclusively of unserrated *Mesogondolella*, in the Roadian and Capitanian were not yet found any serrated *Mesogondolella* whereas in the Wordian they occur rarely in exceptional facies such as in inner atoll lakes which have a similar facies as the intraplatform basins in the Ouachita-Cathaysia province, in which indeed all Guadalupian *Mesogondolella* are serrated (Kozur *et al.*, 2001a,b). For the definition of the Lopingian basin the preconception was to use the FAD of *C. postbitteri* in the Penglaitan section. As the good definition with the FAD of *C. postbitteri* cannot be made in the Penglaitan section because of a gap and gondolellid-free interval close to the Guadalupian-Lopingian, the taxonomy (and perhaps also the stratum typicum) was changed and in violation of the rules of the ICZN a form was assigned to *C. postbitteri postbitteri* which does not correspond to the holotype of *C. postbitteri* and

an other form was discriminated as new subspecies in which the holotype corresponds to the holotype of *C. postbitteri*. And also the kind of polemic is the same. Without any reason Wardlaw and Henderson wrote that Kozur and Wang Cheng-yuan are the only which cannot separate *C. postbitteri* from *C. dukensis*, whereas Henderson, Mei and Wardlaw are the only authors which used inconsistent criteria for the separation of the two taxa (see above). In the Guadalupian question Mei and Henderson wrote: "Previous age determinations for *M. siciliensis* are not consistent. Kozur (1975) and Kozur (1989, p. 392, table 4) showed that *M. siciliensis* is Wordian and basal Capitanian in age, but later Kozur (1993, p. 86) indicated a Roadian age for *M. siciliensis*, and finally Kozur (1995, p. 188, Fig. 2, 1997, p.149, tab. 3, 1998a) showed that *M. siciliensis* ranges from Roadian to basal Capitanian". In Kozur (1993) *M. siciliensis* was not restricted to the Roadian, but a Roadian representative was illustrated and the quoted page 86 is only a plate explanation (!). The occurrence in the Roadian does not mean restriction to the Roadian (!). The downward extension of the occurrence of *M. siciliensis* to the upper Roadian is mainly caused by the change of definition of the Wordian (originally with the FAD of *Waagenoceras*, later with the FAD of *M. aserrata* and by this the former lower Wordian changed to upper Roadian without changing the range of the conodonts). Again Mei and Henderson drastically changed the range of *M. siciliensis* from lowermost Kungurian (Mei et al., 1999a, b, Shi Xiaoying et al., 1999) to uppermost Kungurian (Henderson and MEI, 2000, Mei and Henderson, 2001, 2002) and then again back to middle Kungurian (Mei et al., 2002). None of these correlations was proven, all are unproven assumptions because *M. siciliensis* is a species restricted to the Tethys and its Kungurian age was only established according to the unproven assumption that the Guadalupian gondolellids of the Tethys must be serrated forms. Also the up and down-shifting of the occurrence of *M. siciliensis* is not explained instead they write wrong statements that I had inconsistent age determinations for *M. siciliensis* what is not the case as I have never shifted the age of Rupe del Passo di Burgio away from the Wordian and thus I could never restrict *M. siciliensis* to the Roadian. How dangerous is the correlation of nearly the entire Tethyan Guadalupian with the Kungurian in the numerous papers of Mei and Henderson can be best demonstrated by the smooth *Mesogondolella stampflii*. This species has the same range as the two uppermost radiolarian zones of the Capitanian, which occur in the Lamar Limestone and post-Lamar Capitanian beds. We need not a further such "high-resolution and reliable global conodont zonation" with the definition of the Lopingian base by the FAD of the endemic *C. postbitteri* "postbitteri". The correlation of this South Chinese boundary with the rest of the world can be only based on the same kind of assumptions as the correlation of the Tethyan Guadalupian with the Kungurian by Mei and Henderson. In this respect it was really good that Henderson and Mei (2002) compared their definition of the Lopingian base with their assumed successful correlation of the Tethyan Guadalupian with the Kungurian.

Finally, Wardlaw and Henderson stated that there were no other objections against the proposed Lopingian base with the FAD of the endemic *C. postbitteri postbitteri* then that of Kozur and Wang Cheng-yuan. It is not to expect that specialists on other fossil groups know the taxonomic problems in the gondolellid conodonts, which are even for conodont specialists a difficult group. The only two conodont workers of the Lopingian Working Group,

which are not involved in the ad hoc taxonomic subdivision of *C. postbitteri*, Kozur and Wang Cheng-yuan voted against the proposed boundary. The article Kozur and Wang (2002) was written as we have got the voting paper in the Lopingian Working Group and it appeared after the voting was over. The same will happen with the present discussion and the voting in the Subcommission. Henderson, Mei and Wardlaw know very well why they hurry so much with these two votings about a new boundary which was first proposed about a year ago and the taxon on which the new boundary is based was published and illustrated only in April 2002. The argument that the Lopingian base was long discussed makes no sense because what was discussed was the definition of the base of the Lopingian with the FAD of *C. postbitteri*. In the moment, where this boundary gets a wide acceptance, the new boundary was proposed, surprisingly within a typical Lopingian fauna in all studied faunal elements, with the FAD of an endemic form (known only from 3 sections in South China) which was superficially defined, and is based on a violation of the rules of the ICZN. Finally, I will present the diagnoses of two new taxa, which are in connection with the above discussion.

Mesogondolella stampflii n .sp. Kozur, in press

Fig. 2a-c

Derivatio nominis: In honour of Prof. Dr. G. Stampfli, Lausanne for his outstanding contributions to the Tethyan paleogeography and geodynamic evolution

Holotype: The specimen on Figs. 2a, b, rep.-no. PA-12-2-17 (Geological Institute of Bochum University, Germany

Locus typicus: Isolated limestone block, ca. 100 m S Pietra dei Saracini, Sosio valley near Palazzo Adriano, western Sicily. Paratypes (Fig. 2 c, rep-no. PA-12-2-18and Fig. 2d, juvenile form, rep-no. PA-12-2-20) from the same bed.

Stratum typicum: Upper Capitanian grey limestone with Midian foraminifers, and the radiolarians *Follicucullus dactylinus* Rudenko and Panasenko, *F. porrectus* Rudenko, *Parafollicucullus convexus* (Rudenko and Panasenko) which are characteristic for the second highest radiolarian zone of the Capitanian in the Delaware Basin, the Tethys and Panthalassa.

Material: More than 100 specimens.

Diagnosis: The central morphotype has a parallel-sided posterior and middle platform, which is in upper view either on both sides straight or on one side a little convex, on the other side straight or a little concave. The anterior platform tapers gradually and reaches until the anterior end of the unit. Posterior margin rounded, often with a small button. In another morphotype the platform is somewhat widened before the middle part, immediately behind the anterior narrowing. The adcarinal furrows are in the posterior half shallow, narrowest in the middle part, somewhat wider posteriorly and distinctly wider anteriorly. Platform margins are only slightly upturned in the posterior part, but somewhat stronger upturned in the middle platform until the beginning of the anterior narrowing. Upturned part covered with micro-reticulation, which ranges until the middle of the anterior narrowing part or still further anteriorly, but with the narrowing of the platform the micro-sculptured part becomes rapidly narrower. The cusp is terminal, the posterior brim is, if present, always very narrow. The cusp is in adults not much not much higher, but broader than the last denticles of the carina. The posterior 4-6, mostly 4-5 denticles of the carina have a roundish cross section and are separate or partly fused, always densely spaced in adults. Between the last denticle of the carina and the

Fig. 1: Re-figured holotype of *Clarkina postbitteri* Mei & Wardlaw, 1994, re-figured holotype and 2 paratypes of *C. postbitteri hongshuiensis* Henderson et al., 2002, and *C. postbitteri postbitteri* sensu Henderson et al. (2002)

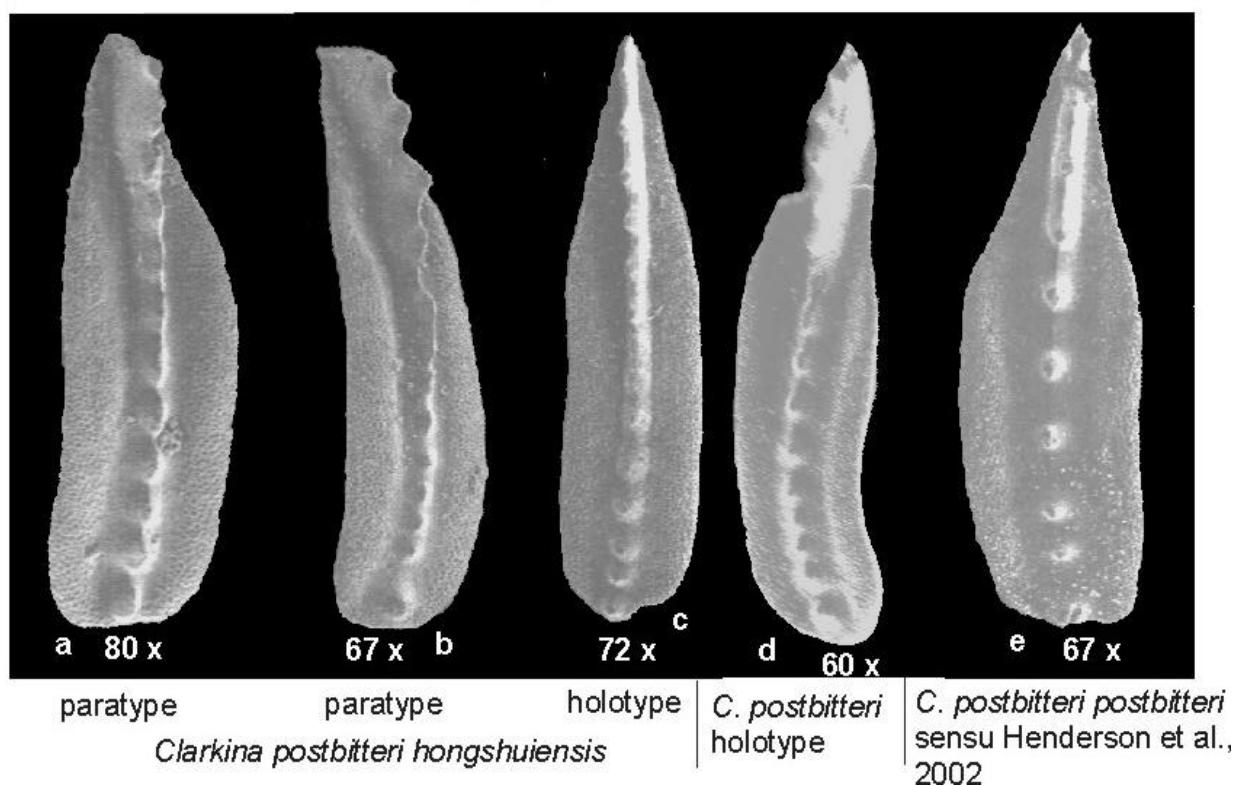


Fig. 2: *Mesogondolella stampflii* n. sp., a, b: holotype, c: paratype, d: juvenile specimen

cusp is generally a distinct gap. The anterior 5-7, mostly 6 denticles are laterally compressed and in their lower parts highly fused to a blade. In juvenile forms the posterior denticles are widely separated and the upturned platform margin is narrow. The attachment surface on the lower part of the platform is slightly excavated. The elongated pit is terminal; its margin is slightly elevated above the attachment surface.

Occurrence: In the Sosio valley (western Sicily), this species occur in blocks with upper Capitanian radiolarians (*P. convexa-F. porrectus* Zone) and in a *Yabeina*-bearing limestones at the margin of the big Pietra di Salomone block. In Oman it occurs both in blocks and in sequences immediately below the FAD of *C. postbitteri*. It occurs in two radiolarian zones, the *P. convexa-F. porrecta* Zone and the *F. ventricosus-I. scholasticus* Zone. The best preserved radiolarian faunas of the latter zone define the uppermost Capitanian in the Delaware Basin, where it begins in the *M. altudaensis-C. crofti* Zone. In Iran, it occurs in the Palaeotethyan sequences around Fariman together with upper Capitanian radiolarians. In SE Siberia it occurs rarely in the same radiolarian zones as in Oman. Without any doubt, it is the Tethyan guide form for the upper Capitanian. In its lower range is a short overlap with *M. siciliensis* and a long overlap with *M. omanensis*. In its upper range, it is the only known Tethyan gondolellid. In slope deposits *C. stampflii* is in its entire range accompanied by numerous *Iranognathus erwini* and other *Iranognathus* species. This is especially interesting because according Mei *et al.* (2002) *Iranognathus* is a Lopingian guide form, but it is common in the entire upper Capitanian of the Tethys and occur in the lower part of upper Capitanian together with last *M. siciliensis* and *M. omanensis* (assigned to *M. idahoensis lamberti* by Mei and Henderson, 2002). Thus, in well radiolarian dated (*P. convexa-F. porrectus* Zone) beds of the Tethyan upper Capitanian, in Wadi Wasit 7-20 m above the occurrence of *Timorites* according the stratigraphic assignment of Mei and Henderson (2001, 2002) species which are restricted to the "Kungurian" and "Lopingian" occur together.

Remarks: *M. stampflii*, as nearly all Tethyan Guadalupian gondolellid species, is an unserrated *Mesogondolella*. According to numerous papers of Mei and Henderson, these smooth *Mesogondolella* of the Tethys should define Kungurian age. In its lower range, it occurs even together with few *M. siciliensis*, which is regarded by Mei and Henderson as lower, middle or upper Kungurian guide form (see above) and with dominating *M. omanensis*, which is determined by Mei and Henderson (2002) as the upper Kungurian guide form *M. idahoensis lamberti*. This shows that the palaeogeographic and stratigraphic evaluation of the Tethyan Guadalupian by Mei and Henderson is basically wrong. The upper Capitanian age of *M. stampflii* is not only proven by the accompanying radiolarian fauna which is identical with that of the Lamar Limestone in the Delaware Basin, but also by the fact that its first occurrences is about 7 m above the ammonoid horizon with *Timorites* in the Wadi Wasit section.

M. stampflii developed by changes in the outline (the strong platform widening before the middle platform in *M. siciliensis* disappeared and the most *M. stampflii* have a parallel-sided middle and posterior platform, but forms with slight platform widening in front of the middle platform are present in some *M. stampflii*, but even in its successor *C. postbitteri*). The excavation of the lower attachment surface in *M. siciliensis* is more distinct. The carina in *M. siciliensis* is similar, but the last denticle of the carina is situated

closer to the cusp. Juvenile *M. siciliensis* have not so widely separated denticles as in *M. stampflii*. At the Guadalupian-Lopingian boundary *M. stampflii* changes gradually into *C. postbitteri*. The main difference is the disappearance of the excavation of the lower surface of the attachment area. Platform outline and denticulation of the carina are similar in both species, even a small button which is common in *M. stampflii* may be present in some *C. postbitteri*, e.g. in the holotype of *C. postbitteri* "hongshuiensis" (= *C. postbitteri postbitteri*) by Henderson *et al.* (2002). Advanced *C. postbitteri* (*C. postbitteri sinensis* n. subsp.) in the South China intraplatform basin are additionally distinguished by widely separated denticles also in adults and by an abrupt narrowing of the anterior platform, which is partly already present in primitive *C. postbitteri*.

Clarkina postbitteri sinensis n. subsp. Kozur, in press

Fig. 1 e

2001 *Clarkina postbitteri postbitteri* n. subsp. Henderson and Mei, 2001, p. 36

2002 *Clarkina postbitteri postbitteri* Mei and Wardlaw 1994 – Henderson *et al.*, p. 730, Pl. 2, Figs. 1-7

Derivatio nominis: According to its endemic restriction to a small part of South China

Holotype: The specimen, illustrated by Henderson *et al.*, 2002, Pl. 2, Figs. 6a, b; Fig. 6a re-figured in this paper as Fig. 1e; rep.-no. NIGP 134600

Stratum typicum: Bed 6k of the Penglaitan section, Laibin, Guangxi, South China, lower Lopingian.

Diagnosis: Platform in the posterior and middle part generally on one side slightly convex, on the other side straight or very slightly concave, but it may be also strictly parallel-sided. Posterior end rounded, bluntly rounded or obliquely rounded. The anterior narrowing of the platform starts always abruptly and in the same level also the height of the upturned platform margin decreases abruptly. Platform margins rather strongly upturned, highest immediately behind the abrupt anterior platform narrowing. Upturned platform with micro-reticulation, which ends close to the abrupt platform narrowing as normally for gondolellids with abrupt anterior platform narrowing. Adcarinal furrows wide, smooth. Cusp terminal or subterminal, with narrow brim or without brim behind the cusp. The cusp is distinctly longer and broader than the posterior denticles of the carina. These 5-6 denticles are both in juvenile and in adult forms widely separated, but the distance between the cusp and the penultimate denticle is generally even larger (denticle gap between in front of the cusp). Cross section of the posterior denticles roundish. The laterally compressed anterior denticles are highly fused to a moderately high blade. Attachment surface on the lower side plane with only slightly elevated narrow margins as typical for *Clarkina*. Terminal elongated pit surrounded by an elevated margin.

Occurrence: *C. postbitteri sinensis* is an endemic form, which occurs only in a small part of the South Chinese intraplatform basin. There it defines the uppermost part of the *C. postbitteri* Zone.

Remarks: *C. postbitteri sinensis* evolved from *C. postbitteri postbitteri* Mei and Wardlaw, 1994 (= *C. postbitteri hongshuiensis* Henderson and MEI, 2001 = *C. postbitteri hongshuiensis* Henderson, Mei and Wardlaw, 2002, see above). It is distinguished by retaining the wide separation of the posterior denticles in juve-

nile *C. postbitteri postbitteri* also in adults. Moreover, the anterior platform narrows always abruptly, but this feature is partly also present in more primitive *C. postbitteri* (e.g. in the specimens refigured from Henderson *et al.*, 2002, in Figs. 1a, b). As generally in gondolellids with abruptly narrowing anterior platform, the platform highly flared just posterior to the sharp beginning of the anterior platform reduction (as in *Clarkina leveni* and other Lopingian *Clarkina* with abruptly narrowing anterior platform, but also in *Paragondolella polygnathiformis*). As in all gondolellid taxa with abruptly narrowing anterior platform, the micro-reticulation of the elevated platform margin ends close to the abrupt narrowing of the anterior platform. These two latter features are obviously function-morphologically connected to the abrupt narrowing of the anterior platform and no independent features for distinction of the two subspecies. Most important is that the wide separation of the posterior denticles of the carina is retained in adult stages, whereas in *C. postbitteri postbitteri* it occurs only in juveniles and is therefore not present in the holotype of *C. postbitteri* (=holotype of *C. postbitteri postbitteri*). Retaining the features of juveniles from the ancestor taxon is quite characteristic for the development of endemic gondolellid species in intraplatform basins. Generally, these endemic taxa cannot re-enter the open sea environments from which the ancestor derived. They are therefore only useful for biostratigraphy in the regionally restricted basins in which they evolved.

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Reply to Kozur, "Definition of the Lopingian base with the FAD of *Clarkina postbitteri postbitteri*"

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Before I start my response, I would like to just say I think the person who cries "wolf" the most, just may be the WOLF (*e.g.*, the one that carries on about personal attacks and "polemics" just may be the polemicist). That said, I would like to conduct a careful review of the history and importance of the Penglaitan section, *Clarkina postbitteri*, and the Guadalupian-Lopingian boundary, but, I guess there are a few sidebars raised by Kozur (this issue) that I should address.

I feel partly responsible for some of the "population taxonomy" employed by Henderson *et al.* (2001, 2002). It was I, when Mei was a postdoctoral student of mine, that taught him to approach each sample as if it contained a single species...and let the specimens prove it otherwise. By this, I meant that unless a complete growth sequence for each species can be demonstrated, one must be very wary of additional species reported from that sample. It appears this practical approach has "morphed" into a sample population concept that I am not comfortable with.

I agree with Kozur (this issue) that Mei and Henderson (2001, 2002) and Henderson and Mei (2003, in press) have misconstrued the distribution of smooth *Mesogondolella* and *Waagenoceras*, but, I do not see that that has much bearing on the Guadalupian/Lopingian boundary and it need not be dealt with here.

I have long complained to my esteemed Chinese colleagues about the use of a bed number system in describing a stratigraphic section, but instead, that they should describe everything in meters above a well-described base (mab). Bed numbering systems only introduce confusion, as is the case here—However, because there is a sample misplacement, do not throw out the baby with the bath water or call "Foul" of the ICZN rules!!

In 1993, it became apparent that the species "*bitteri*" (the genus has changed, seemingly with every publication; so we will just call it by its species name) was misidentified with early *Clarkina* from South China. To resolve this, Mei and Wardlaw (in Mei *et al.*, 1994) proposed *Clarkina postbitteri* for the earliest forms confused with "*bitteri*". The species "*bitteri*" occurs with *Merrillina arcuicristata* and the early forms of *M. divergens* (=*M. praedivergens* of Kozur and Mostler, 1976), a temperate conodont

fauna that has been documented by Wardlaw and Collinson (1979, 1984, 1986) to be Wordian. The paradigm for *C. postbitteri* included abundant specimens from Fengshan (Mei *et al.*, 1994, pl. 2, figs. 7-11), clearly advanced forms of the species, but the senior author insisted on selecting the holotype from the proposed stratotype section at Penglaitan, from sample LPD-115. As the importance of the Penglaitan section increased, it was more and more precisely sampled and the beds were further subdivided. Mei and Wardlaw (1994) had no recovery from sample LPD-115' (bed 6i) and it was unclear if the sample LPD-115 was from the top of bed 6j or bottom of 6k. Clearly, in the more detailed report (Mei, Jin and Wardlaw, 1998) bed 6i, sample 115' shows no fauna, no recovery. It was not until the section was microsampled that 6i was sampled in its upper and lower parts, the lower essentially barren and the upper yielding a modest fauna (Henderson, 2001). Correspondence between Zhu Zilli and Jin Yugan indicated that LPD-115 was actually from bed 6k not the top of 6j. Conodont faunas from recollection of the beds confirmed that the same faunas described from LPD-115 are recovered from the lower part of 6k.

The holotype of *C. postbitteri hongshuiensis* is from bed 6i, a bed never reported on by Mei and Wardlaw (1994). I do not see how, in this God's good earth, that the holotype of *C. postbitteri postbitteri* (as originally designated by Mei and Wardlaw) can be from the same bed as *C. postbitteri hongshuiensis*.

Wang (2000) clearly documented a change in the *Clarkina* faunas in the Penglaitan section at bed 6k, which he attributed to the first occurrence of *C. dukouensis*. Of course, he also shows the first occurrences of several species at that horizon indicating a less sensitive methodology for species discrimination than that employed by Mei, Henderson, or Wardlaw. Still, to Wang (2000), the most important horizon in the Penglaitan section is 6k where he sees a changeover in *Clarkina* species that he favors for the Guadalupian/Lopingian boundary. This is precisely where Jin, Mei, Henderson, and Wardlaw also see a significant change that all can agree with.

I agree with Kozur (this issue) that evolution in many conodonts occurs through transitional morphoclines where successor forms retain the characters of juvenile forms of the ancestor species in progressively later and later growth stages through the transition. This has been documented both qualitatively and quantitatively for *Jinogondolella* (Lambert *et al.*, 2000; Lambert and Wardlaw, 1992; Lambert and Wardlaw, 1996)

I worked on a lot of the material from Oman with Kozur and in our careful description of that material there was no discovery of *Mesogondolella stampflii* or *C. postbitteri*, even though they are reported now (Kozur, this issue) from sections and samples that appear to be the same as those we studied. So, I question the phylogenetic lineage proposed by Kozur. Instead, Lambert *et al.* (2002) carefully document a succession of *Mesogondolella* species leading up to the first occurrence of *Clarkina postbitteri hongshuiensis* that arises from *M. altudaensis* (Kozur) as originally proposed by Kozur (1992)! Further, Lambert *et al.* (2002) clarify many misconceptions and misidentifications caused by the poorly described species *M. altudaensis* (Kozur, now properly revised) that has led to part of the problems of understanding uppermost Guadalupian conodont faunas.

Kozur (this issue) dismisses the criterion of retention of re-

ticulate micro-ornamentation along the anterior lateral margin as insignificant, yet almost all specimens from upper 6i and 6j show this feature and almost none from 6k do. The anterior retention of the micro-ornament, in well preserved specimens, in this case, reflects the degree of upturning of the lateral margins, the arching of the element, the width of the smooth (unornamented) adcarinal furrow and the intensity of the anterior narrowing of the platform so that in forms that have low lateral margins, low arching platforms, narrow furrows, and mild anterior narrowing, the ornamentation is expressed for nearly the entire length of the element and the blade is nearly completely enclosed (*C. postbitteri hongshuiensis*). When the lateral margin is more upturned, the platform more arched, the furrows wider, and the anterior narrowing more intense, the anterior portion of the platform is smooth (the extension of the adcarinal furrows) and the blade is less enclosed (there is a “free” blade, and this is *C. postbitteri postbitteri*). In a transitional morphoclone some of the characters are expressed in the ancestor, but not all, and the retention of micro-ornament is an excellent expression of this character set that clearly distinguishes the subspecies of *C. postbitteri* and there are other differentiating characters as well. All too often, a single character is focused on and this is why there is confusion in species or subspecies differentiation. When all characters are examined, it becomes much clearer.

Finally, Kozur (this issue) states many times that the holotype of *C. postbitteri* fits “precisely” or “shows perfectly” the same characters as the holotype of *C. postbitteri hongshuiensis*.

POPPYCOCK!

Having examined the holotype of *C. postbitteri*, not just its photograph (I better have since I described it), it displays all the character set mentioned above for *C. postbitteri postbitteri* whereas the holotype of *C. postbitteri hongshuiensis* does not. In addition, the denticulation is different between the holotypes, with *C. postbitteri hongshuiensis* having a more fused carina and lacking the gap between cusp and first posterior denticle. The form identified as *C. postbitteri postbitteri* is not *C. postbitteri hongshuiensis*, conforms to the original holotype, paradigm, and stratigraphic horizons, and there is no violation of the ICZN code, nor need for another Kozur species (Whoops, there’s a personal slap) established on someone else’s specimens!

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Reply to Kozur ‘Definition of the Lopingian base with the FAD of *Clarkina postbitteri postbitteri*’

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I would like to thank Heinz Kozur for making the pages of *Permophiles* interesting. It is now over 160 years since Sir Roderick Murchison named the Permian System. The system has changed significantly from that envisaged by Murchison and several stages within it have finally been defined, but we have still not finished with the basic definitions. Those interested in Permian stratigraphy can hardly be accused of hasty decision-making. As I read Heinz’s paper it came to mind that Murchison had his own battles with Sedgwick regarding the definitions of the Cambrian and Silurian that at the time included what later became the Ordovician; there was a lot of polemics between those two and the naming of the Ordovician had to wait until 1879 after both individuals were dead and buried. Let’s hope that we don’t have to wait so long for the rest of the Permian to be defined. I am pleased to report that progress continues and that the Subcommission on Permian Stratigraphy voting members have passed the definition for the base of the Upper Permian Lopingian series (see Secretary Report this issue). The definition is the FAD of *Clarkina postbitteri postbitteri* at the base of bed 6k in the Penglaitan Section of South China.

Before a final document is sent for ratification to the ICS and IUGS I believe it is important that the comments and concerns of Heinz Kozur are given every consideration. I begin that process here and although I do have a few issues that I must point out regarding Kozur’s paper, I will endeavour to do so without any inflammatory remarks or polemics.

How often and how long will I have to be reminded that I made an apparent ICZN error in an informal publication that I co-edit? Bruce and I spend a great deal of time (and money) preparing publication of *Permophiles* so that SPS members can be informed of developments, but sometimes errors or issues of timing may occur. For the record, yes I did indicate Henderson and Mei (2001) as the authors for both of the unpublished (at the time) new subspecies, *Clarkina postbitteri postbitteri* and *C. postbitteri hongshuiensis*. At the time the paper was submitted to the Proceedings volume for the XIV ICCP of which I was also a primary editor. I had expected that the paper would be published in December 2001, but it took longer than I expected and finally appeared as a 947-page volume in April 2002. This paper was submitted initially with Henderson and Mei as the only authors, but Bruce Wardlaw was aware throughout of its development. He initially objected to the implication that the evolutionary event occurred in China, but when we revised the document to indicate that the evolutionary event may have occurred outside of the Jiannan Basin he said “now you can add my name, if you wish”. We did. We (Shilong Mei and I) did not add Bruce’s name at the last minute to lend some authority to our paper; we are both confident in our abilities with Permian conodonts. In that official paper naming the new subspecies (Henderson *et al.*, 2002; CSPG Memoir 19, p. 725-735) we correctly identified authorship. A holotype was named for *C. postbitteri hongshuiensis*, but not for *C. postbitteri postbitteri* because, of course, the holotype for the latter subspecies was indicated by

Mei and Wardlaw (1994).

It is my opinion that *Clarkina postbitteri sinensis* is invalid because it is a morphotype within the sample-population species concept of *Clarkina postbitteri postbitteri*; some specimens have denticles more closely spaced like the holotype and others, with all gradations, are more widely spaced as illustrated in Kozur’s fig. 1e (from Henderson *et al.*, 2002). In all other characters this specimen is identical to the holotype of *C. postbitteri postbitteri*. The holotype of *C. postbitteri hongshuiensis* is different from the holotype of *C. postbitteri postbitteri* and this can be seen in Kozur’s figure 1 (this volume). Yes these two holotypes (Kozur figure 1c [upper view] and 1d [oblique upper view]) are somewhat similar, but they are not identical as claimed by Kozur. An illustrated holotype is only a single specimen within a sample-population and judgments should not be made until viewing more specimens. Notice that the specimens of *C. postbitteri hongshuiensis* have fused middle denticles of the carina and that although they are closely spaced in the holotype of *C. postbitteri postbitteri* they are not fused. The holotype of *C. postbitteri postbitteri* is from bed 6k, despite Heinz’s apparent refusal to accept the documentation in the G-L proposal. I have samples of bed 6k subdivided into 6k lower, 6k upper, and 6k uppermost. In 6k lower there are numerous specimens with the widely spaced denticles as figured by Henderson *et al.* (2002) and only a few with closely spaced, but not fused, denticles as in the holotype. The proportion of specimens with closely spaced denticles (ignoring other characters for the moment) increases in the upper and uppermost subsamples. The sample-population approach of Mei and Henderson (further discussion on this topic with younger Changhsingian *Clarkina* species will be seen in Mei *et al.*, submitted) indicates that these are two morphotypes within *Clarkina postbitteri postbitteri* in which none of the specimens have fused carina (as seen in populations of the underlying *C. postbitteri hongshuiensis*) and that finally as the widely spaced denticle morphotype approaches zero in abundance we see the transition to the succeeding *Clarkina dukouensis*; other subtle character changes also occur. One weakness of designating a holotype is that it can only reflect one morphotype. The holotype of *C. postbitteri postbitteri* is more reflective of the upper part of bed 6k, but if only a single sample of bed 6k were available it would be typically of about half of the specimens. The holotype of *C. postbitteri postbitteri* is actually closer to *C. dukouensis* than *C. postbitteri hongshuiensis* because it exhibits very marked narrowing of the anterior platform, which would be seen better had the specimen not been photographed as an oblique view. Henderson *et al.* (2002) figured only widely spaced denticles to reflect the importance of this morphotype and were not obliged to figure other specimens similar to the holotype, although perhaps in retrospect we should have. Sometimes it isn’t easy getting back to the SEM and you are stuck with those specimens initially selected. Ultimately, a taxon stands by virtue of its use by the paleontological community and I leave it to others to decide the ultimate fate of these various subspecies. Lambert *et al.* (2002) have found it in West Texas and used the concept; they correctly recognized that *C. postbitteri hongshuiensis* and *C. postbitteri postbitteri* are not synonymous.

One of Heinz’s major concerns with respect to the G-L GSSP proposal is that his new species *Clarkina stampflii* is a better ancestor for *Clarkina postbitteri postbitteri* and that our widely spaced denticle morphotype is endemic to South China. I believe

there may be some merit to the first part of that argument, but I reserve judgment since the specimens illustrated are from isolated blocks in Sicily and not from the discussed section at Wadi Wasit in Oman. In my view, *C. stampflii* could be a geographic subspecies with a platform outline like that of *Clarkina postbitteri hongshuiensis*, but with separated denticles in contrast to fused denticles on the middle carina in the latter subspecies. The Permian-Tethys may have been home to all of these different geographic subspecies that migrated in response to changing sea-level, the details of which are probably approaching our resolution limits. Perhaps *C. stampflii* should be better designated as *C. postbitteri stampflii*; either that, or it is simply a morphotype of *C. postbitteri hongshuiensis*. The fact that this species/subspecies occurs immediately above *Mesogondolella siciliensis* at Wadi Wasit is a very different argument and I don't wish to enter into that now; I have addressed some of this problem in Henderson and Mei (2003) and Mei and Henderson (2002), which concludes that there still is a problem. An initial reaction is that perhaps there is an unconformity at Wadi Wasit; they can be very cryptic in carbonate successions at times. I look forward to a careful analysis of these specimens as indicated by Kozur in his article.

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The Newwellian Substage; Rejection of the Bursumian Stage

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Introduction

Introduction of the Bursumian Stage (Ross and Ross, 1994, 1998) as a solution to the Carboniferous-Permian boundary conflict caused by the choice of the Aidaralash Section GSSP (Davydov, *et al.*, 1995) has introduced more problems than it has solved.

Having said this, it now becomes my intention to join in the fray and argue that the Bursum “Formation” fails to fulfill the requirements of a Stage name for either part of the Virgilian (Late Carboniferous) or of the Wolfcampian (Early Permian). This, in spite of the fact that I have intentionally employed the usage in the recent past (1990, 1995). Such intentions rested on: (1) the failure among conodont workers to arrive at a consensus point at the time, and (2) the failure to locate an acceptable stratotype section for the Bursumian Stage in spite of efforts by various workers (Lucas *et al.*, 2000; Wahlman and King, 2002).

Meanwhile, I have had available to me for many years an abundance of material from the Big Hatchet Mountains, Hidalgo County, southwestern New Mexico (Figs. 1, 2), but a press of other responsibilities prevented completion of a comprehensive study, now in progress. Finally, with encouragement from Spencer Lucas, New Mexico Museum of Natural History, Albuquerque, New Mexico, I decided that the time had arrived to introduce into the equation a sequence of limestone that I know with some certainty represents an almost continuous section from near the base of the Pennsylvanian through most of the Wolfcampian. For these reasons, I introduce herein the Newwellian Substage of the Wolfcampian Stage (Permian).

Why Not a Bursumian Stage?

As pointed out by Lucas *et al.* (2000), and Davydov (2001), it is practically impossible to fairly decide on the use of “Bursumian” as a Stage name to represent the interval of geologic time from Late Carboniferous to Early Permian in the North American region.

The name “Bursum” was introduced by Wilpolt *et al.* (1946) as a formation. The name was derived from the “Bursum triangulation point”, located in Socorro County, New Mexico; however that name may well have been derived from “the Bursum Ranch, about five miles east of the north end of the Oscura Mountains” (Thompson, 1942). But this is hardly important in that Wilpolt, *et al.* (1946) gave the exact location of the type section as SE $\frac{1}{4}$ Sec. 1, T-6-S, R-4-E. Socorro County.

I shall not review here the remainder of the location data given in our paper (Lucas, *et al.*, 2000), except to say that there is little doubt as to where and that constituted the Bursum Formation, and what was meant in its designation. Indeed, Wilpolt and Wanek (1951) later mapped the area that included the type section and made the following points clear:

1. Type section – same
2. Thickness – 28 to 234 feet (8.5 – 71 m) (1946); 90 to 250 feet (27 – 76 m) (1951).

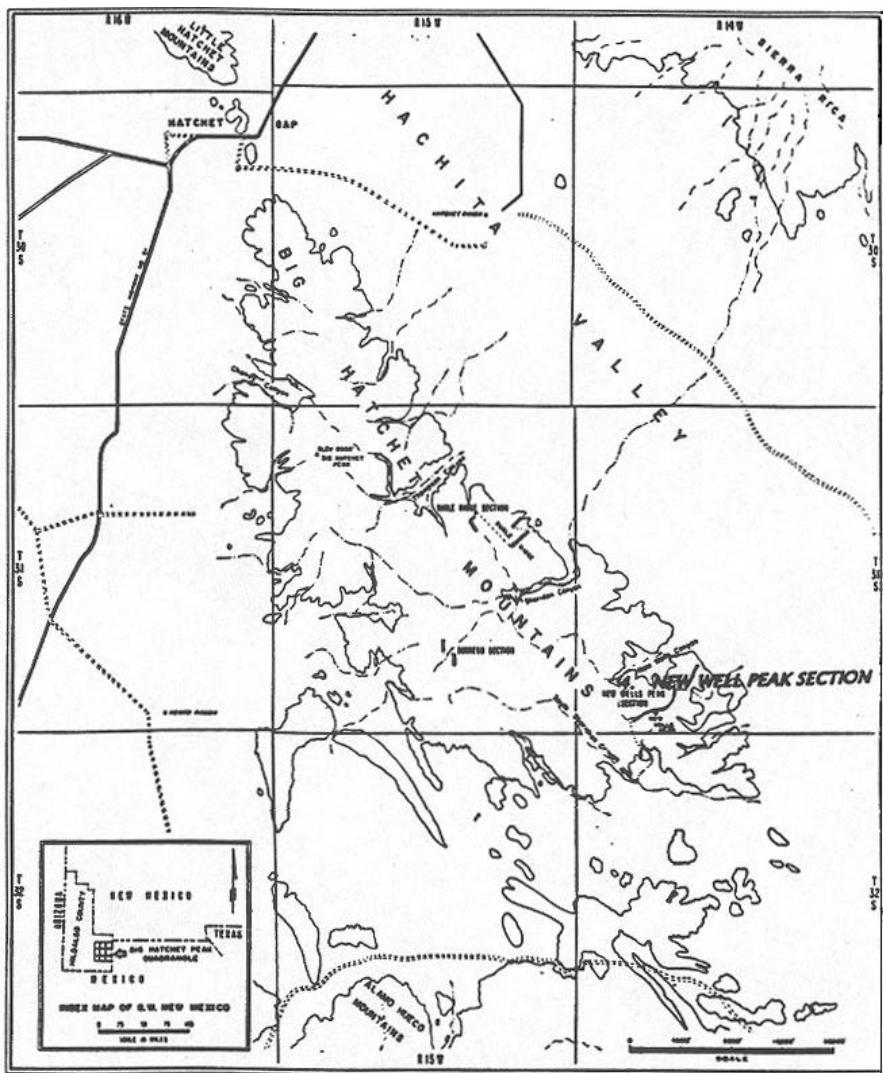


Figure 1. Index map of the Big Hatchet Peak Quad

3. Fusulinids – *Schwagerina*, *Triticites ventricosus* – both reports
4. Lithology – both reported the Bursum to consist of dark purplish-red and green shale separated by thinner beds of arkosic conglomerate and grey limestone.
5. Judging from detailed descriptions by Wilpolt *et al.* (1946), and Wilpolt and Wanek (1951), the Bursum Formation at its type locality is distinct and bounded by Wolfcamp Abo red beds at its top and by Pennsylvanian Madera limestone and shale at its base. As Lucas, *et al.* (2000) reported, the Bursum is transitional between wholly marine (Madera) and wholly nonmarine (Abo).

In 1954 Thompson stated, "As originally defined, the Bursum included thick red beds and thin limestones of Pennsylvanian age at its base" (previously called Bruton Formation by Thompson, 1942). Also Thompson (1954, p. 17) stated that the Bursum beds "unconformably overlie eroded Pennsylvanian rocks of varying age, and they are overlain unconformably by the Powwow conglomerate ...". Thompson further stated (p. 18) "It seems to me that the term Bursum should be redefined so as to apply only to pre-Abo Wolfcampian rocks of New Mexico". (See also Lucas and Wilde, 2000, p. 8). So what was originally, and properly, described as a formation with varying ages at its top and base, was later

referred to as "biostratigraphic/chronostratigraphic" (Lucas, *et al.*, 2000) and as such has been identified on the basis of fusulinid faunas: a formation became a faunal zone, and this faunal zone was elevated to Stage status (Ross and Ross, 1994, 1998).

According to the Stratigraphic Code (1961, p. 659) Stage "... is based on a succession of biostratigraphic zones; the zones may differ in different geographic areas." As one can see, our attempts at establishing a reasonable zonation at the type Bursum section (Lucas *et al.*, 2000) were fraught with difficulty, with only a local separation into two informal zones possible. Furthermore, no top or base of a fusulinid zone was possible within the confines of the Bursum Formation.

Because of these and a multitude of other reasons (discussed later) I must reiterate the objection offered earlier (Lucas and Wilde, 2000, p. 10), namely that "The type section of the Bursum Formation is not a suitable stratotype for a Bursumian Stage. No easily defined biostratigraphic base to a Bursumian Stage can be identified at this section. Furthermore, the section is located on the White Sands Missile Range, managed by the U.S. Army, and thus virtually inaccessible to non-U.S. Citizens."

Other Suggestions to Save the Bursumian

Prompted by criticism from other workers, (Lucas and Wilde, 2000; Lucas *et al.*, 2001, 2002; Wardlaw and Davydov, 2000); Ross and Ross

(2002) sought to discover a better section containing the Bursum faunas and to designate as a stratotype section for the Bursumian Stage. They turned to work that had been done in the Chiricahua Mountains of southeast Arizona (Sabins and Ross, 1963). Choosing data from three fusulinid-rich sections, they picked the thickest and most complete section, Portal locality No. 9, comprising over 3000 feet (1100 m+): "The Portal section is our candidate stratotype section for the type Bursumian Stage based on its fauna and supplemented by the Dunn Springs Mountain section" (Ross and Ross, 2002, p. 39).

It happens that in the 1960s I became particularly interested in the southeastern Arizona region, especially after reading Sabins and Ross (1963) paper on the Chiricahua Mountains. What caught my eye was the reported position of *Pseudoschwagerina* below *Triticites* in the Portal section, and the extreme thickness of the Virgilian-Wolfcampian section (their Fig. 5). I wanted to visit the area, but transfers to different locations within Humble (Exxon) prevented that. This, however, did not prevent my making use of the material at hand, a reprint sent to me by C.A. Ross. As I pondered the strange assortment of fusulinid successions, I saw that faulting had been noted in the area, and a considerably thickened section caused me to remember having studied a 25,000 foot section of "Wolfcamp" in the Oquirrh Formation of the Wasatch Mountains of Utah, supplied to my company by a consultant. I have never seen so many thin sections of *Schwagerina wellsensis*



Fig. 2. South end of New Well Peak, Big Hatchet Mountains, SW New Mexico. Pennsylvanian beds comprise the slope. Newwellian Beds and Permian in back slope. Beds dipping steeply to the southwest.

Thompson and Hansen in my life, and these supposedly occurring over thousands of feet of section! That experience gave me an idea. Could it be that the Portal section was composed of repeated beds, thus placing higher fusulinids below older ones? Figure 6 is my interpretation of the previously published Fig. 5 (with apologies to Sabins and Ross). All that I have done is to break the Portal section into three parts (upper, middle, lower) and attempt to correlate the three sections to Dunn Springs.

The point is this: the Portal Section could hardly become a stratotype section for the Bursumian Stage, because of (1) a reversal of fusulinids unknown in North America, and (2) a strong suspicion of multiple faulting in the section, which could explain the above reversal, and the increased thickness of section. Furthermore, the Portal section is in the Pedregosa basin, not the Orogena Basin, where the Bursum Formation was deposited. There is no Bursum Formation in the Pedregosa Basin, so why would a stage with a stratotype in that basin be called "Bursumian"?

Wahlman and King (2002) have recently published a beautiful paper on fusulinid biostratigraphy from the Robledo Mountains, south-central New Mexico, in which they made rather persuasive arguments for the recognition of a Bursumian reference section in the Robledo Mountains. They said, "The Robledo Mountains has one of the most continuous carbonate stratigraphic sections (not entirely true) across the new Pennsylvanian-Permian in the American Southwest and could be an important regional reference section" (p. 11).

But in the measured sections shown (Seagers, Kottlowski, and Hawley, in press) not a single *Triticites* was reported in the "Bursumian" interval by Wahlman and King (see their Fig. 5, p. 6). Furthermore, they reported *Leptotriticites* aff. *gracilitatus* Skinner and Wilde as occurring near the base of the "Bursumian" interval, whereas the type species was found originally in the lower part of what would now be called Nealian in the Big Hatchet Mountains (Skinner and Wilde, 1965). The species does not occur in the "Bursum" equivalent interval of the Big Hatchets. On the other hand, 18 species of *Triticites* are present in the "Bursum" interval,

to which I shall refer later. One can hardly argue that local environmental differences "prevented" species of *Triticites* from living in the Robledo area when it can be demonstrated that characteristic "Bursum" *Triticites* occur on all sides.

This seems to say that, in the Robledo Mountains, much of the "Bursum" fauna is missing at the base of the "Bursum", due either to erosion, or more probably to non-deposition. The Robledo section could hardly represent a transition from the Virgilian into "Bursum"; a gap of unknown duration prevents a proper understanding of the "Bursum's" age and position in the sections described by Wahlman and King.

The Newwellian Substage, Big Hatchet Mountains

The Big Hatchet Mountains of southwestern New Mexico comprises one of the most complete sequences of Carboniferous-Permian carbonates known in the southwestern United States, consisting of more than 3500 (1067 m) feet of shelf-to-basin-edge sediments, largely limestone, with minimal amounts of dolomite. Zeller (1965) originally mapped the range and in exchange for preliminary identifications of fusulinids from three long sections, gave all of his collections to John Skinner and the author. Skinner was busily working on other matters at that time, so I was given the task of most of the identification work.

Immediately, I began to recognize some discrepancies in the sequences of fusulinids, particularly in the lower part of the section. During that period (1954-1955), much correspondence took place between Zeller and me. Zeller returned to the field, and Hugh Bushnell, of Humble, was sent to the field to accompany Zeller. It was also decided that Bushnell and I were to recollect the entire New Well Peak Section for tighter fusulinid control, and recognition of suspected faults. Much later, Sam Thompson III was assigned the task of measuring and collecting the Big Hatchet Peak Section.

As a result of this work, over 9900 oriented thin sections were ultimately prepared! The task of studying such a large collection

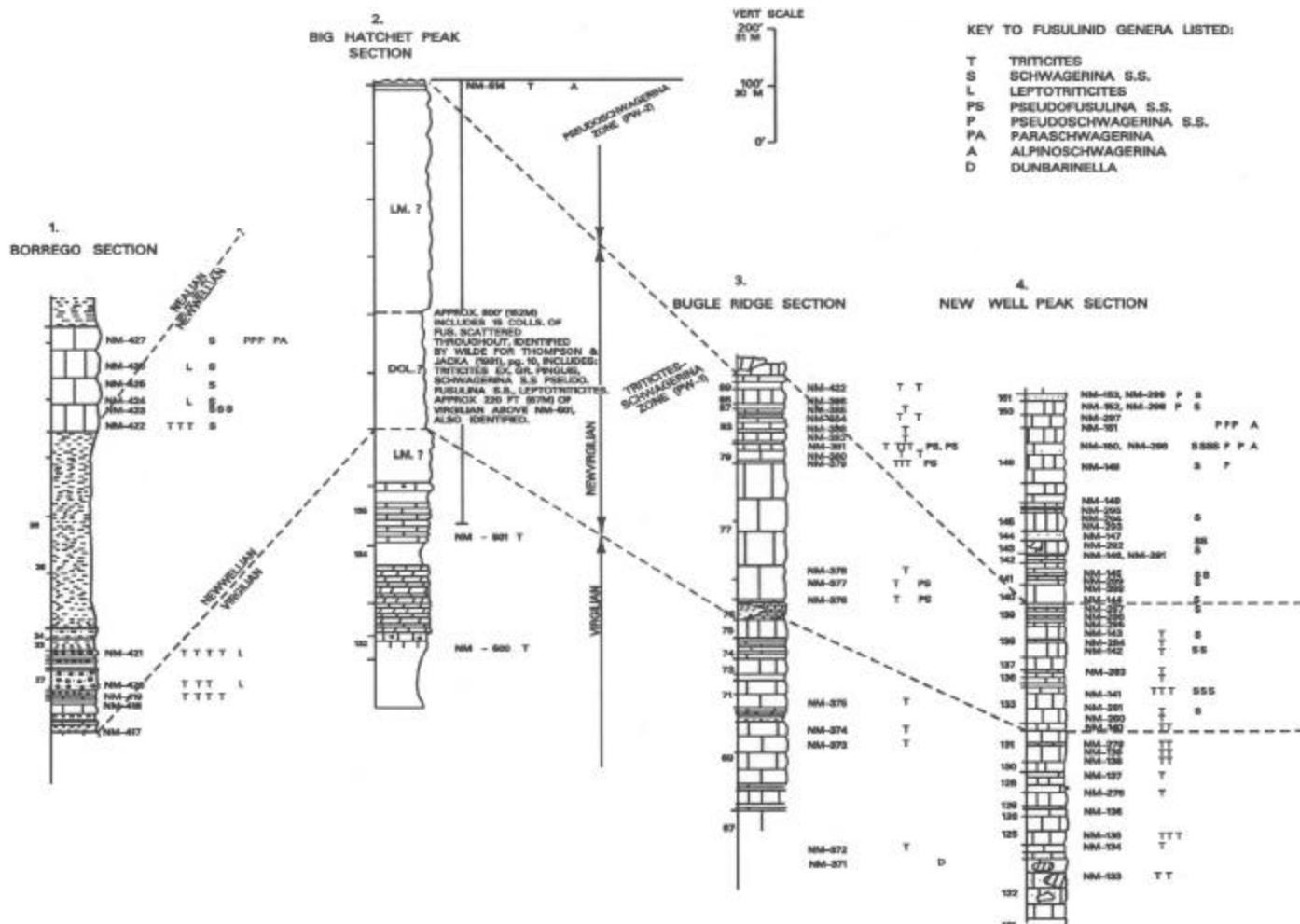


Figure 3. Newellian portion of four stratigraphic sections, Big Hatchet Mts., SW New Mexico, showing general fusulinid control.

was taxing. Many preliminary identifications were made from fresh rock surfaces, and those lists were the ones provided to Zeller and others (Zeller, 1965, table 2, for example).

Between 1963 and 1976, I was transferred twice to Houston and once to Denver on new studies, but carried the almost 10,000 thin sections with me on each occasion, working on them occasionally in my spare time at home. For example, during my 1963-1964 tenure in Houston, I completed two papers (Skinner and Wilde, 1965; Wilde, 1965) dealing with interesting new genera and aspects of fusulinid abnormalities. After returning to Midland in 1976, I was engaged in prospecting for oil and gas. In 1981, opting for early retirement from Exxon, I was determined that the Big Hatchet work would ultimately get published. Through the auspices of the New Mexico Museum of Natural History and the good offices of Dr. Spencer Lucas, completion and publication of this material will finally become a reality.

This lengthy background is given in order to explain differences in early identifications, the listing of collecting localities without identifications, etc. However, close enough identifications from thin sections assure continuity.

The New Well Peak Section has been chosen as the proposed stratotype section of the Newwellian Substage in spite of its thinness of 225 feet (69m). However, maximum thickness of its equivalents in the Big Hatchets exceed 545 feet (166 m), and all of the elements are present in the range to insure its continuity. The following list of requirements is offered:

1. According to Zeller (1965, p. 84), "The New Well Peak Section represents the most complete and least disturbed section of Horquilla Limestone in the Big Hatchet Mountains and southwestern New Mexico, and therefore it is designated as the best reference section for the formation in southwestern New Mexico."
 2. Access into the New Well Peak Section is relatively easy. The Big Hatchet Mountains are controlled by the U. S. Bureau of Land Management (BLM), an agency of the Department of Interior of the U.S. Government and, thus, open to the public. In fact, the Hidalgo County government has recently decided to develop and maintain a bladed road close to and circling the Range for public access. The Continental Divide trail runs just east of the Range, and the U.S. Government has decreed unlimited access, although no road, per se, is involved. The Big Hatchet Range may be reached by following U.S. Interstate I-10 through Deming, New Mexico west 13 miles to State Highway 146, which goes south 20 miles to Hatchita, and another 20 miles to Hatchet Gap, where the pavement ends. Highway 146 continues through Hatchet Gap all the way south to Antelope Wells and the Mexican border. However, the road bladed by the county intersects the road to Hatchet Gap

SYSTEM	SERIES / STAGES (WILDE, THIS PAPER)		FUSULINACEAN ZONES (WILDE, 1990)	PENN.-PERMIAN FMS. BIG HATCHET. MTNS. (ZELLER, 1965)	THICKNESS (MAX.)	GENERAL EQUIVS. U.S.A.	RUSSIAN TYPE SECTION	CONODONT ZONES (VARIOUS SOURCES) FIRST APPEARANCE *
PERMIAN	EARLY GUADALUPIAN (ROADIAN)	EARLY (PG - 1)	CONCHA LM.	1376'	KAIBAB/SAN ANDRES, PT	"KUNGURIAN"		
		LATE (PL - 5+)	SCHERRER FM.	5 - 20'	COCONINO / GLORIETA			
		MIDDLE (PL-2-4)	EPITAPH DOL.	1519'	YESO / VICTORIO PEAK			
		EARLY (PL - 1)	COLINA LM.	505'	YESO / ABO REEF			
	WOLFCAMIAN	?	LOCAL UNCONF.	EARP FM.	997'	ABO / RED BEDS		
		LENOXIAN	LATE (PW-3)	380'	BELLE PLAINS / ADMIRAL / ? SUMMER GR ?	SAKMARIAN	FAD- STREPTOGNATHODUS FLORENSIS OR SWEETOGNATHUS WHITE	*
		NEALIAN	MIDDLE (PW-2)	485'	MORAN / PUTNAM / CHASE - COUNCIL GROVE	ASSELIAN	FAD- STREPTOGNATHODUS ISOLATUS	*
		NEWWELLIAN SUBSTAGE (NEW)	EARLY (PW-1)	545'	PUEBLO / ADMIRE	"ORENBURGIAN"	S. WABAUNSENSIS S. ELONGATUS S. BROWNMILLENSIS	
		VIRGILIAN	LATE (VC-3) MIDDLE (VC-2) EARLY (VC-1)	970'	CISCO	GZHELIAN	S. VIRGIUCUS S. ZETHUS ?	*
		MISSOURIAN	LATE MIDDLE TO LATE (MC-3,4) EARLY TO EARLY MIDDLE (MC-1, 2)	525'	CANYON	KASIMOVIAN	IDIOGNATHODUS SIMULATOR I. MAGNIFICUS I. EXCENTRICUS	
PENNSYLVANIAN	DESMOINESIAN	EARLY LATE (DS-4)	HORQUILLA LIMESTONE	1030'	STRAWN	MOSCOWIAN	I. NODOCARINATUS I. DELICATUS GR.	
		LATE MIDDLE (DS-3)		550'	ATOKA - DERRY		NEOGNATHODUS ATOKAENSIS	
		EARLY TO EARLY MIDDLE (DS-1, 2)		245'	"BEND" - MORROW	BASHKIRIAN	N. BASSLERI	
	ATOKAN (DERRYAN)	LATE (A-4)						
		MIDDLE (A-3)						
		EARLY (A-1, 2)						
	? MORROWAN	MID-CARB [?] BOUNDARY						

Figure 4. Tentative zonation of Horquilla Formation, Big Hatchet Mts., SW New Mexico, including possible relationship to other areas. Zonation based upon fusulinacean species described in forthcoming paper. No decision is made on GSSP for the base of the Permian because that decision is conodont based. Bursumiam Stage is rejected herein.

east of the Gap and north toward the Everett Ranch, so that one may reach the south end of the Big Hatchets (New Well Peak is at the south end) by following the bladed road along the east side of the Big Hatchet range. In such a manner, the entire Horquilla section may be observed dipping rather steeply southwestward, and by following the road all the way around to the south end of the range, the section is observed in profile (Fig. 1-A). The Newwellian base is just below the summit on the back slope of New Well Peak and can be easily followed downdip to the top of the Horquilla in Playas Valley. For anyone with access to U.S. Quadrangle maps, it is the Big Hatchet Quadrangle, east side of the small "boot" or panhandle, extreme southwestern New Mexico (Fig. 1).

3. If the New Well Peak Section is chosen, there is a good chance that the county could be persuaded to blade a road all the way north to the top of the Horquilla Section, and that a permanent marker could be placed in the vicinity.
4. The Horquilla Limestone, beginning in Morrowan (?)

rocks, includes known Virgilian rocks through the Newwellian, Nealian, and most of the Lenoxian, where it becomes cut off by a valley fault, and it is all shelfal limestone, and abundantly fossiliferous. There are no discernible breaks in the section. For conodont workers who may be concerned about the presence of shallow water conodonts, a few miles to the northwest of this section lies the Borrego Section, which contains about 350 feet (107 m) of slope to basinal (Pedregosa Basin) shales within the Newwellian, and which also contain numerous Newwellian *Triticites*, and other forms. All of the fusulinacean species will be described in my monograph. Separating the New Well Peak Section from basinal sediments are two prominent sections of shelf margin and reef deposits, through which may also be traced the Newwellian equivalents, with the reef tract facies being the poorest representative because of inaccessibility in the cliffs. The reef tract needs much more work (Fig. 4).

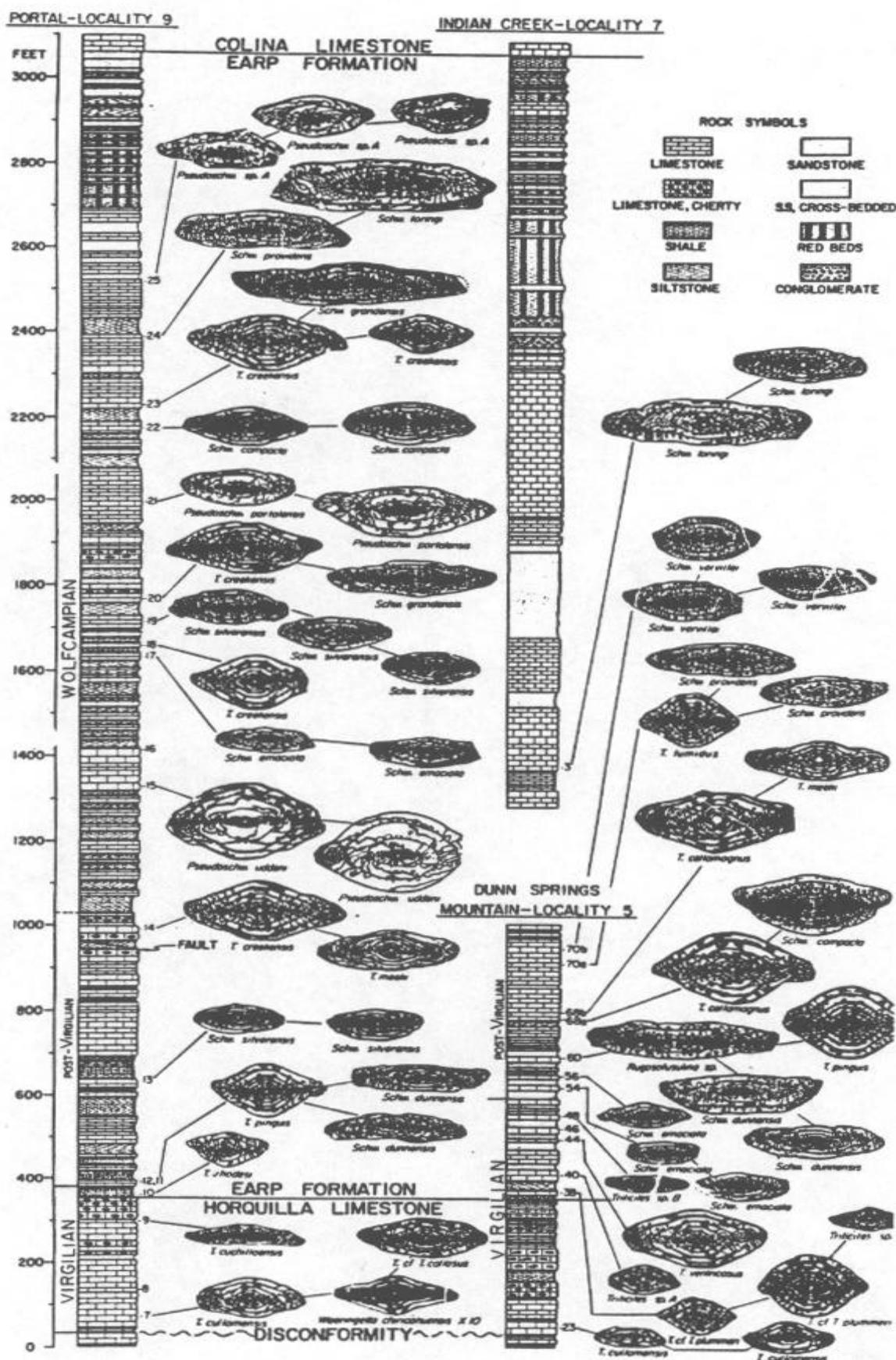


Figure 5. Carboniferous-Permian sections. Chiricahua Mts., Arizona (after Sabins and Ross, 1963).

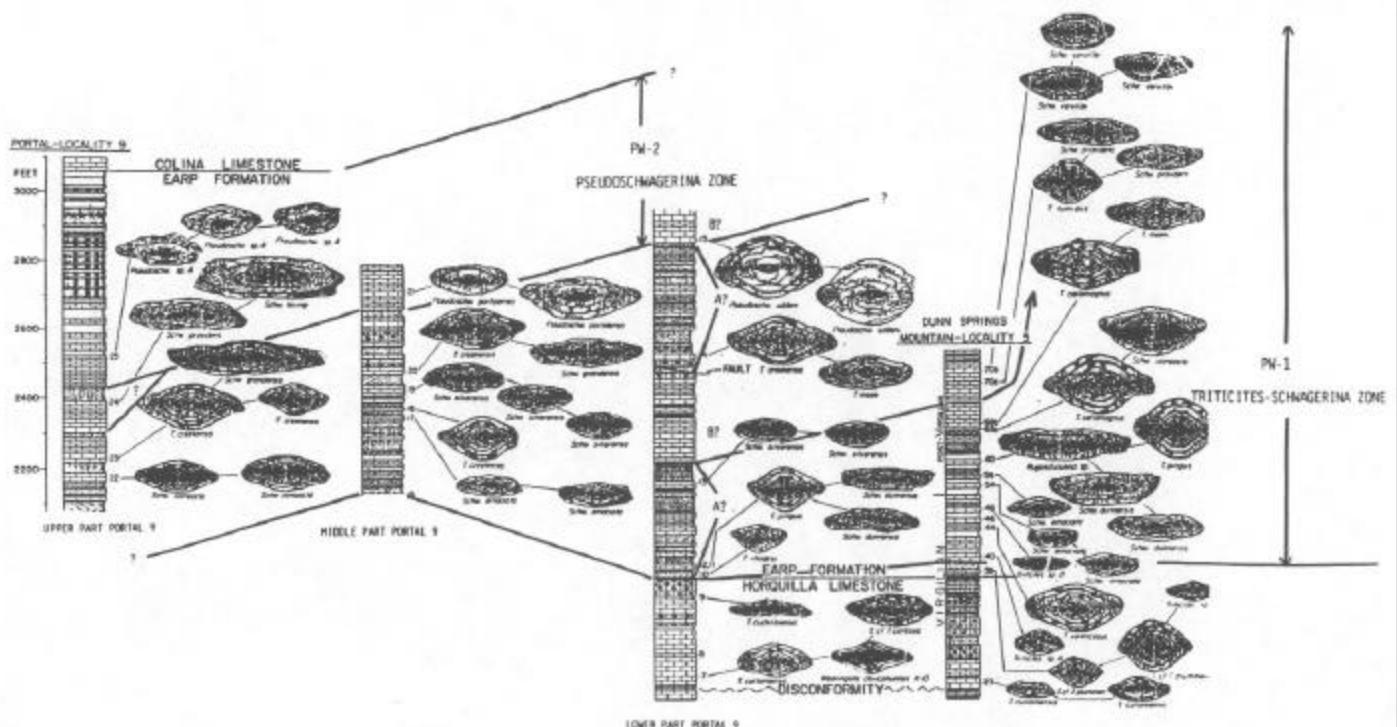


Figure 6. Reinterpretation of Figure 5, based on suggested faulting (modified after Sabins and Ross, 1963).

Late Carboniferous-Permian Fusulinaceans: A Summary

For approximately 50 years I have utilized fusulinaceans from around the world for age dating; however, much of this work has been done in the subsurface and surrounding outcrops of the Permian Basin of West Texas-eastern New Mexico. Admittedly, some ideas have changed over the years, but by the time I published my zonation paper in 1990, I felt as if I had a pretty good handle on how the ranges of fusulinids fit together, particularly in the Wolfcampian. It really makes no difference to me where the Carboniferous-Permian boundary is drawn. Is it based on "... conodont paedomorphoclines, where a temporal series of populations of juvenile characteristics of some ancestral species become progressively expressed in increasingly adult stages of some kind of descendant species"? (Wilde *et al.*, 2000). If so, does the deep-water species prevail over the shallow-water forms? Do we know enough to always separate forms washed into deep water from those living there?

Thus, I truly welcome the work of the conodont and other fossil experts to tell me, before my demise, just where we must call the Carboniferous-Permian boundary. This is why I refuse to make a decision to satisfy others. I shall make my decision and invite others to fit my work to their satisfaction, or dismiss it altogether. This is also why I refuse to give the Newwellian more than sub-stage status. It occupies a certain zone that is easily recognizable. Although I am in much agreement with Wardlaw and Davydov (2000) concerning their ideas on the preliminary placement of the Carboniferous-Permian boundary in the Glass Mountains, I cannot accept Davydov's argument (p. 11) that "However, *Triticites crenatus* from the lower Bursumian looks slightly more primitive than those from the upper Bursumian ...".

Summary of the Newwellian and Related Big Hatchet

Fusulinaceans Newwellian Substage (PW-1)

The fusulinacean faunas of the Wolfcampian portion of the Big Hatchet Mountains are very abundant and diverse. At least 87 species are being described from the Wolfcampian alone, and their generic diversity is extremely interesting. Of the four measured sections considered, *Schwagerina* is represented by 25 species; however, few species were found in more than one section. On the other hand, of 18 species of *Triticites*, 10 species were found in more than one section. These include the well-known *T. crenatus* Thompson, *T. cellamagnus* Thompson and Bissell, *T. ventricosus* (Meek and Hayden), *T. meeki* (Möller) and *T. inflatus* White, plus *Leptotriticites fivensis* (Thompson), and *Schwagerina campensis* Thompson. Of the 15 species of *Pseudoschwagerina*, six species were found in more than one section. Half of the eight species of *Leptotriticites* were found in more than one section; and three of the four species of *Paraschwagerina* were seen in more than one section.

A single species of *Schubertella* appears to range from the Newwellian into the Nealian and Lenoxian stages. But of the 18 species of *Triticites* described from the Newwellian, not a single species occurs in the Nealian or higher; and there are no species of *Triticites* common to the Virgilian, below, although 28 species of the genus are present in the Virgilian.

Only two of the ten species of *Leptotriticites* described are confined to the Newwellian. Only three species of *Pseudofusulina* s.s. (as presently understood) of the 11 species of the genus being described from the Wolfcampian, are confined to the Newwellian.

Skinner and Wilde (1965) described two species of *Leptotriticites* as a subgenus of *Triticites* from abundant material in the Big Hatchet Mountains to demonstrate the range of variation among the many species. After reviewing the group of ten

species referred to *Dunbarinella* by Thompson (1954) from the Wolfcampian of Kansas, Texas, and New Mexico, as well as other forms, such as *Triticites brownvillensis* Douglass (1962), and *Triticites victorioensis* Dunbar and Skinner (1937), they determined that the group was distinctive enough to deserve at least subgeneric rank. Later, in a discussion with M. L. Thompson, he indicated that he was in agreement with us, and stated, "I knew that they were different from *Dunbarinella*, or anything else from the Virgilian, but I really didn't know anything else to do with them." (discussion with Wilde at an AAPG Convention).

Furthermore, Skinner and Wilde (1965), drawing upon years of subsurface and outcrop experience, determined that *Leptotriticites* was confined to the Wolfcampian, and that the Brownsville Limestone belonged to the basal Permian (as then understood) rather than the top of the Pennsylvanian as originally defined by Moore (1940).

Following many years of collecting and study of the Virgilian-Wolfcampian fusulinid faunas of Kansas and Texas by Thompson (1954), and Kauffman and Roth (1966), it was very surprising to see that Sanderson *et al.* (2001) reported six species of *Leptotriticites* from as low as the lower middle Wabunee Group (Burlingame Limestone Member), Virgilian, of Kansas. Further, three of the species were stated to probably belong to species that heretofore had been described as belonging higher in the Wolfcampian. Unfortunately, these reports must remain unverified, inasmuch as plates and descriptions were not included, and references to earlier papers by Sanderson and Verville (1988, 2000, in Sanderson, *et al.* 2001) in support were unpublished company reports (with plates) and a Kansas Geological Survey open-file report (without plates). Nevertheless, as noted in Douglass (1962) and Thompson (1954), the section from which the above was reported had been thoroughly studied before.

Also, in 1963-64, while on an assignment to the Exxon Production Research Center in Houston, undertaking algal studies, I had an opportunity to collect fusulinaceans from the entire Kansas Pennsylvanian-Permian section under the expert guidance of Raymond C. Moore, Daniel C. Merriam, and Russell M. Jeffords. Every fusulinacean locality then known to Dr. Moore was collected. That material, while not completely thin-sectioned, nevertheless is either stored in Houston or, if sectioned, at the University of Kansas Paleontological Institute. Thus, and without verification one way or the other, the present author remains unconvinced as to the correct assignment of the material of Sanderson *et al.* (2001).

Suffice it to say that the Newwellian of the Big Hatchets, formerly referred to as Bursumian (Ross and Ross, 1998; Wahlman and King, 2002), is easily defined with a top and base, both lithologically and faunistically. The Newwellian Substage, from a fusulinacean standpoint, is defined by 18 species of *Triticites*, two of *Leptotriticites*, three of *Pseudofusulina* s.s., one of *Schwagerina* s.s., and a very interesting new species of what, at present, is being referred to *Alpinoschwagerina*, which occurs in the same beds with the highest occurrence of *Triticites*. If there is ever to be an upper Carboniferous-Permian based upon the lowest occurrence of inflated *Pseudoschwagerina*-like forms of fusulinaceans and concomitant changes in the conodonts, this horizon would make a very likely interval to study.

Nealian (PW-2)

Among the 25 species of *Schwagerina* s.s. described from the Big Hatchets, 14 species are from the Nealian. Conversely, of the nine species of *Pseudofusulina* s.s., not a single species was seen in the Nealian. Of the 10 species of *Leptotriticites* described, seven are found in the Nealian, and one is common to both Nealian and Lenoxian. *Pseudoschwagerina*, abundant in the Big Hatchets with 15 species, is represented by only four species in the Nealian, and three occur in both the Nealian and Lenoxian beds. *Paraschwagerina* is represented by four species, and surprisingly, there are only two representatives of this genus in the Nealian, but they also range into the lower Lenoxian.

The Nealian appears to be a time of maximum expansion of *Schwagerina* s.s. and *Leptotriticites*, and a poor development of *Pseudofusulina* s.s., *Pseudoschwagerina*, and *Paraschwagerina*.

Lenoxian (PW-3)

The Lenoxian of the Big Hatchet Mountains probably does not include all of the Late Wolfcampian, either due to erosion, or faulting at its top and/or gradation into red beds of the Earp Formation.

Fusulinacean genera are represented by five species of *Schwagerina* s.s., eight species of *Pseudofusulina* s.s., three species of *Leptotriticites*, one of which began in the Nealian; and nine species of *Pseudoschwagerina*, three of them beginning in the Nealian. *Paraschwagerina* is represented by four species, two of which also occur in the Nealian.

To round out these common generic occurrences, the Lenoxian also contains such rare genera as *Rugosochusenella* (two species), a single species of *Biwella*, three species of *Schubertella*, and a single species of *Monodixodina?*, called by some *Eoparafusulina*.

The Lenoxian is thus characterized by an abundance of *Pseudoschwagerina*, *Pseudofusulina* s.s., fewer species of *Schwagerina* s.s., and a number of exotic forms.

Discussion of the Carboniferous-Permian Boundary Problem

According to the International Lower Permian Working Standard, the Asselian is defined by the first appearance (FAD) of *Streptognathodus isolatus*; base of the Sakmarian is defined by the FAD of *Streptognathodus barskovi* s.s.; and that of the base of the Artinskian is the FAD of *Streptognathodus florensis* or *Sweetognathus whitei* (Wardlaw and Davydov, 2000) (see Fig. 3).

This is well and good if one is dependent upon the conodonts only. For the fusulinid biostratigraphy, everything changes. If the fusulinid nomenclature were completely settled, correlation of the genera and species would be simple, and actually help the conodont biostratigraphy. However, two things prevent this from happening: (1) the North American Province (e.g., Kansas succession) seems to contain a completely different group of fusulinid genera than the chosen Russian Boreal Province, and (2) not only have the International Rules of Zoological Nomenclature not always been applied properly, entirely new and questionable generic names have been introduced with no attempt to define them in such a way as to be identifiable. I first pointed out some of these problems as early as 1979.

For example, and there are many, according to Davydov (2001) at least four fusulinid genera (*Dutkevitchia*, *Ruzhenzenites*, *Schellwienia*, and *Zigarella*) first appeared at the beginning of the Orenburgian, which Davydov correlates to the lower half of the Bursumian. These genera are unknown in North America. Furthermore, he stated that ... “*Licharevitae*, *Ultradiaxina*, *Occidentoschwagerina*, *Schwagerina* and *Rugosochusennella* appeared slightly higher near the base of the *Ultradiaxina bosbytauensis* – *Schwagerina robusta* fusulinid zone.” The first two genera are unknown in North America; *Occidentoschwagerina* is similar to *Pseudoschwagerina texana ultima*; *Schwagerina* might belong to a number of genera, unlike *Schwagerina s.s.* (Dunbar and Skinner, 1936), and *Rugosochusenella* in North America occurs at least as high as Nealian. There is absolutely no way for this fusulinid succession to belong to any part of the “Bursumian”, and certainly not to the Newwellian. This kind of correlation, regardless of what the conodonts say, would place an abundance of species of *Triticites*, completely unknown in Russia, higher than forms that have always and everywhere been known to occur above them!

Sequence Stratigraphic Summary

Because of space restraints required for this preliminary report, only a few words are possible concerning the four measured sections and the sedimentology of the Big Hatchet Mountains. The Big Hatchets are exposed in such a way as to almost parallel the strike of the northeastern edge of the Pedregosa basin. Thus, in a relatively short distance, one sees a subtidal shelf (New Well Peak), a flattened outer shelf with some biohermal development (Bugle Ridge), a slope or shelf margin with abundant reefal development (Big Hatchet Peak), and a basin-edge, with interfingering thick shale intervals bounded by massive clastic carbonates (Borrego). Desmoinesian through Virgilian strata include a backstepping (transgressive) set of sequences followed by Wolfcampian prograding sequences of carbonates and siliciclastics (Kerans *et al.*, 1999)

Conclusions

The Big Hatchet sequence of Carboniferous-Permian rocks fulfills all the requirements necessary to establish a Newwellian Substage for the transition from Late Carboniferous (Pennsylvanian) to Early Permian based upon continuous sedimentation, excellent exposure, an abundance of known marker fossils (fusulinids) throughout, beautiful preservation of megafossils, excellent opportunity for conodont stratigraphy (shelf to basin), and ease of access.

And finally, but very importantly, the base of the Newwellian Substage is recognized by the FAD of primitive *Schwagerina s.s.* or that of primitive *Pseudofusulina s.s.*, or by the FAD of *Triticites cincinnatus* Thompson, or *T. cellamagnus* Thompson and Bissell, or possibly by the FAD of the genus *Leptotriticites*, if my argument on that form is correctly born out. Certainly, any combination of the above appearances would serve to strengthen the argument for recognition of the base.

The top of the Newwellian is recognized by the LAD of the genus *Triticites*, and the FAD of the genus *Pseudoschwagerina*. I consider that the occasionally reported common occurrence of

these two genera, at least in West Texas and New Mexico, to be the result of reworking of the former, as did Thompson (1954, p. 13).

Acknowledgments

I am grateful to Dr. Spencer G. Lucas for having read this paper and for his helpful suggestions for its improvement, but more especially, for his encouragement in this important project.

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IN MEMORIAL

Garner L. Wilde (1926-2003)

Garner L. Wilde died in an automobile accident in Texas on 18 May 2003. Born in Spring Creek, Texas, 29 September 1926, Garner was educated at Texas Christian University, receiving a B.A. (1950), M.A. (1952) and honorary Ph.D. (1976). He served in the U.S. Air Force in Germany immediately after the Second World War.

Employment at Humble/Exxon followed, beginning in 1952 and extending until "retirement" in 1981. At Humble, Garner worked closely with John W. Skinner on a wide range of fusulinids, especially from the American West. Wilde and Skinner, and Wilde himself, published many articles on Permian fusulinids, especially in the *Journal of Paleontology* and the *University of Kansas Paleontological Contributions*.

After "retirement," Garner managed the Harper Oil Company from 1981 to 1986 and then remained active as a consultant. Much stratigraphic and biostratigraphic research by him appeared in the West Texas Geological Society Publications. His 1990 article on fusulinid biozonation (*West Texas Geological Society Bulletin* 29, no. 7) represents a substantial contribution to the use of fusulinids in biostratigraphy. Garner's publications also greatly enhanced our understanding of the lithostratigraphy and biostratigraphy of the type Guadalupian, and he was a major contributor to global recognition of the Guadalupian as a Permian Series. Garner Wilde was one of the most important students of fusulinids, and his astute work did much to improve the Permian timescale. His death is a great loss to all students of the Permian.

From Spencer G. Lucas

Prof. Dr. Alan McGugan (1924-2003)

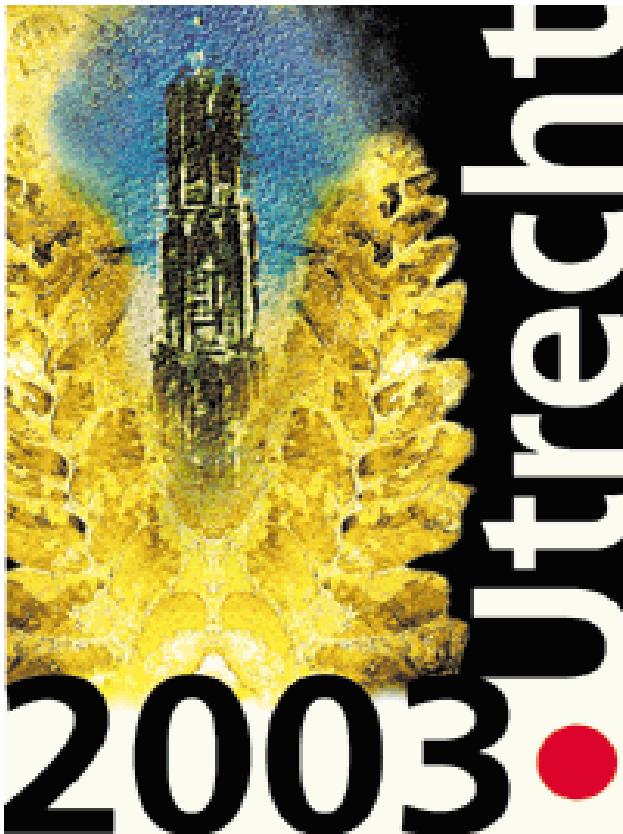
Alan McGugan was born April 17th, 1924 in Belfast, the only son of John Knox McGugan and Eleanor Maude McGugan (nee McCandless). He is survived by Hugh Knox McGugan, Louise Anne Knox McGugan, Brian McGugan, and his wife, Ingeborg van Driel. Alan was a leading aircraftman in the Royal Air Force from 1944-1947. He received a B.Sc. from The Queen's University, Belfast in 1949 and later a M.Sc. from Sedgwick Museum Cambridge, England and D.Sc., again from The Queen's University, Belfast. His academic career began at Queen's University, Kingston, Ontario before coming to the University of Calgary (then the University of Alberta at Calgary) in 1962 as a sessional lecturer, later promoted to Professor in 1974, and finally retiring in 1989. During his career, Alan McGugan was an active researcher in the field of micropaleontology. He studied Pennsylvanian and Permian fusulinids in Western Canada and Cretaceous small foraminifers around the world, focusing on how these microfossils could be applied to practical geologic problem solving. In his spare time he entertained friends with Dixieland tunes on the piano as well as spending considerable time in the garden. This latter pursuit became his passion following his retirement to Cobble Hill on Vancouver Island where he grew a jungle with many unusual plant species until he died peacefully on March 24, 2003. His individualism and name lives on in the minds of family, friends, former students, colleagues, and in his over eighty publications.

Alan was my supervisor at the University of Calgary and I remain grateful for his contributions to my career during my Ph.D. research and in the many telephone conversations and visits to the Island since his retirement.

From Charles M. Henderson

ANNOUNCEMENTS

XVth International Congress on Carboniferous and Permian Stratigraphy (XV ICCP)



The XVth International Congress on Carboniferous and Permian Stratigraphy will be organized by the Netherlands Institute of Applied Geoscience TNO - *National Geological Survey* (TNO-NITG) and the Faculty of Earth Science of the Utrecht University, in Utrecht, the Netherlands. The congress will take place at the campus of the Utrecht University in the period between 10 - 16 August 2003. The venue is within 5 minutes walking distance from the buildings of the Faculty of Earth Sciences of Utrecht University and TNO-NITG.

The theme of the XV ICC-P is the 'Permo-Carboniferous around the Southern North Sea Basin'. Permian and Carboniferous deposits are of great economic importance around this basin. Numerous gas fields occur in these deposits in this mature exploration area. In addition, this area has a long tradition of mining activities related to Carboniferous coal and Permian copper and salt. This led to a good understanding of the geology and stratigraphy of these deposits. Despite the fact that recent oil and gas exploration studies contributed to several new insights, few of these have been published to date. The objec-

tive is to bring these new results to the attention of the participants of this Congress.

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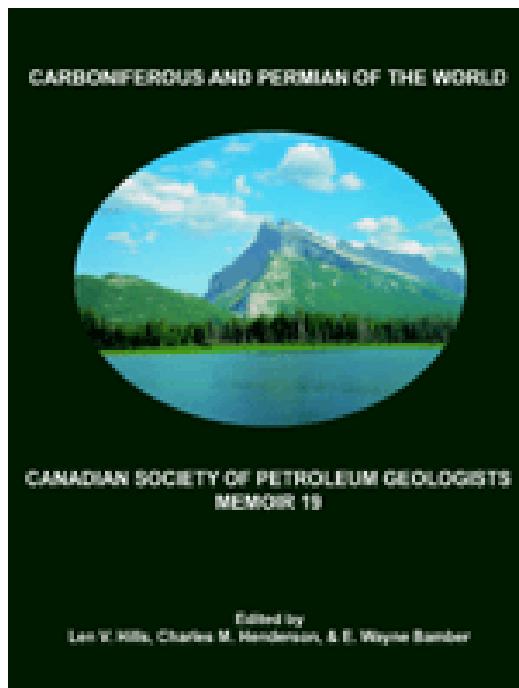
General Symposium G22.04: Global Correlation of the Cisuralian (Lower Permian) stages. Sponsored by SPS. Boris Chuvashov and Charles Henderson are co-chairs. Please contact Charles Henderson if you are interested in presenting at this session.

General Symposium G22.05: Global Permian continental biostratigraphy and biochronology. G. Cassinis and S. Lucas are co-chairs.

Topical Symposium T04.02: Late Permian-Early Triassic events. Bruce Wardlaw and Hongfu Yin are co-chairs.

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Edited by Len V. Hills, Charles M. Henderson, and E. Wayne Bamber, 2002, hard cover, 947 pages, ISBN 0-920230-008

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