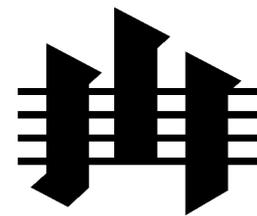


Permophiles



**International Commission on Stratigraphy
International Union of Geological Sciences**

**Newsletter of the
Subcommission on
Permian Stratigraphy
Number 36
June 2000**



Cover Photo

View of Upper Carboniferous and Lower Permian strata surrounding Hare Fiord on northern Ellesmere Island, Canadian Arctic Archipelago. This issue of *Permophiles* includes two articles by Henderson and Mei on the subject of conodonts from Ellesmere Island. Photo by Claude Spinosa 1968.

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EXECUTIVE NOTES

Notes from the SPS Secretary

Claude Spinosa

I want to thank all who contributed articles for inclusion in the 36th issue of *Permophiles* and those who assisted in its preparation. We are indebted to Bruce R. Wardlaw, Charles M. Henderson, Brian F. Glenister, and Vladimir Davydov for editorial contributions; Vladimir Davydov translated the biography of V.E. Ruzhencev by A.A. Shevyrev. We thank Donald W. Boyd, William F. Grauten, Hisayoshi Igo, Spencer G. Lucas, Thomas Martens, Norman D. Newell, Yusuihiro Ota, Ausonio Ronchi, Tetsuo Sugiyama, Paul Wignall, and Garner Wilde for financial contribution to the *Permophiles* publication fund in support of this issue. Publication of *Permophiles* needs additional contributions and readers are referred to the last page of this issue. I am especially thankful to Joan White who came out of retirement as *Permophiles* Technical Editor to conclude this issue.

SPS Officers

My term as Secretary of the SPS will end at the SPS meeting in conjunction with the 31st International Geologic Congress this August and I take this opportunity to thank those colleagues with whom I had the pleasure of working over the last four years.

At the International Congress on Carboniferous and Permian in Calgary, August 17-21, 1999, the subcommission met several times. At one of the meetings, on August 19, the SPS Chair, (Bruce R. Wardlaw), First Vice-Chair (Ernst Ya. Leven), and the Secretary (Claude Spinosa) met during an informal meeting to discuss SPS officers. All officers present wished to remain on the subcommission except Claude Spinosa who, having completed one four-year term, declined renomination. His replacement, Charles M. Henderson, was appointed. Ernst Ya. Leven wished to continue, as did Bruce R. Wardlaw and it was assumed that Clinton Foster also wished to continue. The chair asked the assembled corresponding and voting members whether they objected to the present SPS membership and hearing no objection, pronounced that the present Chair and the two Vice-chairs and Charles Henderson as a replacement for Claude Spinosa would be the new SPS officers.

Future Issues of *Permophiles*

Issue 37 will be finalized by January 10, 2001 and we request that all manuscripts be sent before December 15, 2000, but preferably much earlier. Please see the attached note from Charles Henderson regarding the preferred method of manuscript submission.

Special *Permophiles* Issue for 31st International Geological Congress

We intend to devote Issue 37, which follows the 31st International Geologic Congress, exclusively to publishing extended abstracts of the papers presented at the SPS symposium "International Standard References for the Permian System: Cisuralian of Southern Ural Mountains, Guadalupian of Southwestern North America, Lopingian of South China". We encourage all contributors to submit manuscripts during the congress, however, Charles

Henderson will accept them until December 15. Manuscripts should be no longer than four manuscript pages including illustrations. Illustrations must be black and white line drawings or photographs.

Future SPS Meetings

The SPS will meet in conjunction with the 31st International Geological Congress in Rio de Janeiro, Brazil, August 6-17, 2000. The SPS is the sponsor of the general symposium "International Standard References for the Permian System: Cisuralian of Southern Ural Mountains, Guadalupian of Southwestern North America, Lopingian of South China". Tamra A. Schiappa, Bruce R. Wardlaw, and Brian F. Glenister are the conveners. The symposium consists of an afternoon poster session followed by a morning oral session of invited keynote speakers. Please refer to the site: <http://www.31igc.org> for details. The next regularly scheduled SPS meeting will be in conjunction with the North American Paleontological Convention (NAPC) that will be held on 26 June 2001 at the University of California, Berkeley. Please visit the NAPC site: <http://www.ucmp.berkeley.edu/napc/>

Notes from the SPS Chair

Bruce R. Wardlaw

We are very pleased with the excellent response of the SPS in submitting abstracts for our sponsored session at the IGC "The International Standard References for the Permian System". We plan to dedicate the next issue of *Permophiles* to the presentations by inviting everyone to submit extended abstracts for that issue. In *Permophiles* 35, I presented a working document on the Permian scale for discussion. To my amazement, I have received some comments and present the amended scale here. Once again, this scale is submitted as a working document for discussion and refinement rather than as "the" final statement. First, was the concern that the base of the Permian is too young. I am afraid that that conception is based on old ideas of where the Permian boundary was. The boundary is now officially set at Aidaralash, by the First Appearance Datum of *Streptognathodus isolatus*. Reliable dates are being obtained from near the boundary and indicate 291-292 m.y. age range for the boundary. Second, was the concern about my placement of the Capitanian-Wuchiapingian boundary. As I stated, this is a working scale and I placed my "best" guesses at the potential identifiers for boundaries. As Wang pointed out at the last SPS meeting in Calgary, the evolution of *Clarkina postbitteri* in the proposed stratotype is questionable, but the evolution of *C. postbitteri* to *C. dukouensis* is not and it is only a matter of changing the boundary a metre or so. Again, I presented the scale to develop discussion. I had hoped to get more input on the reliable radiometric ages and get more with good ties to the conodont biostratigraphy. Finally, local zonations, which I view as subzones, were requested to be put into the scale so that a better appreciation of where they fit in to the scheme could be attained. I have begun this process. I hope to see many members this summer at the IGC and look forward to more discussion of the Permian scale.

TIME	STAGE	CONODONT ZONE		
		Identifier/main	auxillary/subzone	
260	CHANGHSINGIAN	251.4	<i>changxingensis</i>	
			<i>subcarinata</i>	
	WUCHIAPINGIAN	253.4	<i>wangi</i>	
			<i>orientalis</i>	<i>inflecta</i>
				<i>orientalis</i>
			<i>transcaucasica</i>	
			<i>guangyuanensis</i>	
			<i>leveni</i>	
			<i>asymmetrica</i>	
		<i>dukouensis</i>		
	CAPITANIAN		<i>altudaensis</i>	<i>postbitteri</i> <i>granti</i> <i>xuanhanensis</i> <i>prexuanhanensis</i> <i>altudaensis</i>
			<i>postserrata</i>	<i>shannoni</i>
		265	<i>aserrata</i>	
		WORDIAN		
	ROADIAN	<i>nankingensis</i>	<i>newelli</i>	
270	KUNGURIAN		<i>sulcopicatus</i>	<i>sulcopicatus</i> <i>n. sp. B</i>
			<i>prayi</i>	2 1
			" <i>exsculptus</i> "	<i>pnevi</i>
280	ARTINSKIAN		<i>pequopensis</i>	
			<i>postwhitei</i>	
			<i>florensis</i>	<i>whitei</i>
290	SAKMARIAN	283	<i>trimilus</i>	
			<i>barskovi</i>	
			<i>fusus</i>	<i>postfusos</i>
290	ASSELIAN	290.6	<i>nevaensis</i>	<i>constrictus</i>
			<i>isolatus</i>	

Emerging Consensus for the Guadalupian-Lopingian Boundary

Charles Henderson, Jin Yugan, and Bruce Wardlaw

In a letter to this issue of Permophiles (see page 42), Dr. Brian Glenister issued a challenge to try and come to a solution for a Guadalupian-Lopingian boundary decision. It appeared that this boundary decision was hopelessly mired in controversy (see Jin Yugan's report in this issue of Permophiles and papers by Wang, 2000 and Jin, 2000). Dr. Claude Spinosa, SPS Secretary, agreed to hold back production of this issue of Permophiles to see if consensus could emerge. Following examination and reconsideration of important collections by Henderson (see Jin Yugan's report) and Wardlaw and following several e-mail discussions between the three of us, we report that a consensus is emerging regarding the boundary. This consensus can be summarized as follows: 1. that the boundary stratotype section should be located at Penglaitan in the Laibin area of Guangxi, South China, 2. that the boundary should be located within the lowstand deposits referred to as the Laibin Limestone, and 3. that the GSSP should be defined by either the first occurrence of *Clarkina postbitteri* (at the upper part of bed 115-6i) or at an arbitrary point within a gradational morphocline from *C. postbitteri* to undisputed *C. dukouensis*. Wardlaw indicates that this latter position could be defined at bed 114.6-6k where increasing numbers of adult specimens of *Clarkina* display a posteriormost denticle reduced in size, a gap between this denticle and cusp, a marked narrowing of the platform, and a higher blade. Henderson recognizes these specimens as *Clarkina postbitteri* and suggests that they could be referred to as a new subspecies of *C. postbitteri*, rather than to *C. dukouensis*.

We also agree that before a decision can be made, further investigation and documentation of the ancestry of *Clarkina postbitteri* and of the morphocline from *C. postbitteri* to *C. dukouensis* is necessary. The ancestry of *C. postbitteri* is disputed at present. Wardlaw believes that it is with *Jinogondolella crofti* whereas Henderson (see Jin Yugan's report) believes that it is with *J. granti*. In addition, the FAD of *C. postbitteri* is controversial. Wang has previously reported this FAD as low as bed 116.4-4f, but Henderson (in Jin Yugan's report) reports that none of the 400 specimens from a sample of 22.5 kg display characters even close to *C. postbitteri*. We regard this irreproducibility of this occurrence as clear evidence that the FAD of *C. postbitteri* is higher in the section. Further study is also needed regarding the correlation between two sections at Tieqiao and the Penglaitan section. Wardlaw reports both *Jinogondolella granti* and *C. postbitteri* in samples from beds C7 and C8 at Tieqiao whereas Henderson reports only *C. postbitteri* from bed C8 and that none of his samples from Penglaitan show overlap between these two taxa. The morphocline between *C. postbitteri* and *C. dukouensis*, although seemingly apparent, is not well documented and needs to be better defined. In addition, the characters used to recognize both of these species need to be better defined and used more consistently. Refined taxonomy of late Guadalupian *Jinogondolella* species will also help in the effort to correlate the type Guadalupian with the Guadalupian of S. China. All of these taxonomic issues, evolutionary relationships, and correlations need to be better resolved before a final consensus can be determined. However, the emerging consensus reported above means that this effort could be focussed on a relatively narrow interval with a clear goal in mind.

In Memory of Vasily Ermolaevich Ruzhencev

By A. A. Shevryev

(Translated by V.I. Davydov)

On the 100th Anniversary of V.E. Ruzhencev's birth

On the 4th of April 1999 V.E. Ruzhencev would have turned 100 years old. He was born in the Smolensk region and he lost his father early in life. After being admitted to the Smolensk secondary school he gave private lessons to augment the family income. After finishing school in 1918, he worked as a teacher for a short period of time and soon afterwards began working as a supervisor in the Smolensk school district.

In 1921 he was appointed to the Moscow Mining Academy, where he attended lectures by A. D. Arkhangelsky and N. S. Shatsky. From 1928 to 1934 he worked as a geologist in the Ministry of Railroads, in the Research Institute of Energy Fluids and in the Oil Exploration Institute. During this period of time he worked on problems of geology and oil and gas exploration in the Caucasus, Emba, and the Urals. He studied phosphorite deposits of west Kazakstan and the Volga region and potassium salts of Middle Asia and other regions of the Soviet Union.

In 1934, subsequent to his involvement with oil projects in the region of the Volga Urals petroleum province (the Second Baku), V.E. Ruzhencev was appointed senior geologist in the "East-Oil" organization, and later worked as the head of field exploration teams. He particularly focused his attention on the stratigraphy of the upper Paleozoic of the south Urals. From 1933 to 1936 he published a series of papers on the Late Carboniferous-Early Permian ammonoids of the south Urals and started planning serious research of ammonoids.

A new path in the life of Vasily Ermolaevich developed in 1937 when he was accepted for work at the Paleontological Institute, where he soon became the head of the department of invertebrates. Two years later he became the head of the laboratory of Advanced Mollusks and from that moment on he began his fulfilling job of ammonoid studies that lasted 40 years.

After a suggestion from the director of the Paleontological Institute, A. A. Borisyak, Vasily Ermolaevich directed his research efforts towards ontogenetic change and phylogenetic relationships of late Paleozoic ammonoids. This approach to ammonoid research was initiated in the 1870's by A.P. Karpinsky on Uralian prolecanitid ammonoids and Vasily Ermolaevich continued these studies on more extensive material. In a very short time, about a year, he finished a monograph entitled "Experience of Natural Systematics of Some Upper Paleozoic Ammonoids", which was published in 1940 and became his Ph.D. dissertation. This work comprised the ideas that he promoted in his later papers, the most important of which was recognition of the ontogenetic method of ammonoid study as the main tool for studying their phylogeny.

After a short break due to World War II, during which V. E. Ruzhencev was engaged in the search for subsurface oil-bearing structures in Bashkiria, he once again returned to late Paleozoic ammonoid research. For this purpose he organized several expeditions to the south Urals. In 1949 he published a significant monograph on the systematics and evolution of pronoritids and medlicottiids, which represents a thorough ontogenetic and phylogenetic investigation of two late Paleozoic ammonoid families.

For this work Vasily Ermolaevich received the A. P. Karpinsky award.

In the 1950s V. E. Ruzhencev completed a long-term research project on late Paleozoic ammonoids with the publication of four major monographs, in which an enormous amount of data was described and evaluated on an ontogenetic and phylogenetic basis. Large collections of well preserved ammonoids were used for ontogenetic research and the construction of specific phylogenetic lineages, which provided scientists the basis for solving many difficult problems of phylogeny and systematics.

Vasily Ermolaevich also focused his intellect on problems of theoretical paleontology. He studied such problems as methods and principles of research, interrelation of individual and historical development, evolution and functional significance of septa in ammonoids, genetic terminology and types of evolutionary changes of suture line, analogy and homology of different septal elements, and so on. In his works Vasily Ermolaevich gives perfectly distinct and persuasive examples of recapitulation in ammonoid evolution. Ruzhencev's view of general regulations of the evolutionary process are most fully expressed in his important manuscript "Principles of Systematics, System, and Phylogeny of Paleozoic Ammonoids" (1960). The first part of this book thoroughly explains the theory of phylogenetic systematics. It describes types of systems, problem of interrelations of ontogeny and phylogeny (ontogenetic recapitulation, ontogenetic and phylogenetic alterations, and ontogenetic acceleration), problems of phylogenetic systematics (interrelationships of systematics and phylogeny, reality and features of taxonomic categories, the problem of transition in systematics), principles of phylogeny and systematics (chronology, principle of homologies, ontogenetic, principle of the main link and chronological principles). The second part presents a thorough description of the system and phylogeny of Paleozoic ammonoids. The first section of this book was translated into several foreign languages and aroused great interest among paleontologists and biologists around the world. The system of ammonoids worked out by Vasily Ermolaevich was accepted in a volume of "Principles of Paleontology" (1962).

On the initiative and under the leadership of Ruzhencev, the Paleontological Institute undertook large-scale projects and thematic research. A major monograph "Development and Change of Marine Organisms at the Boundary of Paleozoic and Mesozoic" that was published in 1965 deserves special attention. It aroused much interest from both Russian and foreign paleontologists.

Ruzhencev was the initiator in providing global summaries on large groups of fossils and characterizing the steps of the evolution of the Earth. For example, a fundamental work by Vasily Ermolaevich (together with M.F. Bogoslovskaya) "Namurian Stage in Ammonoid Evolution" was published in two volumes (1971, 1978).

While studying ammonoids Vasily Ermolaevich was always concerned with their stratigraphic application. He was skeptical regarding the popular idea of global stratotypes, which he considered to have only regional application. However, he believed that all strata of a general stratigraphic scheme were controlled by the corresponding biochronotype, *i.e.* by a definite standard complex of ammonoids. Based mainly on Uralian sections and also on sections of some other regions, Ruzhencev divided the Carboniferous System into 17 ammonoid generic zones and grouped them into 10 stages. Ruzhencev was the first to describe ammonoids of

the Late Carboniferous of the Soviet Union. Based on ammonoid studies he subdivided Upper Carboniferous into two stages: the Zigulevian and the Orenburgian.

Vasily Ermolaevich showed that Early Permian ammonoids, considered by Karpinsky to belong only to the Artinskian, consisted of three complexes - Asselian, Sakmarian and Artinskian, thus two more stages, the Asselian and the Sakmarian were recognized.

Ruzhencev is the author of 130 scientific works, among them 17 monographs, most of which have become reference books for paleontologists throughout the world and are highly praised by specialists.

Vasily Ermolaevich directed the laboratory of Advanced Mollusks in the Paleontological Institute which he himself organized and was active in a science council on the problem "Ways and regulations of evolution of fauna and flora", in Carboniferous and Permian committees, on the Interdepartmental Stratigraphic Committee of Soviet Union, as a member of a committee on Severtsev's award, and for several years as a titular member in committee acceptance. He was the initiator and organizer of several All-Union Paleontological meetings and conferences where he gave important speeches. Ruzhencev's organizational talent revealed itself most fully in the process of compiling and publishing a fifteen volume treatise "Principles of Paleontology." As an editor, he and with U.A. Orlov, organized and selected a group consisting of two hundred and fifty authors, and developed a basic plan for the "Principles of Paleontology" and the uniformity of description of all taxa. Together with the publishing house of the Academy of Sciences he produced a plan for organizing and publishing all the volumes. The successful publication of "Principles of Paleontology" was executed by precise planning, uniformity of description, and a regular inspection. In 1967 Ruzhencev, along with the chief editor of "Principles of Paleontology", Orlov, and two other editors Sokolov and Markovskiy, were awarded the Lenin Award.

From inception of the founding of the "Paleontological Journal" in 1959, Ruzhencev was its editor and after Orlov's death in 1966, he became chief editor. He wrote several programming and methodical articles for the Journal. The scientific style and the mood of this journal were defined by Vasily Ermolaevich. One of Ruzhencev's achievements was the founding of a school of thought of cephalopod specialists. He showed great care in educating a new generation of paleontologists, paid attention to and helped many young specialists. He was not afraid to reveal serious problems to young researchers, entrusted them with important paleontological themes, and was attentive in supervising and directing their research.

The theoretical basics of systematics and methods of ontogenetic research created by V.E. Ruzhencev are widely used by Russian paleontologists and by many foreign specialists. Many ammonoid workers, not only beginners but also those of renown, came to seek his advice. The great contribution made by V.E. Ruzhencev to the study of the stratigraphy of upper Paleozoic, was the establishment of stage and zonal subdivision of the Carboniferous and Permian and also the solution of complex stratigraphic problems, which brought him to a position of great respect among geologists.

Ruzhencev's great scientific and organizational achievements resulted mostly from his personal qualities - wide range of interests, adherence to principles, industriousness, ability to work, exceptional self-discipline, exactness to oneself and others. His papers

are characterized by clarity of thought, taking into account all facts and logical conclusions. Vasily Ermolaevich was a man of principle. He courageously stood up for his scientific beliefs even if they went against accepted concepts. He was never enamoured of popular theories or influenced by scientific authorities. He took into account only facts.

All people who worked with V.E. Ruzhencev enjoyed dealing with him. Students and laboratory staff experienced his constant help and support. For them he was a strict and demanding supervisor, but also a kind, responsive person, an understanding senior friend, always ready to share his life and scientific experience.

I met Vasily Ermolaevich in late summer 1954 when I was accepted as junior scientist at Paleontological Institute, Laboratory of Advanced Mollusks, after graduating from Moscow University. I was to investigate Triassic ceratites and to use ontogenetic and phylogenetic methods, the advantages of which were demonstrated by Ruzhencev's study of Paleozoic ammonoids. I did not have any material then and started by studying the literature. I soon learned that ontogenetic recapitulation, which served as a basis for Vasily Ermolaevich's studies, had been rejected by some quite famous paleontologists and biologists. Some of them fully rejected Muller-Heckel Law ironically saying that this law makes every species climb its own phylogenetic tree. Opponents of the ontogenetic method, for instance, the famous English paleontologists L. Spat and U. Arkell, considered the study of ontogeny to be useless, and they thought that the need for breaking back the shells would ruin paleontological collections.

As I had no experience of my own, I felt at a loss. For me, arguments of both supporters and opponents of the ontogenetic method were equally persuasive. Vasily Ermolaevich observed my doubts, but was not trying to influence me; he was patiently waiting for my decision. At first he was controlling my work, checking the precision of my measurements of shells, the correctness of sketching lobe lines and of my descriptions, but after I defended my Ph.D. thesis, he allowed me to work independently.

Vasily Ermolaevich had a bad temper. Negligence or poor quality of work drove him out of his wits. Once during a field trip Vasily Ermolaevich was working hard to break a paleontological sample out of rock. After putting it very carefully on a boulder, he went to look for another sample. Meanwhile, a student from Moscow Mining Institute came up to the boulder, saw the sample, and struck it with a hammer. The sample was smashed to pieces. When Vasily Ermolaevich saw what happened to the results of his hard efforts, he exploded. All of us quickly retreated leaving our miserable friend to the mercy of fate. Soon the "storm" was over. When we looked out of our shelter we found Vasily Ermolaevich searching for a new sample, as if nothing had happened. The incident was forgotten. Vasily Ermolaevich never referred to it again. He did not keep bad memories.

Vasily Ermolaevich was a great optimist. He believed in a bright future for our science. It is not the best time for paleontology now, but let us take example from Vasily Ermolaevich and never lose hope.

[Editors note: The previous note is a translation of a tribute made to V.E. Ruzhencev that appears in a volume dedicated to him on the occasion of his 100th birthday. The volume, entitled "Fossil Cephalopods: Recent Advances in their Study", edited by A. Yu. Rozanov and A.A. Shevyrev, (ISBN 5-201-15403-4) contains sixteen original articles regarding cephalopods. The volume is avail-

able for purchase and the reader is referred to the Paleontological Institute of the Russian Academy of Science, Profsoyusnaya 123, 11767 Moscow, Russia]

SUBMISSION GUIDELINES FOR ISSUE 37

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 .2". 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. 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 articles with names of new taxa will not be published 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 98 PC with Corel Word Perfect 8, Corel Draw 8, Adobe Page Maker 6.5, and Microsoft Office 97 programs; documents compatible with these specifications will be easiest to work with.

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**SUBMISSION DEADLINE FOR
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REPORTS

The Bursum Formation Stratotype, Upper Carboniferous of New Mexico, and the Bursumian Stage

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Introduction

The term Bursum has been used to refer to a lithostratigraphic unit, a biostratigraphic zone or to a stage (Bursumian) of the earliest Permian or latest Carboniferous in North America. The type section of the lithostratigraphic unit Bursum Formation has never been described in detail, so the exact lithostratigraphic boundaries of the Bursum Formation have not been certain. Furthermore, the Bursum lithostratigraphic unit and the Bursum biostratigraphic unit do not necessarily coincide.

Lucas *et al.* (2000) describe in detail the type section of the Bursum Formation in order to define it more precisely as a lithostratigraphic unit, and we present a brief summary here. Results of our preliminary study of fusulinids from the Bursum type section establish the biostratigraphic position of the Bursum For-

mation stratotype. This biostratigraphy suggests that the base of the Bursum Formation (lithostratigraphic unit) does not correspond to the base of the Bursumian Stage (chronostratigraphic unit) as used by some workers.

Previous studies

Different concepts of the Bursum Formation (Fig. 1) reflect the lack of a detailed description of the type section and different concepts (lithostratigraphic vs. biostratigraphic) applied to the term Bursum. Wilpolt *et al.* (1946) named the Bursum Formation, but the type section is outside of the area they mapped, so they provided no detailed description. However, they did map the Bursum Formation throughout a large area and presented several measured sections in columnar form, and this provided a basis for recognition and correlation of the formation in central New Mexico.

Wilpolt and Wanek (1951) mapped an area that included the type section of the Bursum Formation. Here, they mapped the Bursum overlying a tongue of the Abo Formation, which overlies the upper arkosic member of the Madera Formation. They noted that

....a thick, white-weathering limestone, occurring at the top of the formation in the Oscura Mountains, has been considered by Thompson (1942, pl. 2, opposite p. 20) to be of Wolfcamp age. Thompson assigned the strata below this massive bed and above the massive limestone of the arkosic limestone member of the Madera limestone to his Bruton formation. Thompson's Bruton formation is equivalent to all of the Bursum formation except the uppermost massive ledge and the thin beds of limestone

Lithology (schematic) and key fusulinids	Thompson (1944)	Wilpolt et al. (1946) Wilpolt and Wanek (1951)	Thompson (1954)	Lucas et al. (2000)
	Abo Formation	Abo Formation	Abo Formation	Abo Formation
	fusulinid-bearing Wolfcamp limestone	Bursum Formation	Bursum Formation	Bursum Formation
	Bruton Formation	Abo Tongue	Virgilian (Fresnal Group)	
		arkosic limestone member of Madera Formation		Madera Group

Figure 1. Changing concepts of the Bursum Formation stratotype.

interbedded with red and green shale that lie just above the top of the arkosic limestone member of the Madera in the Oscura Mountains and Hansonburg Hills.

Thompson (1954, p. 18) made it clear that his concept of the Bursum was biostratigraphic/chronostratigraphic when he stated that "the term Bursum should be redefined so as to apply only to pre-Abo Wolfcampian rocks of New Mexico." Thompson therefore reassigned the Wolfcampian part (upper 40 ft) of his Bruton Formation to the Bursum Formation, but he also stated that "a lower part of the Bursum as defined by Wilpolt *et al.* here is retained in the Bruton formation." Thompson (1954) did not provide a description of the Bursum Formation type section, and his cross-section (Thompson, 1954, fig. 5) is so generalized that it is unclear exactly how he might have interpreted that section. However, he evidently modified his concepts of Bruton and Bursum, probably in part as a result of the work of Wilpolt and Wanek (1951).

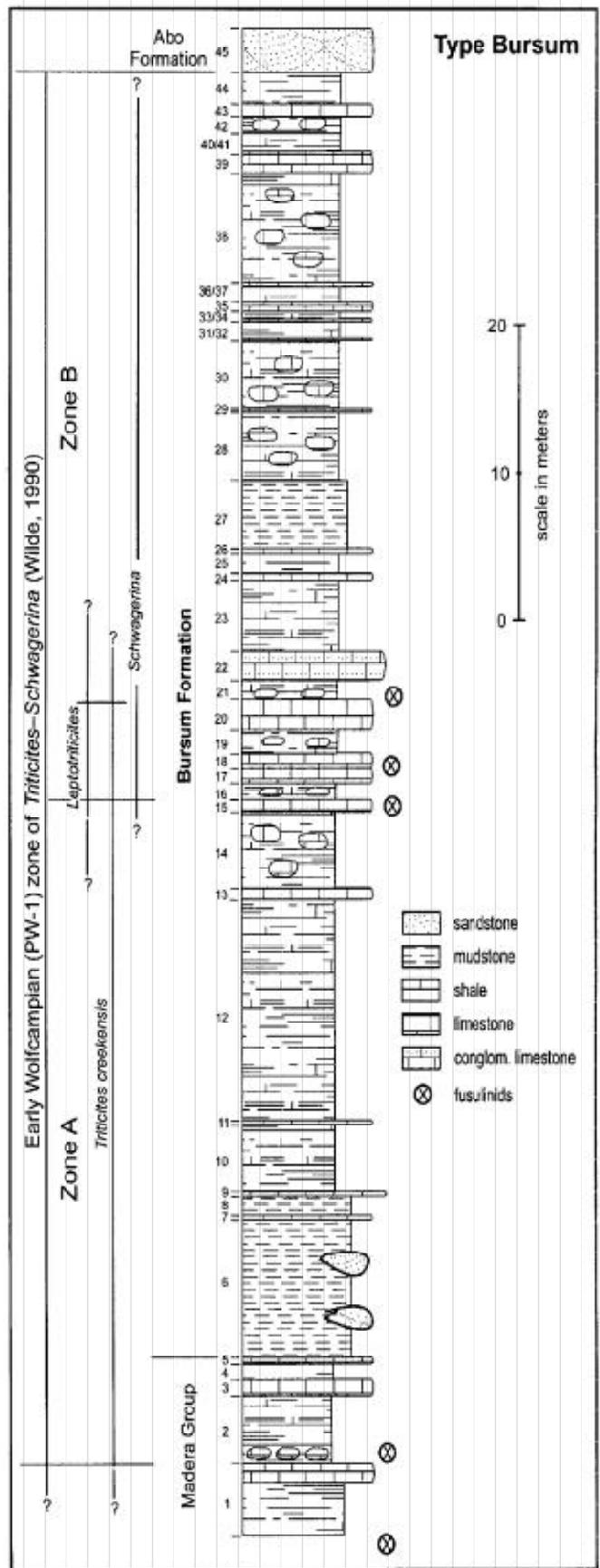
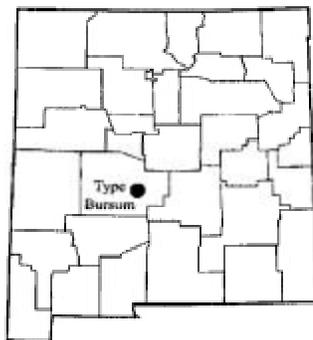
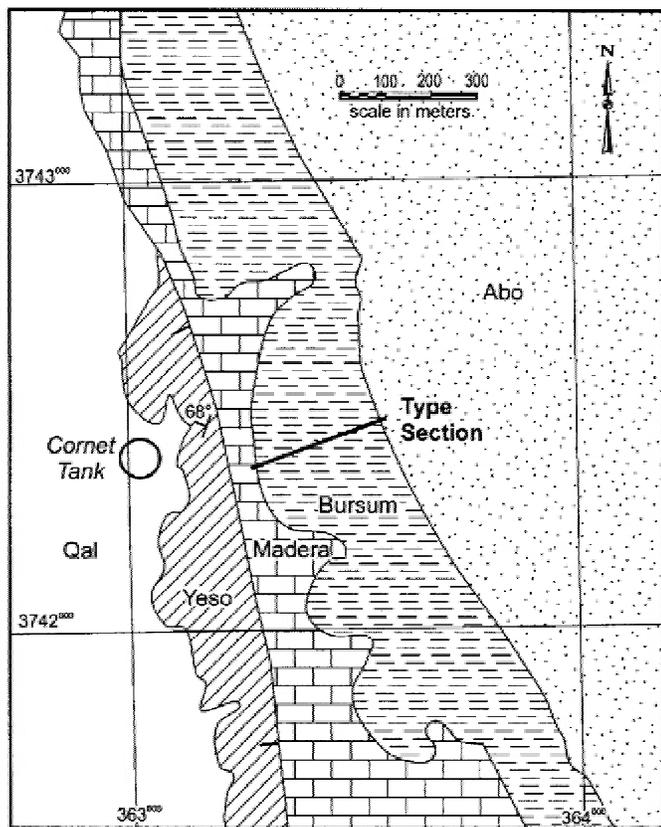


Figure 2. Map of New Mexico showing location of type section of Bursum Formation, geologic map of the area around the type section of the Bursum Formation and measured section of the type section of the Bursum Formation showing fusulinacean distribution.

Stratotype

The type section of the Bursum Formation designated by Wilpolt *et al.* (1946) is in the Hansonburg Hills of Socorro County, New Mexico, in the NE ¼ SE ¼ sec. 1, T6S, R4E, between Cornet Tank and the Bursum Triangulation Point (Fig. 2). Here, the Bursum Formation crops out as a NW-SE-striking belt of strata that dip about 25° to the NE. Cornet Tank is built in valley floor alluvium, and outcrops immediately east of the tank are strata of the Permian (Leonardian) Yeso Formation that dip about 60° to the NNW. This is because a high angle normal fault has downropped Yeso strata west of limestones and drab calcareous shales of the upper Madera Group (Bruton Formation of Thompson, 1942; arkosic limestone member of Madera Formation of Wilpolt and Wanek, 1951) that dip eastward on the east side of the fault. Indeed, east of the fault, a single, eastward-dipping section of Madera, Bursum and Abo formations is present (Fig. 2).

At the type section (Figs. 2), we place the Bursum-Madera contact at a point of maximum lithologic contrast that facilitates mappability of the base of the Bursum Formation. Thus, the basal bed of the Bursum Formation is “red” (pale brown) mudstone with numerous limestone (calcrete) nodules (Fig. 2, bed 6), which overlies gray limestones and brownish gray shale of the upper part of the Madera Group (Fig. 2, beds 1-5). Probably, Wilpolt and Wanek (1951) mapped the lower red beds we assign to the Bursum Formation (Fig. 2, units 6-12) as a tongue of the Abo Formation. However, these beds do not merge laterally with the Abo and are thus assigned by us to the Bursum (for similar assignment, see Bachman, 1968).

The Bursum-Abo contact is also a readily mappable boundary characterized by distinctive lithologic contrast. Thus, the basal Abo is reddish brown and grayish red sandstone (Fig. 2, unit 45) at the base of a nearly monochromatic succession of red beds of mudstone and fluvially-deposited sandstone and conglomerate. Underlying Bursum strata are grayish limestones and pale red and yellow shales (Fig. 2, units 38-44).

At the type section, the Bursum Formation is 85 m thick. It is mostly shale (55% of the measured section) and lesser amounts of mudstone (23%) and limestone (19%). Minor rock types are conglomerate (2%), sandstone (< 1%) and calcarenite (< 1%). Bursum shales are dominantly “red” (pale reddish brown) and calcareous. Some shale intervals have abundant nodules of limestone. Bursum limestone beds are medium gray or dark gray and are either unfossiliferous micrites or fusulinid-brachiopod-bryozoan packstones. The limestone beds form ledges or cuestas between shale slopes. Some shale beds, and the mudstone beds, particularly in the lower half of the type section (Fig. 2, units 6-16), are “red” (pale brown or grayish red). Conglomerate beds are clast supported and composed of limestone pebbles.

Thus, at its type section the Bursum Formation is a lithologically distinctive, readily mappable lithostratigraphic unit between Madera and Abo strata. Unlike underlying Madera strata, the Bursum contains substantial intervals of red-bed shale and mudstone, and some beds of limestone-pebble conglomerate and trough-crossbedded sandstone. Unlike the overlying Abo Formation, the Bursum contains beds of marine limestone and calcareous shale. The unit is thus transitional between wholly marine (upper Madera) and wholly nonmarine (Abo) units, but retains an unique lithologic character.

Biostratigraphy of the stratotype

Macroinvertebrate fossils are common in only a few limestone beds of the Bursum Formation at its type section. Collections we made come primarily from beds 21 and 29 (Fig. 2) and are dominated by brachiopods of Virgilian affinities (Barry S. Kues, written commun., 1999).

Our study of stratotypical Bursum fusulinaceans (Lucas *et al.*, 2000) should be considered preliminary because the material at our disposal is not sufficiently representative to be definitive, inasmuch as most of the species are identified from too few specimens. For example, from five stratigraphic levels (Fig. 2), a total of 31 thin sections were available, for an average of little more than six sections per collection. Nevertheless, two zones appear to be represented in the type Bursum, although their usefulness regionally might be called into question. Zone A extends from well below the base of the Bursum to the top of bed 15 (Fig. 2), or about 62 m, and includes *Triticites* sp. C, *T. creekensis*, and *Leptotriticites fivensis*. Zone B extends ostensibly to the top of the Bursum, or about 50 m, although our material occurs within an interval of only about 10 m in the middle of the formation and includes *Triticites creekensis*, *Leptotriticites glenensis*, *Schwagerina grandensis*, and *S. campensis*.

Inasmuch as *T. creekensis* is in the lowest and highest collection, the entire section could be referred to that zone. Also, *Leptotriticites* occurs in beds 15 and 18 only, which could be representative of a thin zone of that genus. *Schwagerina* does not occur in Zone A. We know from other areas of Kansas, Texas, and New Mexico, that this zonation must be a local one, and thus not useful regionally. We can say, however, that the entire fauna is rather typical of the early Wolfcampian (Wilde, 1990, zone PW-1), which is recognizable throughout North America.

The Bursumian Stage

In North America, the Carboniferous (Pennsylvanian)-Permian boundary has long corresponded to the base of the Wolfcampian Stage (Virgilian-Wolfcampian boundary), which traditionally corresponded to the first appearance datum (FAD) of the fusulinid *Schwagerina* (e.g., Baars *et al.*, 1992). The recent establishment in western Kazakstan of the GSSP for the Carboniferous-Permian boundary (Davydov *et al.*, 1995) forces the position to change in the North American regional scale. Thus, the GSSP in Kazakstan corresponds to a so-called “conodont boundary,” which is at the FAD of the conodont *Streptognathodus isolatus*, which is very close to the base of the *Sphaeroschwagerina vulgaris* (*S. aktjubensis*) fusulinid zone. Correlation of this boundary to the North American fusulinid zonation indicates that the base of the Permian is now close to the FAD of *Pseudoschwagerina*, which is within the Wolfcampian Stage (Fig. 3).

In the standard global chronostratigraphic scale, each System base corresponds to the base of a Stage (e.g., Aubry *et al.*, 1999). The secondary standard provided by the North American provincial stages should also have the Carboniferous-Permian System boundary correspond to the base of a stage, but this requires some modification and/or redefinition of the regional stages (Fig. 3). Baars *et al.* (1992, 1994a, b) have “solved” this problem by redefining the Virgilian Stage to encompass strata previously included in the lower Wolfcampian (Fig. 3). A second solution, advocated by Ross and Ross (1987, 1994), is to recognize a Bursumian

PER	ST	RUSSIAN PLATFORM FUSULINIDS	N. AMER. FUSULINIDS	N. AMER. STAGES			PER
PERMIAN	Asselian	<i>Sphaeroschwagerina fusiformis</i>	<i>Pseudoschwagerina beedei</i> and <i>Paraschwagerina gigantea</i>	Wolfcampian	Wolfcampian	Wolfcampian	PERMIAN
		<i>Sphaeroschwagerina vulgaris</i> (<i>aktjubensis</i>)					
UPPER CARBONIFEROUS	Ghzelian	<i>Ultradaixina</i> spp.	<i>Triticites creekensis</i> , <i>Schwagerina</i> and <i>Pseudofusulina</i>	Wolfcampian	Virgilian	Bursumian	PENNSYLVANIAN
			<i>Triticites</i> and <i>Dunbarinella</i>				

Figure 3. Position of Carboniferous-Permian boundary on the Russian platform (left) and the position with respect to the North American stages with three alternative stage usages: traditional (left), expanded Virgilian (middle) and use of Bursumian (right).

Stage equivalent to the lower Wolfcampian of earlier usage (Fig. 3).

Our study of the type section of the Bursum Formation has some bearing on recognition of a Bursumian Stage. Fusulinid distribution at the type section indicates that the base of the Bursum Formation (lithostratigraphic unit) does not correspond to the base of a fusulinid zone. This means that the base of a Bursumian Stage, if it corresponds to the base of a fusulinid zone, is stratigraphically lower, at an unidentified stratigraphic level in the Madera Group.

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. The search for a Bursumian stratotype will thus have to focus elsewhere.

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Preliminary Placement of the International Lower Permian Working Standard to the Glass Mountains, Texas

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Conodonts

The International Lower Permian Working Standard is based on conodont distributions in the southern Urals, Kansas, and West Texas. Asselian is defined on the first appearance of *Streptognathodus isolatus*. This occurs at the base of the Bennett Shale of the Red Eagle Limestone in Kansas. The current working definition for the base of the Sakmarian is the FAD of *Streptognathodus barskovi* (*sensu strictu*). This occurs in the Eiss Limestone of the Bader Limestone in Kansas and is very close to the FAD of *Sweetognathus merrilli* which is in the upper part of the Eiss. The working definition of the base of the Artinskian is the FAD of *Streptognathodus florensis* or *Sweetognathus whitei* which both first appear in the base of the Florence Limestone of the Barnston Formation in Kansas. After Barnston deposition the Kansas section remains very shallow during marine incursions and only sparse to common *Sweetognathus* or *Rabeignathus* faunas are recovered. The working standard for the Kungurian conodont zonation is based on the distribution of conodonts from the Glass Mountains, Texas. The working definition of the base of the Kungurian is the FAD of *Neostreptognathodus "exsculptus"*.

The Grey Limestone Member of the Gaptank Formation is a shallow-water carbonate that forms the top of the formation. Conodont faunas are sparse, but the base of the Grey Limestone Member contains a conodont fauna that correlates to the Foraker Limestone with the overlap of the ending range of *Streptognathodus brownvillensis* and the FAD of *S. elongatus*. The top of the Grey Limestone contains a conodont fauna that correlates to the Grenola Limestone with *Streptognathodus nevaensis* and *S. elongatus*. Therefore, the Carboniferous-Permian boundary is located within the Grey Limestone.

The Neal Ranch Formation is dominated by prodelta siltstones with common plant debris and limestone and limestone conglomerate interbeds. The limestones yield a fair conodont fauna. At 52 m above the base *Streptognathodus barskovi*, *S. isolatus* and *Sweetognathus merrilli* occur (equivalent to bed 9 of Ross, 1963). The overlap of *barskovi* and *isolatus* indicates the base of the *S. barskovi* Zone. *Streptognathodus barskovi* occurs higher at 71 m where it occurs with *S. postconstrictus* which indicates the upper part of its zone.

The Lenox Hills Formation is largely delta conglomerates and does not yield many conodonts. However, in the Dugout Mountain area, it contains common limestone which yields a sparse fauna of *Sweetognathus whitei* and *Neostreptognathodus transitus*. This fauna indicates the upper Artinskian. Conodonts do not constrain well the Sakmarian-Artinskian boundary in the Glass Moun-

tains area.

The Skinner Ranch Formation is largely limestone and limestone conglomerate with abundant conodont faunas. Its type section it contains *Neostreptognathodus pequopensis* at its base. At 17 m, a plethora of species of *Mesogondolella* and *Neostreptognathodus* occur, including *Neostreptognathodus "exsculptus"* which marks the base of the Kungurian.

First Appearance	Stratigraphic Position
<i>N. "exsculptus"</i>	17 m above base, Skinner Ranch Fm.
<i>S. barskovi</i>	52 m above base, Neal Ranch Fm.
<i>S. nevaensis</i>	Top of Grey Limestone Member
<i>S. elongatus</i>	Base of Grey Limestone Member

Fusulinids

Basically, the fusulinid distribution in the Midcontinent and the Southwest support the conodont distribution. However, its interpretation is much more complex. The Late Pennsylvanian fusulinid biostratigraphy of Kansas and New Mexico was studied by Thompson almost 50 years ago and never has been revised. The Cisuralian fusulinid biostratigraphy in the classic region of West Texas was studied by Ross (1959, 1962, 1963, 1965). Recently, the Bursumian stage was suggested, "to fill a gap between top of Virgilian and base of the Nealian" (Ross and Ross, 1994). Several subdivisions were suggested for the Wolfcampian: Nealian and Lenoxian as equivalents of Asselian and Sakmarian, and for the Leonardian: Hessian and Cathedralian as equivalents for Artinskian and Kungurian (Ross and Ross, 1987, 1994). Predominantly generalized data of fusulinid assemblages for those stages with no species distribution in the sections were available for our analyses. Recent study of Bursumian in its stratotype provides new detailed information (Lucas *et al.*, 2000, Lucas and Wilde, *this issue*).

The Grey Limestone of Gaptank Formation in Glass Mountains contains fusulinids which were described as *Triticites comptus* (Ross, 1963). However, major morphological features, such as three-layered wall with outer tectorium, character of septal fluting and presence of axial fillings suggest that this fauna belongs to the eastern hemisphere form, *Schellwienia* (Staff and Wedekind, 1910; Davydov, 1986, 1988; Rauser-Chernousova *et al.*, 1996). *Schellwienia* in the Urals and Central Asia appears in early Orenburgian, is still abundant in lower Asselian and is rare in middle Asselian. *Schellwienia comptus* from the Grey Limestone are advance representatives of the genus and therefore may characterize either latest Orenburgian or earliest Asselian. The population of *Schellwienia comptus* figured by Ross (1963) looks heterogenous because some specimens from lower Gaptank Fm. look more primitive (Ross, 1963, pl. 4, figs. 13, 17) and the rest of population including the holotype from Grey Limestone look more advanced (Ross, 1963, pl. 4, figs. 14, 18). Additional investigation of this species is necessary.

In the type section of Bursumian, the lower half of the section is characterized by *Triticites creekensis* which ranges all the way through the formation. However, *Triticites creekensis* from the lower Bursumian looks slightly more primitive than those from the upper Bursumian and; therefore, this species most probably represents a morphocline of subspheric *Triticites*, which can be divided into several independent species (one author is known to split species).

There are no *Leptotriticites* in the lower Bursumian portion of the section and what was identified as "*Leptotriticites fivensis*" probably is a microsphaeric specimen of *Triticites* (Lucas *et al.*, figs. 74-7.5). The upper half of the section is characterized by true *Leptotriticites glenensis* (Thompson) originally described from Glenrock Limestone, which based on conodonts belongs to the uppermost Gzhelian, immediately below the Asselian (Boardman *et al.*, 1998). The other fusulinids recovered in the upper Bursumian were identified as "*Schwagerina grandensis*" which Thompson (1954) described from the overlying Hueco Limestone in Robledo Mountains.

To summarize all the above, we can suggest that the C/P boundary should be placed within the Bursumian, probably somewhere between bed 15 and 18 (Lucas *et al.*, 2000). The limestone package of beds 15-22 in the Bursumian stratotype likely represents transgressive and highstand system tracts which corresponds well with the sedimentary cycle recognized in C/P transition in Southern Urals (Snyder *et al.*, 1996, Davydov *et al.*, 1997), Carnic Alps (Krainer & Davydov, 1998) and Arctic (Davydov *et al.*, 1999).

Pseudoschwagerina does not characterize the base of the Permian in North America. In Nevada and the Glass Mountains, typical *Pseudoschwagerina* occurs predominantly in the Artinskian (Davydov, 1996, Davydov *et al.*, 1997b). The most primitive and probably earliest representative of the genus (*Pseudoschwagerina rhodesi*) described by Thompson from the Hueco Formation in Rhodes Canyon, New Mexico (Thompson, 1954) occurs well above the Bursum Formation. The other fusulinid species that co-occurs with *Pseudoschwagerina rhodesi* is *Schwagerina anderssoni* Thompson, very similar to *Schwagerina exuberata* (Shamov), a characteristic upper Asselian species in the Urals. In the Urals, Russian Platform, Norwegian and Russian Arctic and Central Asia there is a significant time interval between the FAD of *Sphaeroschwagerina* and the FAD of *Pseudoschwagerina*, which we estimated as 1.0-1.2 Ma. Therefore, the statement that the FAD of *Pseudoschwagerina* in North America is close to the base of the Permian (Ross and Ross, 1994; Lucas *et al.*, 2000) is not supported by the fusulinid data.

Ross suggested that the Nealian (stratotype - section 22 of Wolf Camp Hills in the Glass Mountains, Ross, 1963) is characterized by *Paraschwagerina*, *Pseudoschwagerina uddeni*, *Stewartina texana*, *Eoparafusulina allisonensis* and "*Schwagerina compacta*", and correlates with the Asselian of the Urals. The analysis of Ross's data from the type section of Nealian allows us to recognize two different fusulinid assemblages. The first one encompasses beds 1-6 in the type section 22 and is represented mostly by the low diversity *Triticites* species (*T. pinguis*, *T. ventricosus*, *T. subventricosus*). This fauna is characteristic for the Midcontinent-Andean province and cannot be compared directly with Uralian fusulinids. However, one species, *T. pinguis*, is similar to the *Triticites ortashensis*, a very characteristic species of the uppermost Gzhelian in the Southern Urals (Davydov, 1986).

The next assemblage comprises the majority of the Nealian fusulinid fauna and occurs in beds 7-28 of section 22 of Wolf Camp Hill in Glass Mountains: *Leptotriticites koschmani*, *Pseudoschwagerina uddeni*, *Stewartina texana*, *Paraschwagerina kansanensis*, *P. gigantea*, *Schwagerina pugunculus*, *Schwagerina sp. A*, "*S. compacta*", "*S. sp. C*".

Leptotriticites and *Stewartina* are provincial taxa and cannot be used for correlation with the Urals. *Pseudoschwagerina uddeni*

and *P. beedei* in the Urals first occur in the middle Asselian, but range into the upper Asselian. In Central Asia, Tethyan province, these species range through the middle-upper Asselian, and into the Sakmarian (Leven, Scherbovich, 1980; Leven *et al.*, 1992; Kahler, 1989; Ozawa and Kobayashi, 1990; Zhou *et al.*, 1987; Chang, 1963). The Nealian *Paraschwagerina gigantea* is an advanced form most similar to *Paraschwagerina mira* from upper Tastubian, Sakmarian of the southern Urals (Rausser-Chernousova & Scherbovich, 1949). Recently, *Paraschwagerina ex gr. gigantea* (White) and *Paraschwagerina kansanensis* (Beede et Kniker) were identified from the Tastubian of the central Urals (Echlov, 1993).

The *Schwagerina sp. A* (Ross, 1963, pl. 22, figs. 2-4,6) is similar to *Schwagerina moelleri* (Schellwien), the index species of lower Tastubian (Lower Sakmarian) of the Urals. Currently, the base of the Sakmarian in Kondurovsky section, the type section of the Sakmarian in Southern Urals, is suggested to be placed within bed 9, 75 m below its original position (Wardlaw *et al.*, 1999). Several significant steps in fusulinid evolution were recognized within the *Schwagerina moelleri* group (Davydov *et al.*, 1999). *Schwagerina sp. A* from the Nealian stratotype is most similar to the most advanced representative of *Schwagerina moelleri* group in the Urals, characteristic for upper Tastubian.

"*Schwagerina?*" *sp. C* (Ross, 1963, pl. 13, figs. 11,12) in modern nomenclature should be named *Eoparafusulina* and can be compared with the primitive *Eoparafusulina* (*E. perplexa*, *E. tersus* group) from the Tastubian of the Arctic Russia (Northern Timan, Kolguev Island) and Spitsbergen (Grozilova and Lebedeva, 1961; Nilsson and Davydov, 1997; Davydov, 1997). Also *Eoparafusulina allisonensis* was described by Ross (1967) from the upper portion of the Neal Ranch Formation in the Wolfcamp Hills (Ross, 1967). This is perhaps a junior synonym of the *Eoparafusulina parolinearis* (Thorsteinsson), which is known from the Tastubian of Spitsbergen and Canadian Arctic (Nilsson and Davydov, 1997; Harker and Thorsteinsson, 1960) and occurs in upper Tastubian in Barents Sea.

"*Schwagerina compacta*" is quite similar with *Zigarella callosa*, which in the Urals occurs in the upper Tastubian and Sterlitamakian (Rausser-Chernousova, 1965).

The upper Nealian in its stratotype should be correlated with the upper Tastubian (Lower Sakmarian) in the Urals. It is important to emphasize that the well developed fauna from the upper Nealian appears abruptly in the rock record; most of these important taxa have no ancestral elements in underlying strata. The lower portion of the Neal Ranch Formation is perhaps equivalent to the uppermost Gzhelian and lowermost Asselian. Furthermore it can be suggested that there is a time gap within the Neal Ranch Formation (somewhere between beds 5-7 or 9 in stratotype). However, because the fusulinid fauna in the lower portion of the Neal Ranch Formation is very poorly studied, it remains enigmatic.

The fusulinid succession of the Lenoxian in its type section 8 of Lenox Hill in Glass Mountains, by Ross (1963) can be divided into two assemblages. The first one appears in beds 1-10 in the type-section. Some species range from Nealian into the overlying Lenoxian. The most characteristic species for this assemblage are: *Schwagerina tersa*, *Schwagerina cribrosepta*, *Schwagerina extumida*, *S. bellula*, and *Pseudofusulina lineonada*. The fusulinids from this assemblage are different from those of Tastubian and Sterlitamakian of the Urals, but can be compared with Tethyan fusulinids. *Schwagerina cribroseptata* is similar to

Schwagerina sairykensis (Leven), and *Pseudofusulina lineonada* is similar to *Pseudofusulina subashiensis* (Chang), both forms are from the lower portion of Safetdaron Formation of Darvas, Central Asia (Leven *et al.*, 1992), which correlates to Artinskian.

The upper portion of the Lenox Hill Formation is characterised by a very distinctive assemblage, which includes: *Stewartina laxissima*, *Chalartoschwagerina nelssoni*, *Schwagerina dispansa*, *Schwagerina diversiformis*, and *Eoparafusulina linearis*. These fusulinids have no similarities with those in the Urals, but show quite strong similarity with Tethyan fusulinids. In the Darvas region of Central Asia, *Chalartoschwagerina* first appears at the base of the Yakhtashian, which probably is equivalent to the Artinskian (Leven *et al.* 1992). *Ch. nelssoni* is similar with *Ch. vulgaris*, which is wide spread within the Tethys and is the index-species of the upper Yakhtashian (Artinskian). Based on this information we can suggest that the age of upper portion of the Lenox Hill Formation in its stratotype probably is upper Artinskian.

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The Base of the Permian System in China Defined by *Streptognathodus isolatus*

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Conodonts are the leading fossil group for Permian biostratigraphy. The definitions of all stages of the Permian System should be defined by conodonts.

The Aidaralash Creek section in northern Kazakhstan has been accepted as the Global Stratotype Section and Point (GSSP) for the base of the Permian System (Davydov *et al.* 1995). *Streptognathodus isolatus* as a new species and definer for the base of Permian System also has been described and proposed (Chernykh. V. V., Ritter. S. M. and Wardlaw. B. R.,1997). In the meantime, eight new species of *Streptognathodus* from the Aidaralash Creek section have been described, and six conodont zones from the late Gzhelian to early Sakmarian have been established (Chernykh.V. V. and Ritter. S. M., 1997). The definition of the base of the Permian System is the first appearance of *Streptognathodus isolatus* within the evolutionary lineage from *Streptognathodus wabaunsensis* to *S. isolatus*.

To use *Streptognathodus isolatus* and the new conodont zones as an international standard for recognizing the base of the Permian System, we can enhance our level of understanding for the base of the Permian System in China.

1. When *Streptognathodus isolatus* as a new species was described, Chernykh *et al.* (1997) listed a synonym of the species from Chinese literature: *Streptognathodus gracilis* Stauffer and Plummer. Kang, Wang and Wang, 1987, p.196, pl.2, fig.8. This specimen was collected from the lower part of the bed 02 of the Zisong Zhen Formation in Yangchang section in Ziyun County, Guizhou, only 1.00 m higher than the basal boundary of the Zisong Zhen Formation of the Zisongian Stage that is the lowermost stage of Chinese Permian chronostratigraphy (Zhang, Z.H,1988). *Streptognathodus barskovi* occurs in bed 6 of the Zisong Zhen Formation in Yangchang section. The lower part of the Zisongian Stage (from bed 03 to bed 6) correlates with the Asselian Stage.

2. One specimen illustrated and identified by Wang Zhi-hao and Zhang Wen-sheng (1985, pl.1, fig.10a,b.) as *Streptognathodus wabaunsensis* is a typical *Streptognathodus isolatus*. It co-occurs with *S. elongatus* and *S. wabaunsensis* in bed 2 (=Limestone L7) of the upper part of the Taiyuan Formation in Yuxian, Henan Province. *Streptognathodus whitei* occurs in bed 7 (=Limestone L10), 15 m higher than the level of the occurrence of *Streptognathodus isolatus* (i.e. bed 2). Bed 2 (=Limestone L7) should belong to early to middle Asselian Stage. The Taiyuan Formation is Early Permian in age.

3. Two specimens illustrated and identified by Wang Zhi-hao and Li Run-lan (1984, pl. 1, figs.15-16,17-18) as *Streptognathodus gracilis* Stauffer and Plummer from the Taiyuan Formation in Taiyuan and Shuoxian, Shanxi Province, should be assigned to *Streptognathodus isolatus*. The Xishan (west hill) section in Taiyuan contains four limestone layers, in ascending order L1, K2, L4, L5. All limestone layers yield conodonts and *Pseudoschwagerina*. These two specimens of *S. isolatus* occur in the lower part of the Taiyuan Formation. The Limestone L1 (=the

Miaogou Limestone) is close to the basal boundary of the Permian. Wang *et al.* (1984) assigned the Taiyuan Formation to the Late Carboniferous. The Taiyuan Formation should assign to the early Permian based on the conodont *Streptognathodus isolatus*.

4. Another three specimens illustrated and identified by Wang Zhi-hao and Wen Guo-zhong (1987) as *Streptognathodus wabaunsensis* (1987, pl.4, figs. 1, 3?, 4) from the Taiyuan Formation in southeastern Shanxi (Lingchuan County) also should be assigned to *Streptognathodus isolatus*. Wang *et al.* (1987) assigned the Taiyuan Formation to the Late Carboniferous.

The Taiyuan System was named by Wong Wen-hao and Grabau (1925), then the people use different names; The Taiyuan System, Taiyuan Series, Taiyuan Formation and Taiyuan Group. Now most geologists in China use the Taiyuan Formation representing the Late Carboniferous deposits in North China Platform. But according to the conodonts from the Taiyuan Formation, this formation should belong to the Early Permian rather than Late Carboniferous.

The Sanlizhong section at Xikou of Zhen'an, Shanxi, studied by Xia *et al.* (1996), contains very good conodonts, unfortunately Xia *et al.* (1996) collected samples too small to find *Streptognathodus isolatus*. If we collect enough conodont samples from this section, especially from the bed 1 to bed 4, then *Streptognathodus isolatus* may be found.

Streptognathodus isolatus is widely distributed both in South China and in North China. The Carboniferous- Permian boundary in China should be defined by the FAD of *S. isolatus*, keeping consistency with the international standard. The taxonomy of genus *Streptognathodus* and the boundary strata between the Carboniferous and Permian should be studied thoroughly in China.

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Preliminary Cool Water Permian Conodont Zonation in North Pangea: a Review

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1. Introduction

Conodonts are regarded as the most important fossils for chronostratigraphy of the Permian. One reason for their importance is that they are thought to be more cosmopolitan than other important fossils such as fusulinaceans, ammonoids, brachiopods and corals all of which show clear provincialism within the Tethyan Realm, the Notal and Boreal Realms, and the Gondwana Realm. Kozur (1995a, p. 172) stated: "The conodonts are the only stratigraphically important faunal group, in which provincialism affects only few stratigraphically important forms... Most Permian conodont guide forms can be traced through areas as distant as Bolivia, Texas, Svalbard, Cis-Urals, Pamirs and China, allowing an exact correlation between these areas that belong to different faunal provinces and even to different faunal realms (Notal, Tethyan and Boreal realms)." As a result, a single generalized zonation, usually entitled "standard zonation", tended to be used (Kozur, 1994; 1995a; 1996; Wang Chengyuan, 1995) with only acknowledgement of facies differentiation and minor discussion on provincialism. This is generally true for Asselian to Artinskian, but provincialism is an important factor in the Kungurian and younger Permian strata impeding the development of a standard scheme of global scope. Recent literature indicates that varying levels of provincialism can be seen for conodonts of Asselian (Henderson and Orchard, 1991), Artinskian (Nicoll and Metcalfe, 1998), Kungurian and Guadalupian (Behnken, 1975; Wardlaw, 1995), Lopingian (Mei and Wardlaw, 1996), and Permian-Triassic boundary interval (Matsuda, 1985; Mei, 1996). Limited appreciation for conodont provincialism has caused taxonomic misidentification for Permian-Triassic conodonts at Selong (for detail see Orchard *et al.*, 1994; Mei, 1996) and the construction of non-existent zones (for details see Mei and Wardlaw, 1996). A survey of available references of Permian conodonts lead Mei *et al.* (1999a, 1999c) to recognize an increasing degree of conodont provincialism throughout the Permian. As a result, three provinces, referred to as North Cool Water Province (NCWP), Equatorial Warm Water Province (EWWP) and peri-Gondwana Cool Water Province (GCWP), have been recognized for Permian conodonts (Mei *et al.*, 1999a, 1999c). In contrast to the observations of Kozur (1995b), the conodont successions of Kungurian to basal Triassic of NW Pangea cratonic basins such as Sverdrup and Western Canadian basins are entirely different from that established in EWWP such as in South China (Mei *et al.*, 1999a, 1999c; Mei and Henderson, 2000). The recognition of such distinct provincialism identifies problems in the existing taxonomy of Permian neogondolellids. The introduction of the concept of geographic clines may provide a reasonable solution (Henderson and Mei, 2000). This paper attempts to present a brief review on conodont zones and correlation of NW

Pangea cratonic basins including the Phosphoria Basin, the Ishbel Trough, the Sverdrup Basin, the Eastern Greenland Basin and the Zechstein Basin and some Cordilleran terranes (Fig. 1).

2. Cool water conodonts in North Pangea cratonic basins

The main components of cosmopolitan Asselian and Sakmarian conodonts in order of decreasing abundance are *Streptognathodus*, *Adetognathus* and *Mesogondolella*. Provincialism is indicated only by less common endemic elements such as *Gondolelloides* and New Genus A Henderson (Henderson and Orchard, 1991) in northern Pangea and the relative abundance of *Diplognathodus* and early *Sweetognathus* species in equatorial areas (Mei *et al.*, 1999b, 1999c). The Artinskian is marked by flooding at the base and the influx of a cosmopolitan fauna dominated by *Sweetognathus whitei* and *Mesogondolella bisselli*, which may correspond to the very interval of final melting of the Gondwana ice cap.

The base of Kungurian is suggested to be defined by the base of the *Neostreptognathodus exsculptus* Zone (Jin *et al.*, 1997). It is generally thought that the *Neostreptognathodus pequopensis* Zone precedes the *N. exsculptus* Zone. However, a recent study shows that the first occurrences of *N. pequopensis* and *N. exsculptus* nearly coincide and that *N. exsculptus* might have evolved from an ancestor different from that of *N. pequopensis* (Mei *et al.*, 1999b). As a result, the Kungurian could be defined by the first appearance and dominance of *Neostreptognathodus* which could possibly be polyphyletic.

North Pangea underwent a cooling trend from Middle Kungurian to the end of the Permian (Henderson, 1990; Beauchamp *et al.*, 1999; Mei *et al.*, 1999c). As a result, conodont faunas in North Pangea are very different from those in equatorial areas such as South China, West Texas and Sicily. The following provides a review of Kungurian and younger Permian conodonts in northern Pangea from basin to basin (Figure 1).

2.1 The Phosphoria Basin

Kungurian conodonts in the Phosphoria Basin are dominated by *Neostreptognathodus* and *Mesogondolella* is much less common. As a result, the zonation is mainly based on *Neostreptognathodus* (Mytton *et al.*, 1983; Wardlaw, 1995; Wardlaw *et al.*, 1998). Wardlaw (1999) recognized three Kungurian zones, *N. "exsculptus"*, *N. prayi* and *N. sulcopicatus*. This zonation is roughly similar to those recognized for the Ishbel Trough and Sverdrup Basin (see below). However, definitions of *Neostreptognathodus* species vary considerably among authors (see Orchard and Forster, 1988; Mei *et al.*, 1999b). Consequently, the taxonomy of *Neostreptognathodus* species needs to be refined before detailed correlation can be made.

Kungurian *Mesogondolella* in the Phosphoria Basin are represented by only one species, *Mesogondolella idahoensis*; it was reported by Youngquist *et al.*, 1951. The holotype of *M. idahoensis* is from the basal part of the Phosphoria Formation at Bear Lake, Utah, and is characterized by a relatively large cusp, discrete denticles on the middle carina and a low and discrete blade in the anterior platform. It differs from *M. idahoensis* previously reported from the Equatorial Warm Water Province in South China, Japan, Sicily and West Texas in that the latter has a relatively small cusp, more closely spaced to fused denticles on the middle carina and mostly fused and high blade. *Mesogondolella siciliensis*, reported

from western Sicily and assigned to Wordian by Kozur (in Catalano *et al.*, 1992; Gullo and Kozur, 1992), is correlated with late Kungurian of South China and is probably equivalent to *M. idahoensis* of the Equatorial Warm Water Province (Henderson *et al.*, 1999; Mei *et al.*, 1999c). Kozur (in Kozur *et al.*, 1994; Kozur, 1995; Kozur, 1998) regarded *M. siciliensis* as a cold water element and attributed the presence of cool water *Mesogondolella* species in tropical Sicily, Pamirs and Darvas to “cold bottom water”, but we believe that the “cool water” faunas are, in fact, typical of a warm water setting (Mei *et al.*, 1999c).

Guadalupian conodonts in Phosphoria Basin are dominated by neogondolellids and *Merrillina*. Like Kungurian *Mesogondolella*, the Guadalupian neogondolellids in the Phosphoria Basin are characterized by a relatively large cusp, compressed and fairly discrete middle carina and low and discrete blade (except *Mesogondolella bitteri*). They show a systematic, minor difference from the equivalent, *Jinogondolella*, of the Equatorial Warm Water Province. As a result, Guadalupian neogondolellids in the Phosphoria Basin were once referred to as *Pseudoclarkina* (Wardlaw and Mei, 1998; Mei *et al.*, 1998; 1999a). The recognition of detailed morphological differences between neogondolellids from both the Equatorial Warm Water Province and the North Cool Water Province has created a major problem in taxonomy. We believe that recognition of a geographic cline would be useful for better understanding this taxonomic problem (Henderson and Mei, 2000; and this issue of Permophiles). Detailed explanation of this geographic cline concept is beyond the present paper, and it will be dealt with later by Henderson and Mei. The present authors now tentatively regard *Pseudoclarkina* as a synonym of *Mesogondolella* from populations with a low percentage of serrated specimens, because the configuration of platform and denticulation in *Pseudoclarkina* can not be differentiated from *Mesogondolella*. Conodont zones in the Phosphoria Basin can be determined, in ascending order, as *M. gracilis*, *M. phosphoriensis*, *M. bitteri* and *M. wilcoxi*. Mei and Henderson (2000) showed that this zonation is very different from that established in West Texas (Clark and Behnken, 1979; Wardlaw, 1996) and South China (Mei *et al.*, 1994a; b, c). As a result, precise correlation has not been achieved. The fundamental basis for correlation of Guadalupian conodonts in Phosphoria Basin with those of the Equatorial Warm Water Province is based on an assumption that the serration in the anterior platform of neogondolellids appears simultaneously at the base of Guadalupian in the cool water Phosphoria and Sverdrup basins and in warm water basins of west Texas and South China. The early serrated specimens in Phosphoria Basin have been referred to *Jinogondolella serrata* (junior synonym of *Jinogondolella nankingensis*). We recognize them as serrated specimens of *M. gracilis* within a geographical cline (Henderson and Mei, 2000).

The *M. bitteri* Zone has been consistently shown to be late Wordian by Wardlaw and Collinson (1979, 1984, 1986). Their most crucial argument is that a bed, overlying an unconformity at the top of the Phosphoria Basin succession and below which *M. bitteri* gave rise to *M. wilcoxi*, has yielded *Merrillina divergens* and *J. aserrata* (Wardlaw and Mei, 1998); the latter is an indicator of Wordian (Jin *et al.*, 1997). We suggest that the reported *J. aserrata* may be *M. wilcoxi*, which leaves the age of the top of the Phosphoria Basin Permian sequence undetermined. The youngest known occurrence of *M. wilcoxi* is in the *Timorites* beds of Gordon and Merriam (1961) from the Inyo Mountains, California, thought

to be Capitanian. Spinosa (pers.comm., 1999) indicated that ammonoid specimens of Gordon and Merriam are actually *Cyclolobus* (Wardlaw and Mei, 1998, p. 38), which is regarded as Lopingian in age (Zhou *et al.*, 1996). This suggests an even younger age for *M. wilcoxi*.

2.2 The Ishbel Trough

Henderson and McGugan (1986) reported Artinskian and Kungurian conodonts from the Ross Creek Formation of the Telford thrust plate of southeast British Columbia and the Johnston Canyon Formation in Banff, Alberta. The Kungurian conodonts are exclusively dominated by *Neostreptognathodus*, indicative of a typical cool water fauna. As mentioned before, the taxonomy of *Neostreptognathodus* needs to be refined and stabilized before a detailed and useful zonation can be made. In the Urals, the holotype of *N. clarki* was obtained from a sample collected by V.E. Ruzhencev from an outcrop at Aktasty. Kozur (in Kozur and Mostler, 1976) also named *N. ruzhencevi*, *N. transitus*, *N. tshuvaschovi* and *N. pequopensis* from the same sample. From the same interval, Chernykh (in Chuvashov *et al.*, 1990) named *N. obliquidentatus*, which was regarded as a synonym of *N. ruzhencevi* by Kozur (1995). A very shallow, medium groove and a smooth transition from the blade to the carina characterize all of these forms. We believe they represent different morphotypes of a single population (Mei *et al.*, 1999b). Specimens referred to as *N. ruzhencevi* from northern Pangea are different from the holotype of *N. ruzhencevi* and are herein tentatively referred to “*N. ruzhencevi*”. Presently, we tentatively subdivide the Kungurian *Neostreptognathodus* in the Ishbel Trough into two zones, the lower *N. pequopensis* Zone, and the upper *N. sulcopicatus* - “*N. ruzhencevi*” Zone.

Unconformably overlying both the Ross Creek Formation and the Johnston Canyon Formation is the Ranger Canyon Formation, which is dominated by bedded diagenetic chert with limestone concretions. Abundant and typical specimens of *M. bitteri* have been recovered from these concretions at Sundance Canyon in Banff area. The top of the Ranger Canyon Formation, which is usually represented by a phosphatic conglomerate bed and separated from the underlying beds by an unconformity, yields abundant *M. rosenkrantzi*. It has been also found abundantly from the equivalent beds of sandy limestone facies to the east within the top of the Mowitch Formation.

At Mile 381, Alaska Highway in northeast British Columbia, Chung (1993) reported *M. rosenkrantzi* from the upper part of the Fantasque Formation, poorly serrated specimens of *M. gracilis* from the lower part, and *M. idahoensis* from the basal part. The youngest Permian conodonts are recovered from limestone concretions of the Fantasque Formation at the Ursula Creek section, Williston Lake, northern British Columbia. They are exclusively dominated by *Mesogondolella sheni*. This indicates that the Fantasque Formation at Mile 381, Alaska Highway can be correlated with the Ranger Canyon Formation in southern Ishbel Trough, while at least part of the Fantasque Formation at Williston Lake is younger.

In summary, the Kungurian to Lopingian conodont zones recognized in Ishbel Trough can presently be generalized in ascending order as: *N. pequopensis*, *N. sulcopicatus*-“*N. ruzhencevi*”, *M. idahoensis*, *M. bitteri*, *M. rosenkrantzi* and *M. sheni* (Table 1). The latter 5 zones are separated from each other by unconformities.

2.3 Sverdrup Basin

Henderson (1981, 1988, 1997) made an extensive study of Permian conodonts from Sverdrup Basin. The Kungurian fauna is dominated by *Neostreptognathodus*, and the Guadalupian and Lopingian faunas are dominated exclusively by *Mesogondolella*. A typical cool water setting is indicated for the Sverdrup Basin by *Mesogondolella* bearing a large cusp, low and discrete denticles on the carina and anterior blade as well as the absence of the *Diplognathodus-Sweetognathus-Iranognathus* lineage since middle Kungurian. As a result, the conodonts from the Sverdrup Basin correlate well with those of the Ishbel Trough and those of the Phosphoria Basin (Table 1).

The upper parts of the Great Bear Cape Formation and the Trappers Cove Formation (Beauchamp *et al.*, 1989; Beauchamp and Henderson, 1994) include the lower to middle Kungurian *N. pequopensis* Zone and the *N. sulcopicatus*-“*N. ruzhencevi*” Zone. As shown in figure 2, the late Kungurian is represented by the Sabine Bay Formation, from the top of which *M. idahoensis* was recovered (Henderson, 1981). The Assistance Formation overlays and is separated from the Sabine Bay Formation by an unconformity and/or a conglomerate bed. The lower part of the Assistance Formation yields abundant serrated specimens of *M. gracilis*. The overlying Trold Fiord Formation contains an extensive conglomerate bed, which separates it into lower and upper parts. The lower part yields a few specimens of *M. bitteri*, and the upper part yields abundant *M. rosenkrantzi*.

In conclusion, the conodont zones recognized from the Sverdrup Basin correlate very well with those from the Ishbel Trough (Table 1).

2.4 Eastern Greenland Basin and the Zechstein Basin

The Permian conodont fauna from the Ravnefjeld Formation in eastern Greenland contains abundant *M. rosenkrantzi* and less common *Merrillina divergens* (Bender and Stoppel, 1965; Sweet, 1976; Rasmussen *et al.*, 1990). In contrast, the Permian conodont fauna in the Zechstein Basin is dominated by *Merrillina divergens* (Szaniawski, 1969; Swift, and Aldridge, 1986; Swift, 1995). This may indicate that the eastern Greenland Basin is under a colder setting than the Zechstein Basin. *Mesogondolella* is not common in the Zechstein, but is referred to *M. phosphoriensis* by Swift (1995) and *M. britannica* by Kozur (1998a).

The conodont faunas from both eastern Greenland and the Zechstein Basin are entirely different from the coeval faunas in the Equatorial Warm Water Province such as in South China. As a result, direct correlation of conodonts in Eastern Greenland and the Zechstein Basin with those in the Equatorial Warm Water Province is not likely. The *M. rosenkrantzi* and *Merrillina divergens* fauna in eastern Greenland is interpreted to be Lopingian, as it is associated with *Cyclolobus*, represented by *Cyclolobus kullingi*. *Cyclolobus* has been found to occur with late Wuchiapingian to lower Changhsingian conodonts in the Chhidru Formation of the Salt Range (Wardlaw and Mei, 1999). This is confirmed by Zhou *et al.* (1996), who suggest that *Cyclolobus* is Wuchiapingian to Changhsingian in age. The Zechstein Formation is referred to Lopingian based on a discovery that the Illawarra Reversal occurs in the upper part of the underlying Rotliegend Formation (Menning, 1995), which is separated from the Zechstein Formation by an unconformity. The Illawarra Reversal has been found to occur in the top part of the Maokou Formation in South China (Heller *et al.*,

1995), in the basal part of the Wargal Formation of the Salt Range (Haag and Heller, 1991) and in the Upper Guadalupian Bell Canyon Formation (Glenister *et al.*, 1999).

The holotype of *M. rosenkrantzi* has a carina with closely spaced denticles and a moderately high blade, showing a close similarity to *M. sheni*. This may indicate that *M. rosenkrantzi* is the direct ancestor of *M. sheni*. The objective superposition of *M. sheni* over *M. rosenkrantzi* in Ishbel Trough also appears to suggest that the *M. rosenkrantzi* and *Merrillina divergens* fauna in Eastern Greenland is younger than the *Merrillina divergens* and *M. britannica* in the basal Zechstein Formation.

3. Conodonts from some Cordilleran Terranes

Global distribution patterns of Permian conodonts suggest that *Vjalovognathus*, *Gondolelloides* and *Merrillina* are cool water residents, and *Diplognathodus*, *Sweetognathus* and *Iranognathus* are warm water residents. *Neostreptognathodus* is more common in temperate zones than in the equatorial and colder bipolar zones. Neogondolellids, *Hindeodus* and *Sweetina* are cosmopolitan and the most temperature tolerant. Neogondolellids persist as *Mesogondolella* with a big cusp and low and discrete blade in bipolar temperate zones during Kungurian through Lopingian, except *Mesogondolella bitteri*, which shows similarity to *Clarkina*. However, in equatorial regions such as South China, Sicily and West Texas they differentiated into *Mesogondolella* with a small cusp, a carina with tightly spaced to fused denticles, and a high and mostly fused blade during Kungurian, *Jinogondolella* during Guadalupian and *Clarkina* during Lopingian. Three provinces, the North Cool Water Province (NCWP), the Equatorial Warm Water Province (EWWP) and the peri-Gondwana Cool Water Province (GCWP), were well established by Kungurian (Mei *et al.*, 1999a, 1999c). The *Diplognathodus-Sweetognathus-Iranognathus* complex becomes confined to the Equatorial Warm Water Province since middle Kungurian due to the early cooling event in northern Pangea (Mei *et al.*, 1999b).

The well established Permian conodont distribution and provincialism pattern mentioned above allows us to precisely determine the nature of conodont faunas from some of the Cordilleran terranes. Conodonts from the Cache Creek Terrane are represented by abundant *Jinogondolella* and a few *Sweetognathus* in Guadalupian, *Clarkina* and *Iranognathus* in Wuchiapingian, and exclusive dominance of *Hindeodus* around the Permian-Triassic boundary interval (Beyers and Orchard, 1991; Orchard *et al.*, 1999, 2000). As a result, they are typical of warm water fauna (Orchard *et al.*, 2000; Mei and Henderson, 2000). In the Baker Terrane, Eastern Oregon, Nestell and Orchard (2000) reported a Kungurian conodont fauna with *Mesogondolella idahoensis* and two species of *Sweetognathus*. The specimens they referred to as *Mesogondolella idahoensis* have a relatively small cusp, closely spaced to fused carinal denticles, and a largely fused and high blade. They are almost identical to specimens we found from the upper Kungurian in South China and could be referred to *Mesogondolella siciliensis*. The fusulinacean found in the same locality as the conodont fauna in the Baker Terrane contains *Neoschwagerina craticulifera* (Nestell and Orchard, 2000; and personal communication with Nestell at the GSA Cordilleran section meeting). This also matches the data we obtained from the Luodian section, South China, where *Neoschwagerina craticulifera* co-occurs with *M. siciliensis* in the upper Kungurian.

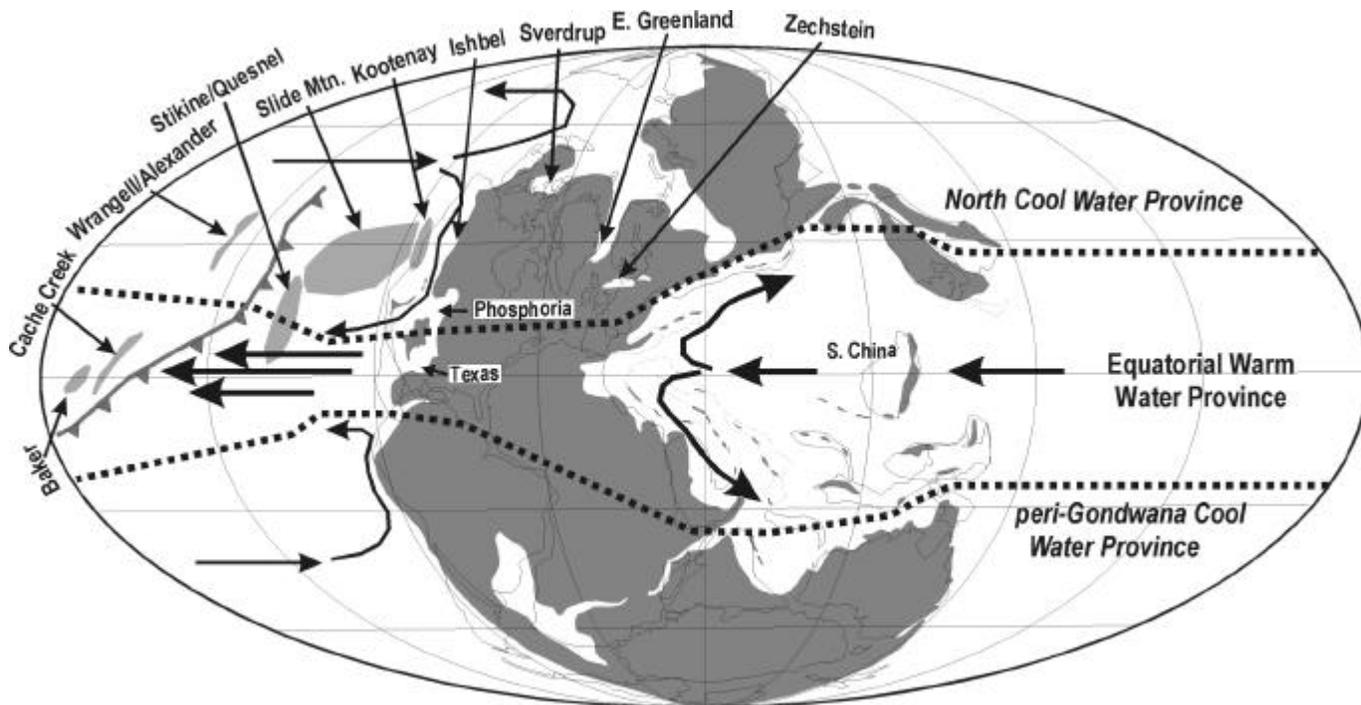


Figure 1 Relative paleogeographic positions of Cordilleran accreted terranes, conodont provinces and Pangea during the Guadalupian. Paleogeographic reconstruction is modified after Ziegler et al., 1996.

Chronostratigraphic Scale	Conodont Zones	Western Canada	Peace River Basin	Sverdrup Basin	Phosphoria Basin	Eastern Greenland	Zechstein Basin	Sea Level Changes
Permian	L. Triassic	Duressian	Ursula Creek	Alaska Highway Mile 381	W. Central Alberta	Montney Fm.		
		Griesbachian	Grayling Fm.	Spray River Group	Montney Fm.			
	Leptagian	Changhsingian	Fantouque Fm.					
		Wachapingian	M. roseifrons					
	Guadalupian	Capitanian	M. wilsoni	Fantouque Fm.				
		Wordian	M. phosphoricus					
		Roadian	M. gracilis	Telford Thrust Plate				
		Kungurian	M. alabamensis					
	Carboniferous	Artinskian	N. microplicatus					
		Sakmarian	N. parviperatus	Row Creek Fm.				
Sakmarian		Sa. whitei						
Asselian		Ad. parvifrons						
U. Carboniferous	Gzhelian	St. aleksovi	Telford Fm.					
	Kasimovian	St. oeydetae						
U. Carboniferous	Moscowian	No. bozhrovi - No. ovalobolus						
	Bashkirian	St. marshallensis	"Johnson Canyon" Fm.					
Permian	L. Triassic	Duressian	Ursula Creek	Alaska Highway Mile 381	W. Central Alberta	Montney Fm.		
		Griesbachian	Grayling Fm.	Spray River Group	Montney Fm.			
	Leptagian	Changhsingian	Fantouque Fm.					
		Wachapingian	M. roseifrons					
	Guadalupian	Capitanian	M. wilsoni	Fantouque Fm.				
		Wordian	M. phosphoricus					
		Roadian	M. gracilis	Telford Thrust Plate				
		Kungurian	M. alabamensis					
	Carboniferous	Artinskian	N. microplicatus	Row Creek Fm.				
		Sakmarian	N. parviperatus					
Sakmarian		Sa. whitei						
Asselian		Ad. parvifrons						
U. Carboniferous	Gzhelian	St. aleksovi	Telford Fm.					
	Kasimovian	St. oeydetae						
U. Carboniferous	Moscowian	No. bozhrovi - No. ovalobolus						
	Bashkirian	St. marshallensis	"Johnson Canyon" Fm.					

Table 1. Northern Pangea Cool Water Conodont zones and Correlation.

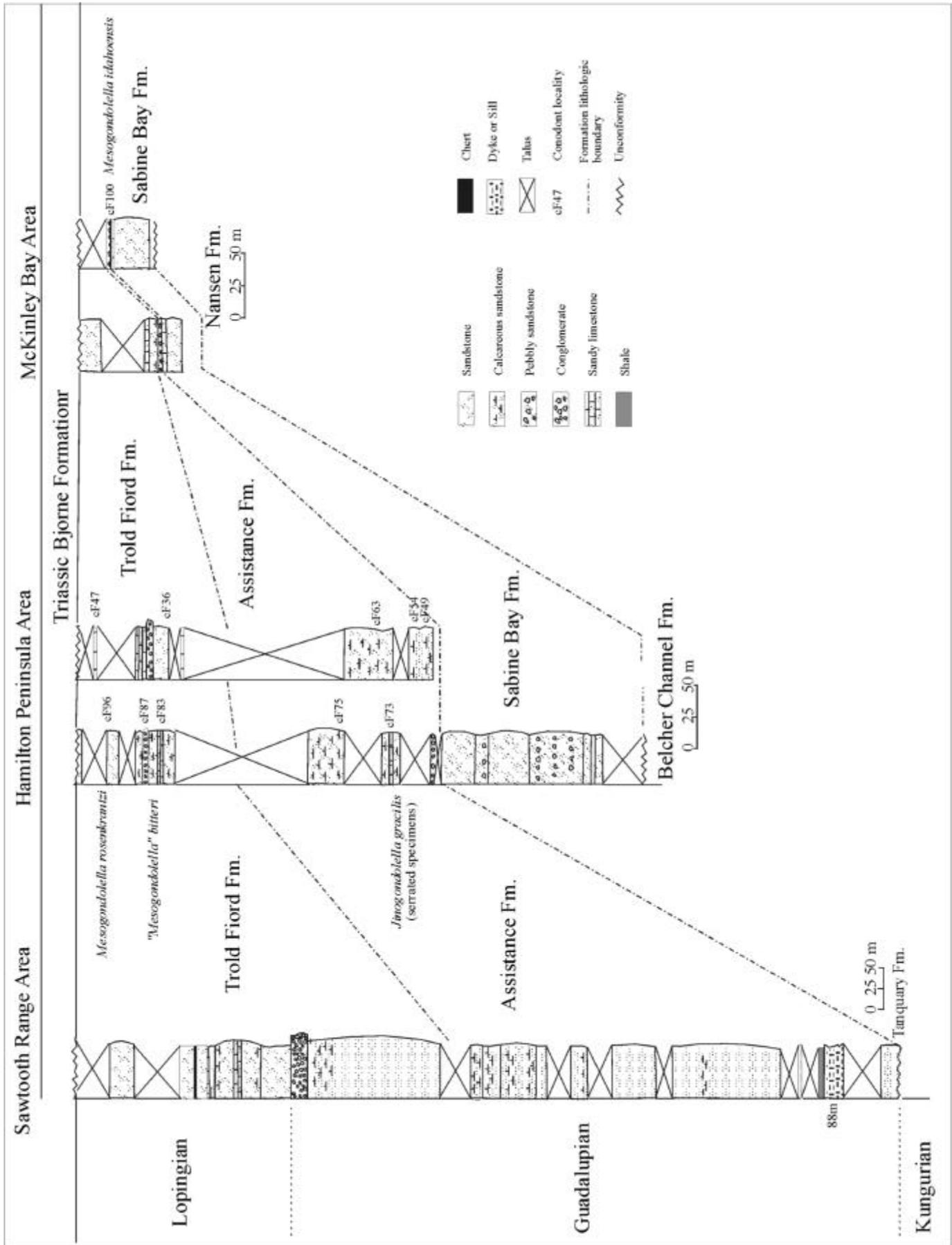


Figure 2. Kungurian to Lopingian conodont locations in the Sverdrup Basin

Consequently, like the conodonts of South China and Sicily, the Baker Terrane conodonts are typical of warm water setting.

Conodonts reported by Orchard (1987) from Fennel Formation near Seymour Arm, British Columbia, a unit that occurs in the Slide Mountain Terrane, contains serrated specimens of *M. gracilis* that are characterized by a relatively large cusp, and discrete denticles and low blade. The fauna is similar to the coeval fauna in the Sverdrup Basin, and typical of cooler water settings. Conodonts from the Quesnellia Terrane Harper Ranch beds near Kamloops, south-central British Columbia are represented by fairly abundant *Neostreptognathodus*, but *Sweetognathus* and *Diplognathodus* in Kungurian, and primitive forms of *Jinogondolella nankingensis* in Early Guadalupian also occur (Orchard and Forster, 1988). This fauna may be transitional between the Equatorial Warm Water Province and the North Cool Water Province, but it is more typical of a warm water setting.

The Upper Permian fauna reported by Clark *et al.* (1997) from the Northwind Ridge of the Arctic Ocean were misidentified by Kozur (1998b, p. 249) as containing early Lopingian species such as *Clarkina postbitteri* and *C. niuzhuangensis*. The neogondolellids in this fauna are similar to Triassic *Neogondolella* in configuration of denticulation and platform and clearly different from the Lopingian *Clarkina* in South China.

The position of some Cordilleran terranes are shown in figure 1, interpreted in part on the basis of conodont provincialism.

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Paleobotany of the Upper Carboniferous/Lower Permian of the southern Urals. Part 2. Roots and Woods

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The present paper is a continuation of the preliminary description of the Upper Carboniferous - lowermost Lower Permian flora discovered from the famous Aidaralash section of the Southern Urals (Naugolnykh, 1999) and some other localities of the same region. Fossil wood and root remains are briefly characterized in this part. The remains were studied under SEM (Stereoscan 600).

Dadoxylon sp. Fig. 1, fig. 2. A small fragment of gymnosperm wood (perhaps of cordait or conifer affinity) 20 mm long and 9 mm wide. Since the wood is petrified, some data of its anatomical structure were obtained. Secondary xylem consists of the tracheids and parenchymatous tissues. The tracheids have round bordered pit pairs (pores) of araukarioid type, which are located on radial cell walls. Diameter of the pores together with borders (limbs) is 8 μ . Diameter of the pore itself is 2 μ . Pore border is wide and bears concentric ribs and furrows between ribs. Single bordered pit pair demonstrates a torus, attached to one of the pore walls and covering the pore perforation. Crassulas are absent. Xylem rays are relatively rare, homocellular, one cell wide. Commonly, the rays consist of two vertical cells in number, rarely one or three cells. In a single case, the ray has more than five vertical cells. Ray cell walls are thin. Tracheid walls are considerably thicker. Tracheids are polygonal in cross section, their diameter is 9-15 μ . Tracheid walls bear well-developed stair-like thickenings. Central part of the wood is not preserved. Because of this it is not possible to study any primary tissues.

Remarks. Several different form genera are used for Angaran Upper Paleozoic fossil wood of gymnosperms (*Mesopitys*, *Coenoxylon*, *Dadoxylon*, *Araucarioxylon*). The most popular names are *Dadoxylon* Endlicher 1847 and *Araucarioxylon* Krausel 1870. The synonymy of these genera is suggested (Vogellehner, 1964; Stewart, 1983; Stewart, Rothwell, 1993). Commonly the name *Dadoxylon* is used for Paleozoic woods, and the name *Araucarioxylon* is preferred for the same type or very similar woods from Mesozoic. At the same time, type species of *Araucarioxylon* (*A. carbonaceum* (Witham) Krausel) is described from the Carboniferous of England (Schimper, 1870; Witham, 1833). Although the same type of woods from the Permian of Angaraland were determined as *Dadoxylon*, *Araucarioxylon* and *Araucarites* spp. (Naugolnykh, 1995; Kossovskaya *et al.*, 1996), I prefer to use the name *Dadoxylon* because of its priority.

Locality. Aidaralash, layer 17/2, *Daixina bosbytauensis-D.robusta* zone, Upper Gzhelian.

Radicites sp. Fig. 3. There is a single, though quite well preserved fossil root 40 mm long and 5 mm wide. Several tangential and cross section slides were prepared. The root is almost straight, cylindrical or slightly flattened, round or ovoid in cross section. The root surface is covered by fine cross ribs and furrows. The ribs have angulate form, the furrows are more flattened. Width of the furrows is 0.1-0.2 mm. There are rare, but regularly disposed round struc-

tures in the furrows. These structures are depressions filled by parenchymatous tissues. Wherever these structures are well preserved, one can see a small channel 2-5 μ in diameter in their central parts. These round structures can be interpreted as the root hair scars, small channels in their center - as remains of primarily conducting tissues. Microrelief of the furrows is formed by very fine striae.

Remarks. Several morphotypes of isolated fossil roots were described recently from the Permian of the Russian platform and Cis-Urals (Arefiev, Naugolnykh, 1998), but none of those morphotypes is similar to the root described above, since it has quite specific relief of cross ribs and furrows. Moreover, the root hair bases are reported from the Russian Permian for the first time.

Locality. Aidaralash, layer 21, *Spharoschwagerina vulgaris-S.fusififormis* zone, Asselian.

Some more fossil woods of *Calamites* spp. (Calamostachyales order) as well as conifer trunk of *Tyloidendron* sp. (Coniferales order, Walchiaceae family) were collected from the Asselian (layer 21) of Aidaralash section, but these remains need more detailed investigation.

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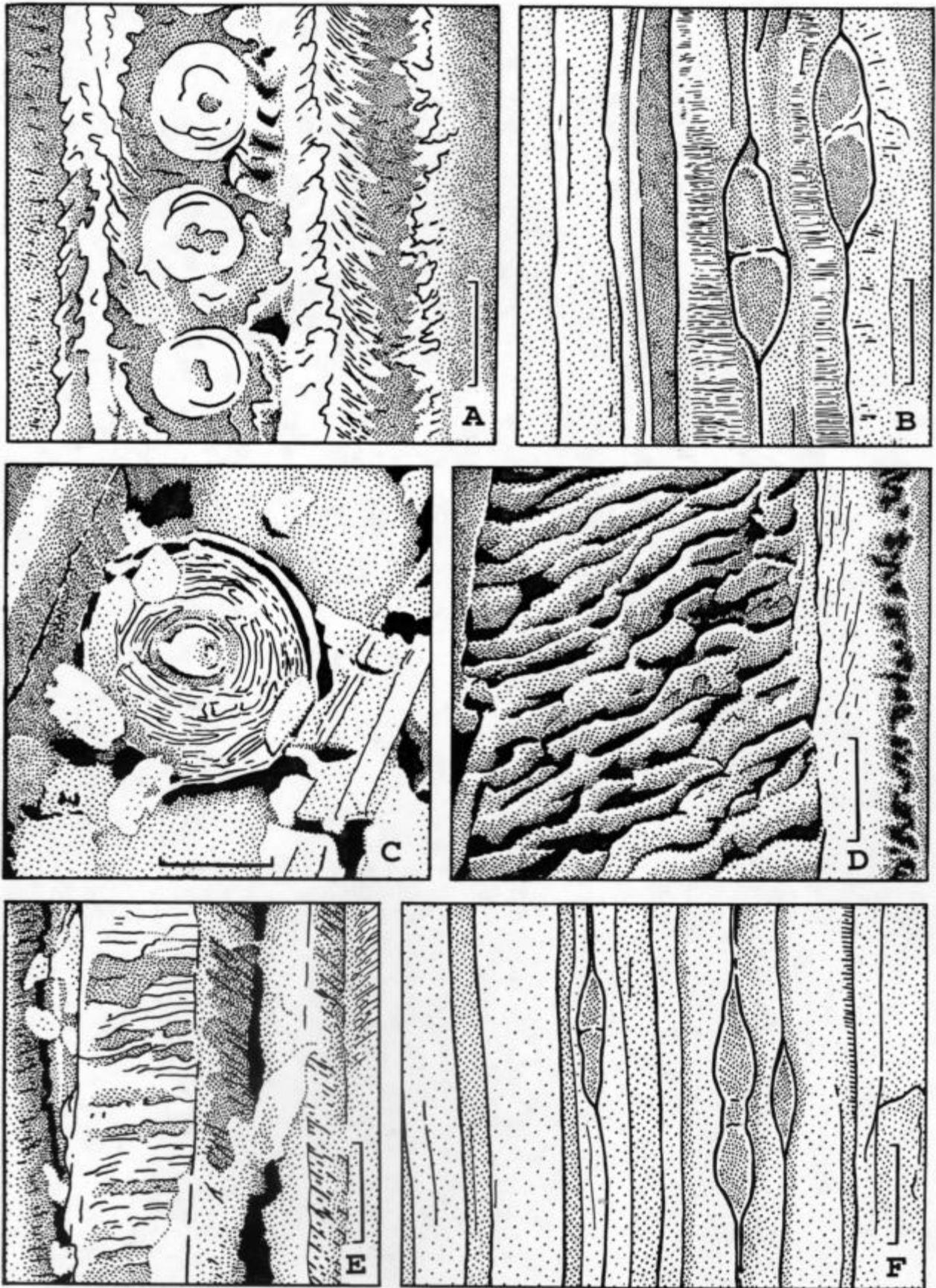


Figure 1. *Dadoxylon* sp. Inner structure of petrified wood in SEM. Southern Urals, Aidaralash, layer 17/2, *Daixina bosbytauensis*-*D.robusta* zone, Upper Gzhelian. Scale bar: 4 mkm (C, D); 10 mkm (A, E); 20 mkm (B); 40 mkm (F).

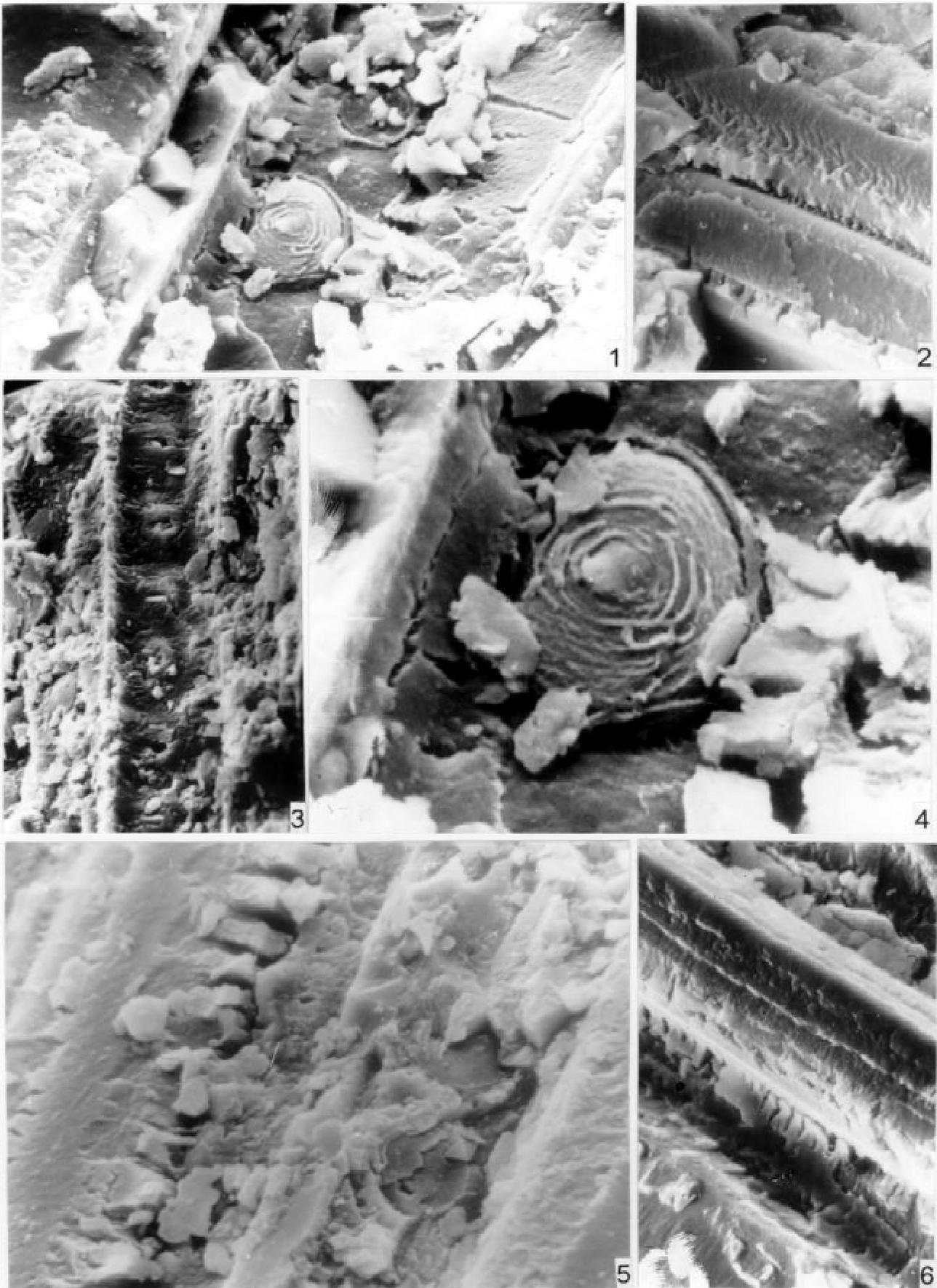


Figure 2. *Dadoxylon* sp. Petrified wood; some morphological details in drawings after SEM microphotography. Southern Urals, Aidaralash, layer 17/2, *Daixina bosbytauensis*-*D.robusta* zone, Upper Gzhelian. Magnification: x 900 (Figs. 2, 3, 6); x 1800 (Figs. 1, 5); x 4500 (4).

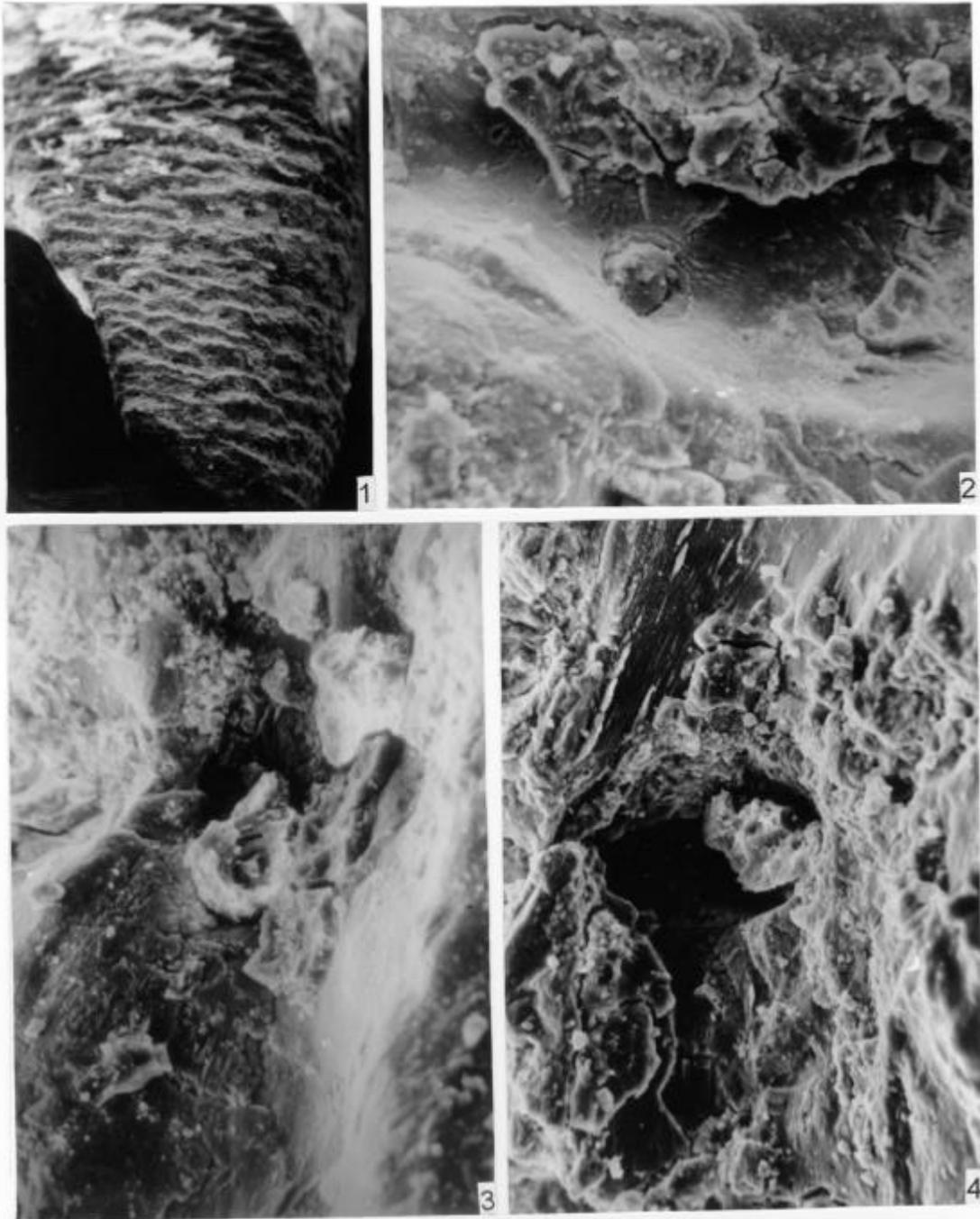


Figure 3. *Radicites* sp. Surface structure of petrified root in SEM. Southern Urals, Aidaralash, layer 21, *Spharoschwagerina vulgaris*-*S.fusiformis* zone, Asselian. Magnification: x 10 (Fig. 1); x 450 (Figs. 2-4).

Designing A Computer-Based Information System for Quantitative Palaeobiogeography of Permian Brachiopods

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The aims of biogeography are to (1) establish comprehensive data bases of the distributions of concerned taxa, (2) analyze the data bases and derive patterns, and (3) interpret the results (Rosen, 1992).

Neither data nor maps are static information in paleobiogeographic research. They need to be frequently revised and updated. New taxa and localities are continuously reported and should be added to our database. Also, old data may be emended and removed. It keeps palaeobiogeographers and palaeontologists busy in data compilation and calculation for the purpose of palaeobiogeographic pattern analysis.

Our current project aims to build a computer-based information system specifically for the palaeobiogeography of Permian Brachiopoda. We prefer to call it *BrachBase*. This information system will improve the productivity of palaeontologists and palaeobiogeographers by automating labor-intensive tasks and eliminating nonvalue-added processes. The distinction of this information system lies in:

- 1) The database of our system holds the detailed distribution records of every brachiopod species in each of the smallest time and space units, stage-by-stage and station-by-station.
- 2) It is the first attempt that tries to connect together the three major stages in palaeobiogeographic research, i.e., data acquisition and editing, data analysis, and graphic pattern presentation or map generation, in a whole computer based information system.

1. Some Terms Used in the Information System

1.1 Operational taxonomic units (OTUs)

The database is built up to incorporate all taxonomic information about species, genera, family, order, and class, as well as their geographic distribution. The OTUs adopted in this project for palaeobiogeographic pattern analyzing can be genus or species, whichever we like. Choices will be provided for selection before running any queries.

1.2 Operational geographical units (OGUs)

The OGUs used in this project are stations. There are several methods to define stations, e.g., unit areas (equal sized), geological entities, etc. The OGUs adopted in *BrachBase* are hybrid unit areas, i.e., 5-degree by 5-degree latitude/longitude grid cells. Each of the stations will be granted a Station ID as $(5m+3)$, $(5n+3)$

which implies that this station spans from $5m$ to $5m+5$ longitude and from $5n$ to $5n+5$ latitude (Both m and n are integers here, $-36 \leq m < 36$, $-18 \leq n < 18$). Please note that we use negative numbers when specifying west longitude and south latitude coordinates.

There are some exceptions for the format of station ID; for example, when there is a tectonic boundary across an equal area station. At this case, we divide one 5-by-5 degree station into two or more stations according to their tectonic identity. Then mean longitude and mean latitude are used directly (excluding decimals) as the station ID of each station.

We will use station ID, instead of station name, prevalently in different tables in our database to avoid any confusion and mistakes, but we will be able to look up a station's name at any time. A station's name usually is its normal geographic location name and comes from a widely recognized gazetteer.

1.3 Time span

The choice of time parameter is critical in analysis of fossil distributions. The smallest practicable time *interval* is desirable because interpretation of an instant of geological time is the goal. A biozone would be ideal, but few are globally recognizable. So, stages are used as the primary time attribute in our system.

1.4 GIS or DTMS

A geographic information system (GIS) is a computer-based information system. The feature of a GIS tools package or GIS technology is its ability to integrate common database operations such as query with the unique visualization benefits offered by maps. These abilities distinguish GIS from other information systems.

An information system can be defined as a combination of computer hardware, software, data and people (Hoffer, 1999), resulting in some people giving GIS a very broad definition the same as a common information system (Taylor, 1991).

Normally what we can buy from the vendor is a GIS tools package (like *GeoMedia Professional*, *ARC/INFO*, etc), not an information system. The information system needs to be carefully designed first according to our specific requirement, and the data structure of the system needs to be identified and verified before we can implement it with a set of selected software. The database management system (DBMS) does not need to be included in the GIS tools package, i.e. purchased from the same vendor. It can be any DBMS product available on the market.

Just like the Geographic Information Systems, Desktop Mapping Systems also allow us to integrate conventional database data with maps and generate information and results that are not available from the database or maps alone. Desktop Mapping Systems (DTMS), such as *MapInfo* (MapInfo Corporation, 1999), provide us an economical and approachable alternative to a full-blown GIS.

Desktop Mapping Systems are already acquiring many of the capabilities of GIS, either directly or as add-on software, in much the same way that word processors have acquired many of the attributes of desktop publishing.

2. Software Components and Context Level Data Flow Diagram

The *BrachBase* information system constructed in this project will consist of three core parts:

- (1) A relational database management system (we chose MS Access here) for data input, storage and management.

(2) Analytical software package (we chose STATISTICA as principal analytical software and PATN as supplementary one) for data analysing.

(3) A desktop mapping system (we chose MapInfo Professional) for the integration of RDBM's tabular data with geographic maps

The data flow between the different system components can be showed by the diagram in figure 1.

Because both *STATISTICA* and *MapInfo* support ODBC - an industry standard interface to SQL-based database engines, these two software packages have a flexible access to a wide variety of database management files, certainly including *MS Access* files. (Table 1 and 2, Figure 2)

After four steps of normalization (1NF, 2NF, 3NF, BCNF), eight normalised relations have been recognised as follows:

- i. Class-Order Relation (class, order, order reference)
- ii. Order-Family Relation (order, family, family reference)
- iii. Family-Genus Relation (family, genus, genus reference)
- iv. Species Diagnosis (genus, species, diagnosis, pictures, species reference)
- v. Species Distribution Through Time and Space (species herein, species in original report, station ID, stage, stratigraphic unit, lithology, distribution reference)
- vi. Station (time-dependent) Properties (stage, station ID, palaeolatitude, tectonostratigraphic units, province)

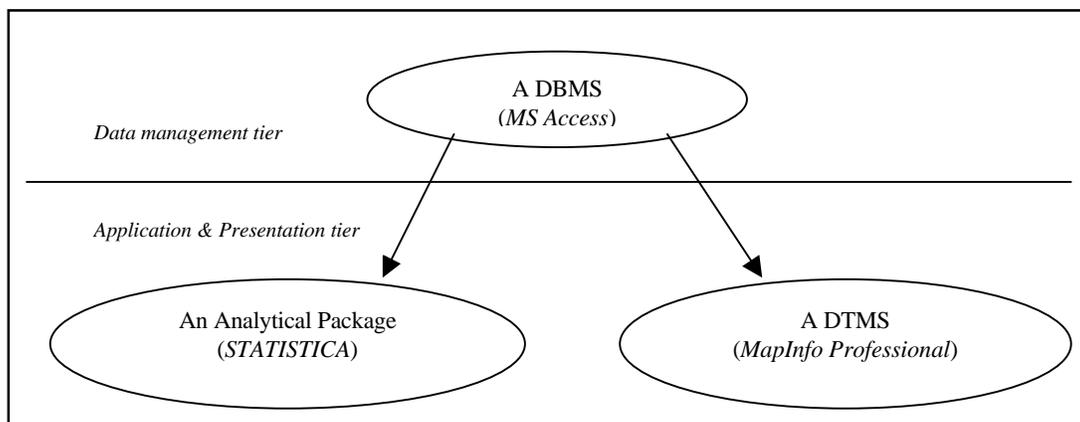


Figure 1. Software Components and Context Level Data Flow Diagram

Table 1. Document Entities and Attributes in the System

Entities	Attributes
OUT	class, order, family, genus, species, diagnosis, pictures, species reference
Station (Time-Independent) Properties	station ID, mean longitude, mean latitude, station name, country, station reference
Station (time-dependent) Properties	stage, station ID, palaeolatitude, tectonostratigraphic units, province
Species Distribution Through Time and Space	Species herein, species in original report, station ID, stage, stratigraphic unit (formation), lithology, and distribution reference
Province-Key Species Relation	stage, province, province reference, 1 st key species/genus, 2 nd key species/genus, 3 rd key species/genus, ... 40 th key species/genus (If we have fewer than 40 key species/genus, the attributes just get null value. The database is designed to be able to store as many as 40 key species/genus. The rest will be ignored)

Table 2. Identifying the Candidate Keys and the Primary Key

Entities	Candidate Keys	Primary Keys
OUT	species	species
Station (Time-Independent) Properties	station ID, station name, (mean longitude, mean latitude)	station ID,
Station (time-dependent) Properties	(stage, station ID)	(stage, station ID)
Species Distribution Through Time and Space	(stage, station ID, species herein) (composite key consists of three attribute)	(stage, station ID, species herein)
Province-Key Species Relation	(stage, province) (composite key consists of two attributes)	(stage, province)

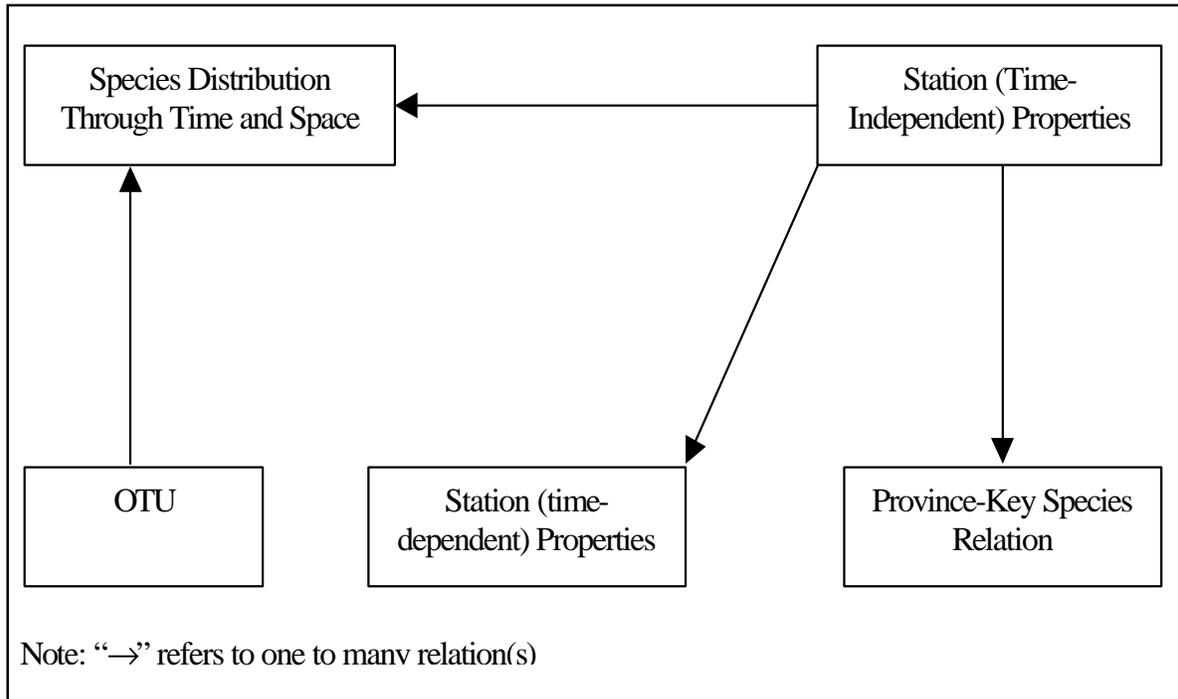


Figure 2. The Entity – Relationship Diagram

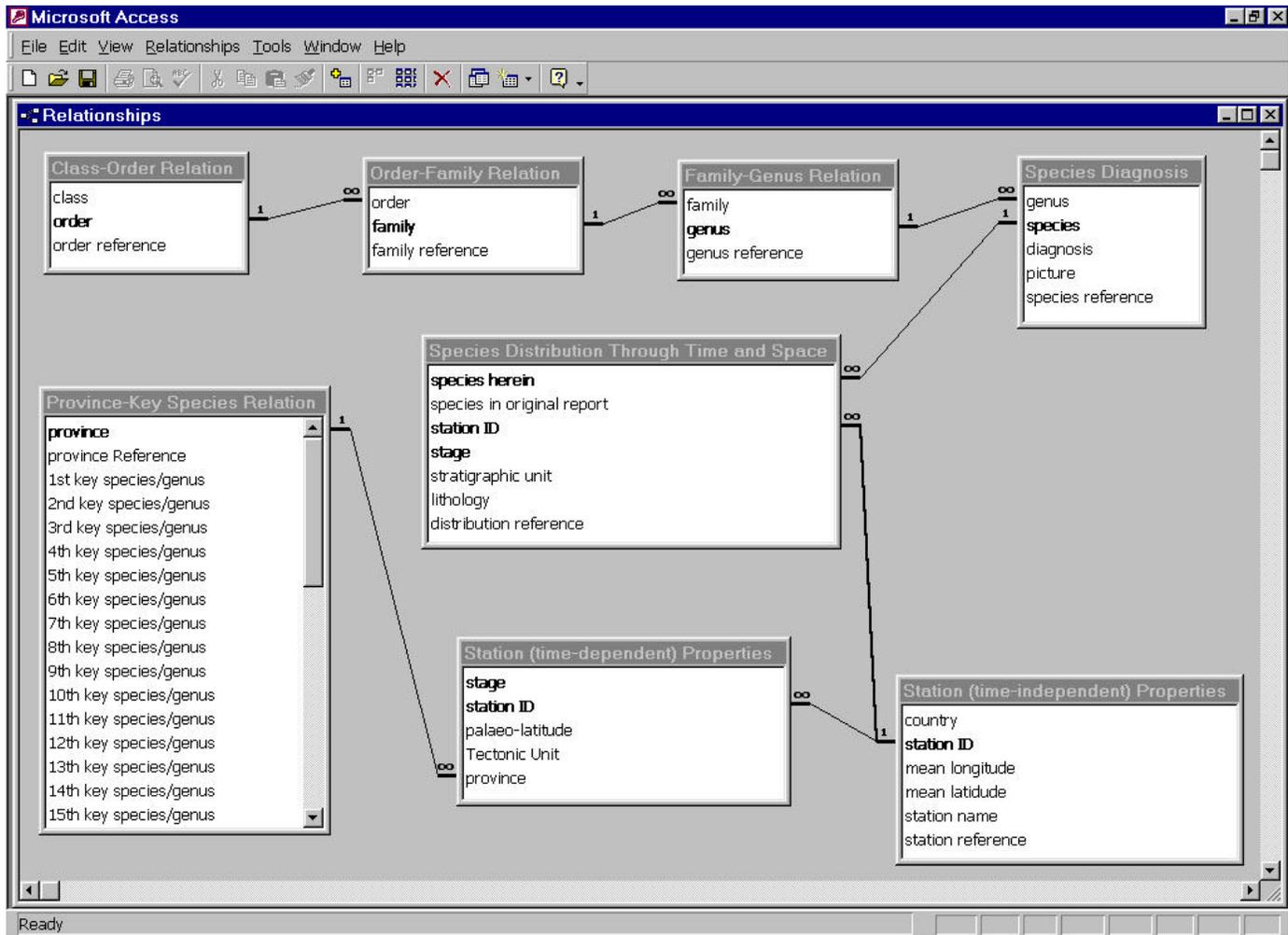


Figure 3. The relationship of Base Tables

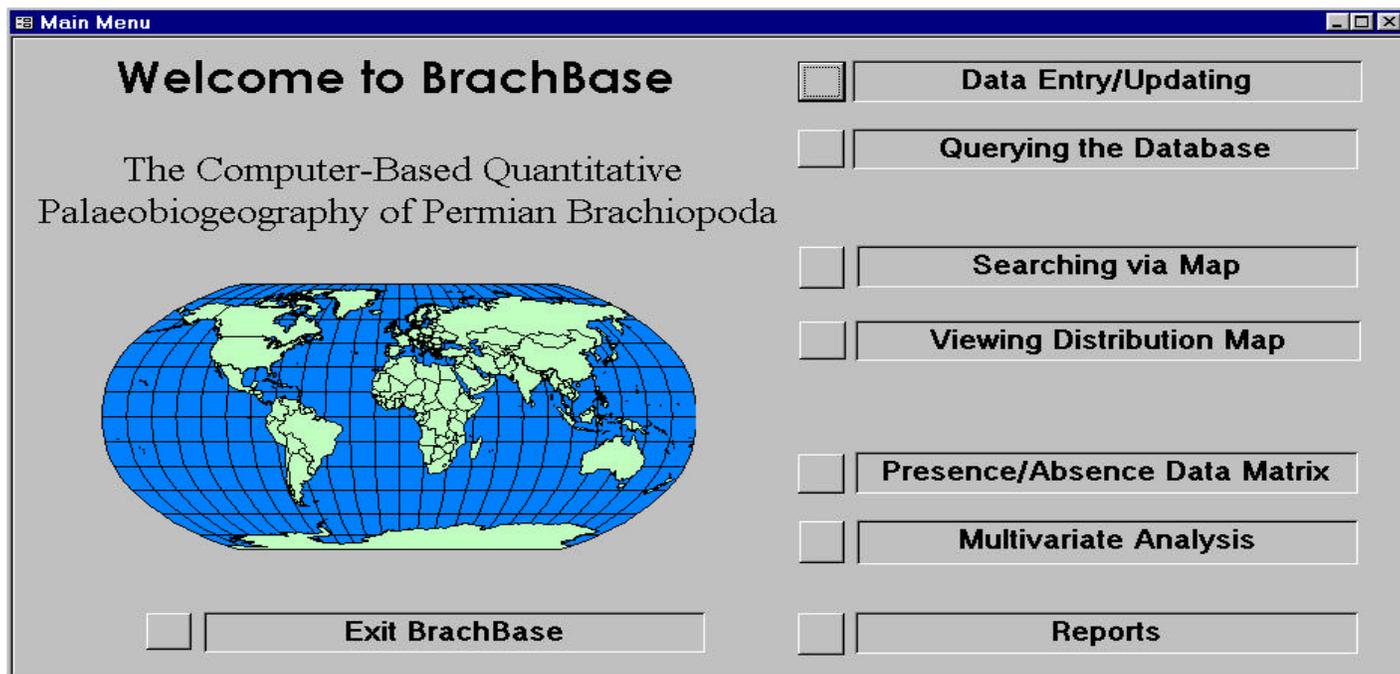


Figure 4. Main Menu of the Computer-Based Information

- vii. Station (Time-Independent) Properties (country, station ID, mean longitude, mean latitude, station name, station reference)
- viii. Province-Key Species Relation (stage, province, province reference, 1st key species/genus, 2nd key species/genus, 3rd key species/genus, ¼ 40th key species/genus)

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4. Physical Database Design with MS Access

There are many database management softwares available on the market today for our choice, e.g., Oracle and MS Access (O'Brien, 1997; Simpson, 1997), etc. We decided to choose MS Access just because all PCs in the library and in the computer labs at Deakin University have been installed with this software. All staff and students have ready access to these facilities for their study and research activities without further payment.

Eight base tables are recognized and built in Access DBMS. The relationship charts of Base Tables is shown in figure 3

5. User Interface

Our system requires a lot of user interfaces, which can be arranged in a hierarchic architecture, to navigate between many different applications. The top-level user interface, or the main switchboard is shown figure 4.

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Geographical Cline in Permian Neogondolellids and Its Role in Taxonomy: A Brief Introduction

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The recognition of profound Permian conodont provincialism since Kungurian (Figure 1), which is represented by the North Cool Water Province (NCWP), Equatorial Warm Water Province (EWWP) and peri-Gondwana Cool Water Province (GCWP) (Mei *et al.*, 1999a, b; Mei and Henderson, 2000; Henderson and Mei, 2000a, this issue), identifies important problems in the existing taxonomy of Permian neogondolellids and correlation. As a result, Henderson and Mei (2000b, c) introduced the concept of geographical clines to Permian conodonts as a possible solution. This report attempts to give a brief introduction of applying the geographical cline concept to Permian conodonts by showing examples in Permian neogondolellids in comparison with a modern biotic example. A lengthy manuscript for formal publication is in preparation.

A cline is defined as a continuous and gradational change in some morphologic character that varies with geographic position. Biologists recognize this concept within many extant biotic groups, but clines are rarely discussed in the paleontological literature. The paleontological literature does often refer to continuous and gradational chromomorphoclines, but these are evolutionary changes

within lineages. Clines are an indicator of continuity of populations and a prime example of the effects of natural selection operating on environmental change. Speciation would occur when this continuity is broken up by some isolating mechanism.

1. A modern example of geographical cline

Before applying the geographic cline concept to Permian conodonts, we will first examine a modern example of a geographic cline within the well known fruit fly, *Drosophila subobscura*.

Drosophila subobscura is a temperate-zone fly native to a region stretching from Spain northward into southern Scandinavia and from North Africa eastward to the Middle East (Huey *et al.*, 2000 and Schwarz, 2000). *Drosophila subobscura* has occupied temperate Europe for about 10,000 years, since the last ice age, and exhibits a geographic pattern of increasing wing size in areas of higher latitude. Thus wings of flies in Denmark are 4 percent longer than those from Spain (Figure 2). Huey *et al.* (2000) believe that this probably has some connection with temperature, but the precise reason has yet to be determined.

Drosophila subobscura was accidentally introduced into North and South America. In South America, it was first found near the Chilean port city of Puerto Montt in 1978. The flies quickly colonized much of coastal Chile, although scientists detected no change in wing length a decade later. They were initially discovered in North America in the early 1990s in Port Townsend, Washington. Both introduced populations are nearly identical genetically, leading geneticists to believe they stem from a common stock that hitchhiked on a ship that probably stopped in Chile and in North America sometime around 1978. Since then, the flies have spread over an area spanning more than 16 degrees of latitude in Chile and across the Andes Mountains into coastal Argentina. In North America, *D. subobscura* has spread from Santa Barbara, California, north to the tip of Vancouver Island in Canada. They also have been trapped as far east as near Salt Lake City.

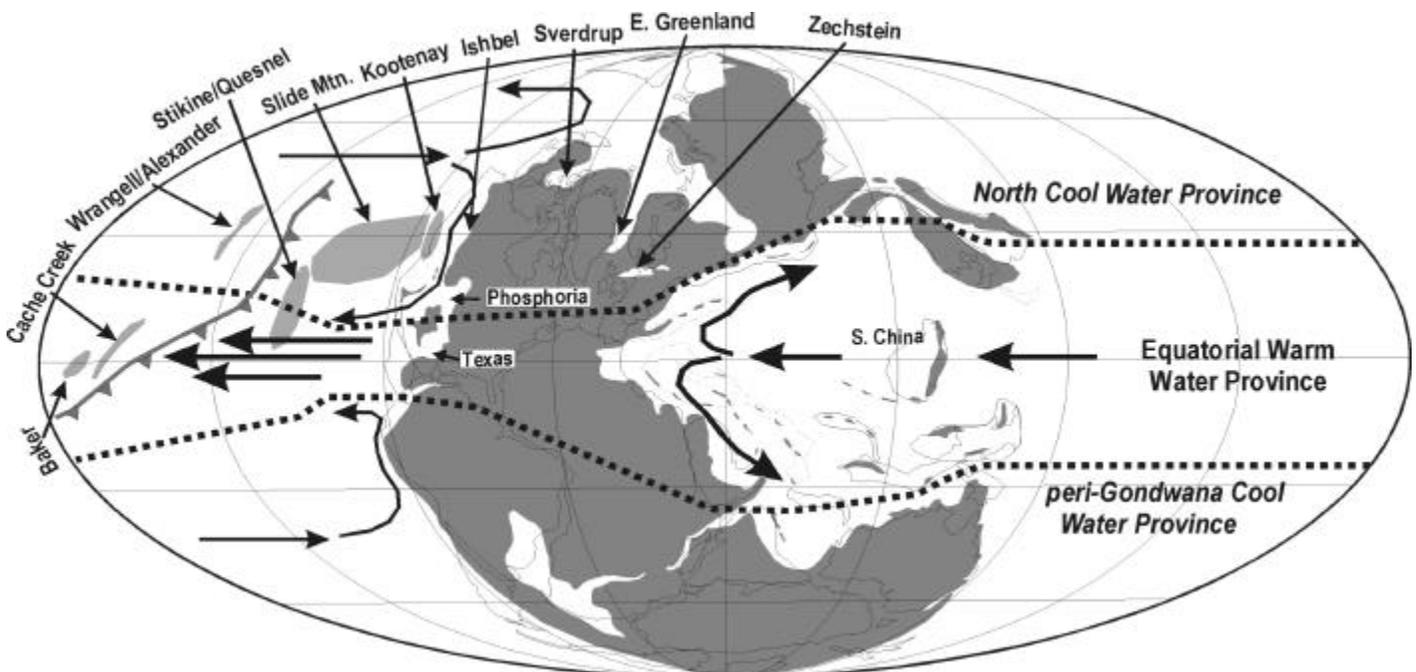


Figure 1 Relative paleogeographic positions of Cordilleran accreted terranes, Conodont Provinces, and Pangea during Guadalupian. Paleogeographic reconstruction is modified after Ziegler *et al.*, 1996.

To check for evolutionary change, Huey and his colleagues trapped flies at 11 North American sites in 1997 and 10 in Spain, France, the Netherlands and Denmark in 1998. Then they raised five or six generations of flies in similar environments, measuring the wing lengths of the last generation. Biologists use wing length because it is an easily measured and highly repeatable index of body size.

Measurements of the North American flies revealed that these introduced flies had evolved a similar pattern in less than two decades. Like the European flies, higher latitude female flies were four percent larger than those from central California. For males, however, the size difference was only 1 to 2 percent. The two continental populations show subtle differences in the part of the wing that lengthens with increased latitude; presumably natural selection is operating on a different gene, but the end result of the cline is similar. European flies have what could be called longer “biceps” while North American flies have longer “forearms.”

Knowing that evolutionary change pattern is the main concern of Huey *et al.* (2000), we are especially interested in the examples of latitudinal cline presented by them. Figure 3 is from Huey *et al.* (2000) and shows that the latitudinal cline in wing size of both native European and introduced North American *D. subobscura*. Figure 3A shows that the wing size of both male and female *D. subobscura* in both European and North American increases with latitude. However, the increasing of wing size in the male North

American *D. subobscura* is less than in the male European *D. subobscura*. Figure 3B shows the relative length of the basal portion of vein IV versus latitude for female *D. subobscura*. As shown clearly, in the native European populations, the relative length of the basal portion increases with latitude, whereas in North American, it decreases with latitude. The male *D. subobscura* shows the similar pattern. As a result, the wing section controlling the cline in wing length differs between North American and European populations.

2. What we learn for Permian conodont taxonomy from the modern example of geographical cline?

The modern example mentioned above reminds us once again that Permian conodont taxonomy has to be based on as large a number of specimens (a population) as possible so as to achieve a useful and powerful solution in subdivision and correlation. As we can see in Figure 3, measurements of rare specimens in native European *D. subobscura* population fall into the scope of the North American population, and vice versa. The difference between these two subpopulations can be recognized only by the entire population.

The other point we have learned is that the configuration of the wing of *D. subobscura* is one of the key, stable and reliable characters in identification. Similarly, we believe the configuration of denticulation in Permian neogondolellids is the key and reliable char-

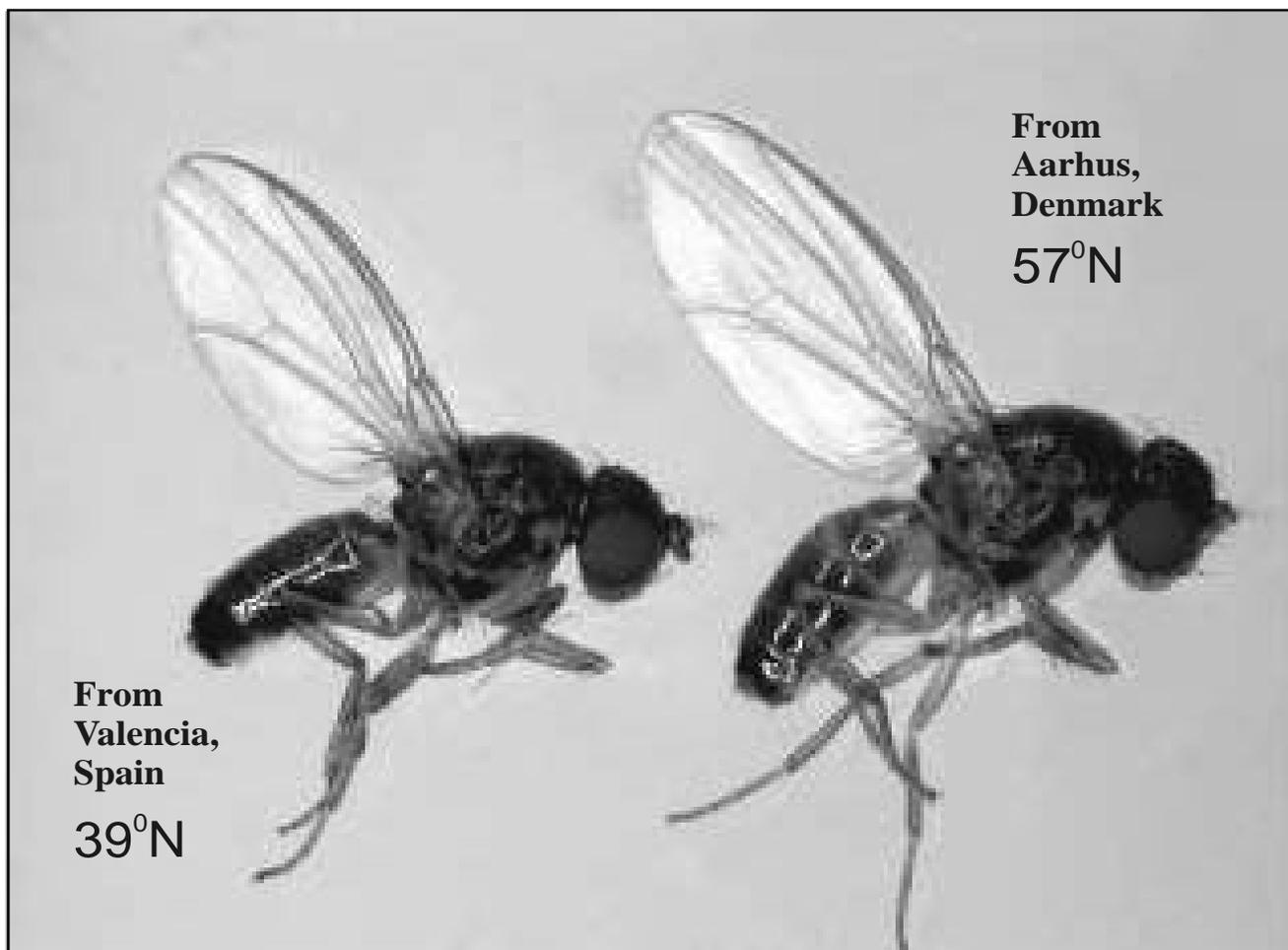


Figure 2 Difference in Wing Size between Female *D. subobscura* in Spain and Denmark (after Schwarz, 2000)

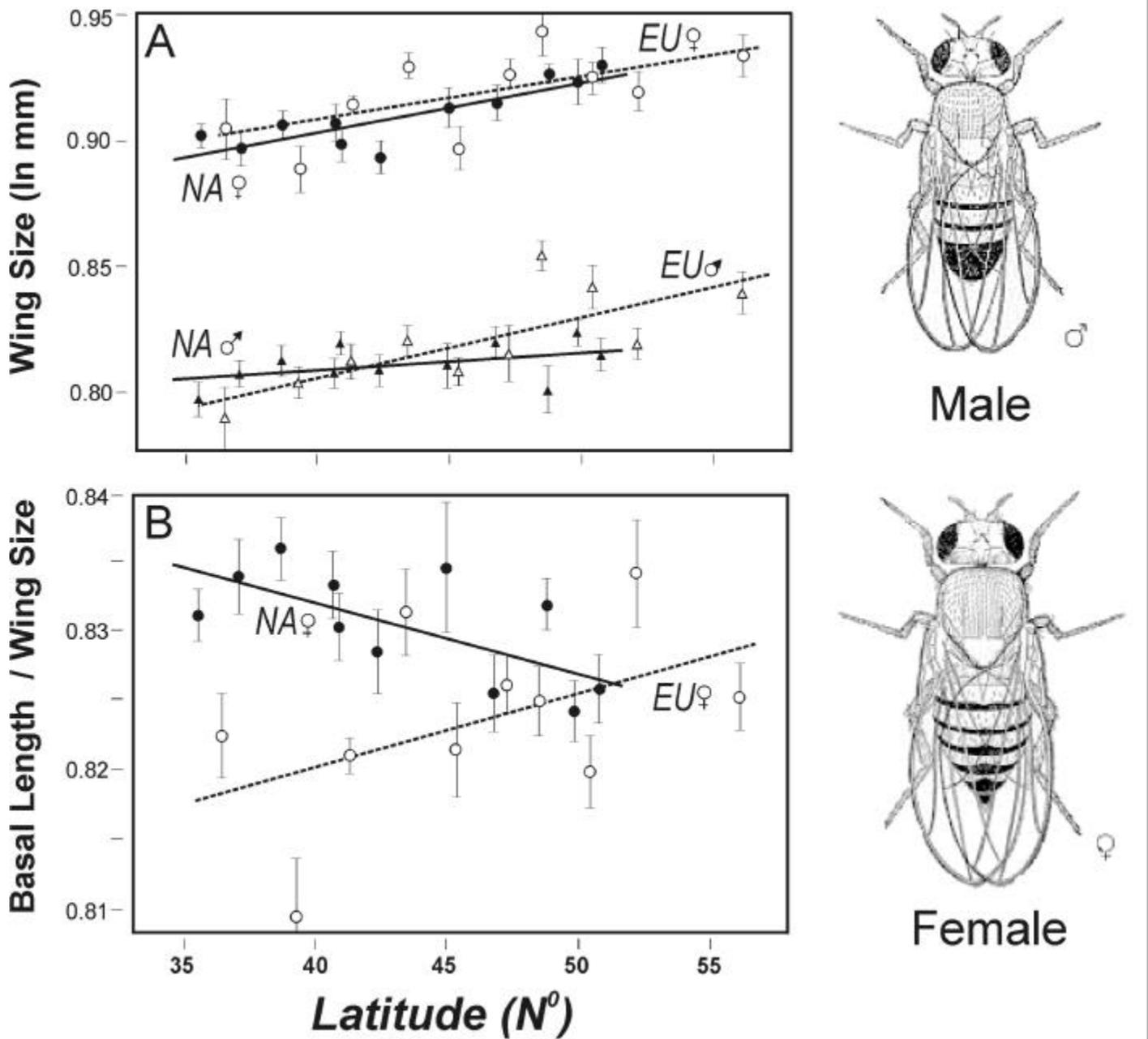


Figure 3 Latitudinal Cline in Wing Size of *D. Subobscura* (after Raymond et al., 2000)

3A: Female wing length increases with latitude in the same pattern in both North America and Europe; Male wing length also increases with latitude but slower in North America than in Europe.

3B: Relative length of the basal portion of vein IV in females versus latitude. Males show the same pattern.

acter in identification, as shown by an example given by Mei *et al.* (1998) for Changhsingian conodonts at Meishan.

Wardlaw and Collinson (1979, p.156) stated: "Representatives of Upper Permian species of *Neogondolella* show much morphologic variability and therefore are difficult to classify. Rare individuals within a population may exhibit one or several characteristics that are thought to be diagnostic of another species. The analysis of large numbers of individuals and the use of several characters to define a species are necessary to resolve this problem." Mei (1996) and Mei *et al.* (1998b) pointed out that three morphotypes, i.e., round-morphotype, square-morphotype and narrow-morphotype can be recognized in a neogondolellid population,

and they represent distinct variants of a single population (Mei *et al.*, 1998b, p. 216). Mei *et al.* (1998b, 214) stated: "that the most consistent and reliable character in Lopingian neogondolellids is the general configuration of the denticles, which can be used to define a natural population or apparatus species. Of secondary importance is the shape of the platform, which can be used only to identify a form species within a natural population, as did most previous authors, or a temporal subspecies." The taxonomy of Permian conodonts based on denticulation, population and ontogeny was first demonstrated by Sweet (1973), and has been proven successful by Orchard *et al.* (1994) and Mei (1996) in clarifying the confusion of the Selong

and Meishan Permian-Triassic boundary conodonts, and Mei *et al.* (1994a, b, c, 1998a, b), Mei and Wardlaw (1996) and Sweet and Mei (1999) in establishing and correlating Guadalupian and Lopingian conodont zones. It is this taxonomy that has led Mei *et al.* (1999a, b) and Henderson and Mei (2000a, this issue) to recognize the profound provincialism for Permian conodonts. It is by looking at the detailed configuration of denticulation that has led Henderson and Mei (2000b) to recognize the geographic cline in Permian neogondolellids (see below).

3. Examples of geographical cline in Permian conodonts

A geographical cline can be recognized for Permian neogondolellids by looking at the denticulation, especially the cusp, how discrete the posterior and middle denticles are, and how discrete and high is the anterior blade. Permian neogondolellids persist as *Mesogondolella* with a big cusp and low and discrete blade in bipolar temperate zones during Kungurian through Lopingian, except during the *Mesogondolella bitteri* Zone when it resembles *Clarkina*. In equatorial regions they differentiated into *Mesogondolella* with a small cusp, a tightly spaced to fused posterior and middle carina, and a high and mostly fused blade during Kungurian, *Jinogondolella* during Guadalupian and *Clarkina* during Lopingian.

Figure 4 shows a geographic cline for neogondolellid conodonts around the Cisuralian-Guadalupian boundary. The specimens from the type section in the Guadalupe Mountains, West Texas are characterized by a small cusp, closely spaced posterior and middle

denticles and a largely fused and high anterior blade. The specimens from the Sverdrup Basin are marked by a relatively large cusp, discrete posterior and middle denticles, and a discrete and low cusp. The specimens from the Phosphoria Basin in Idaho are transitional in denticle configuration. A similar cline has also been recognized by Mei and Henderson (2000) for conodonts from the Cache Creek, Quesnellia and the Slide Mountain terranes (see both figure 1 and Figure 5).

We believe that further detailed study will reveal more examples. One of them may be represented by *Clarkina liangshanensis* in South China with a reduced cusp, largely fused carina and a high and mostly fused blade, "*Clarkina*" *jesmondi* from the Cache Creek Terrane with a big cusp, closely spaced to fused carina and a high and largely fused blade, and *Mesogondolella rosenkrantzi* in Sverdrup with a large cusp, discrete or slender carina and a mostly discrete and low blade. Another example can be recognized for late Kungurian neogondolellids (Henderson and Mei, 2000b). *M. idahoensis* from the cool water provinces, like its holotype in Idaho, is characterized by a large cusp and a considerably discrete and low blade. Its equivalent in the Equatorial Warm Water Province such as South China, Sicily and West Texas, is marked by a relatively small cusp, mostly fused carina and a mostly fused and high blade, as exemplified by *M. siciliensis*. Detailed explanation of these examples is beyond the scope of this brief report.

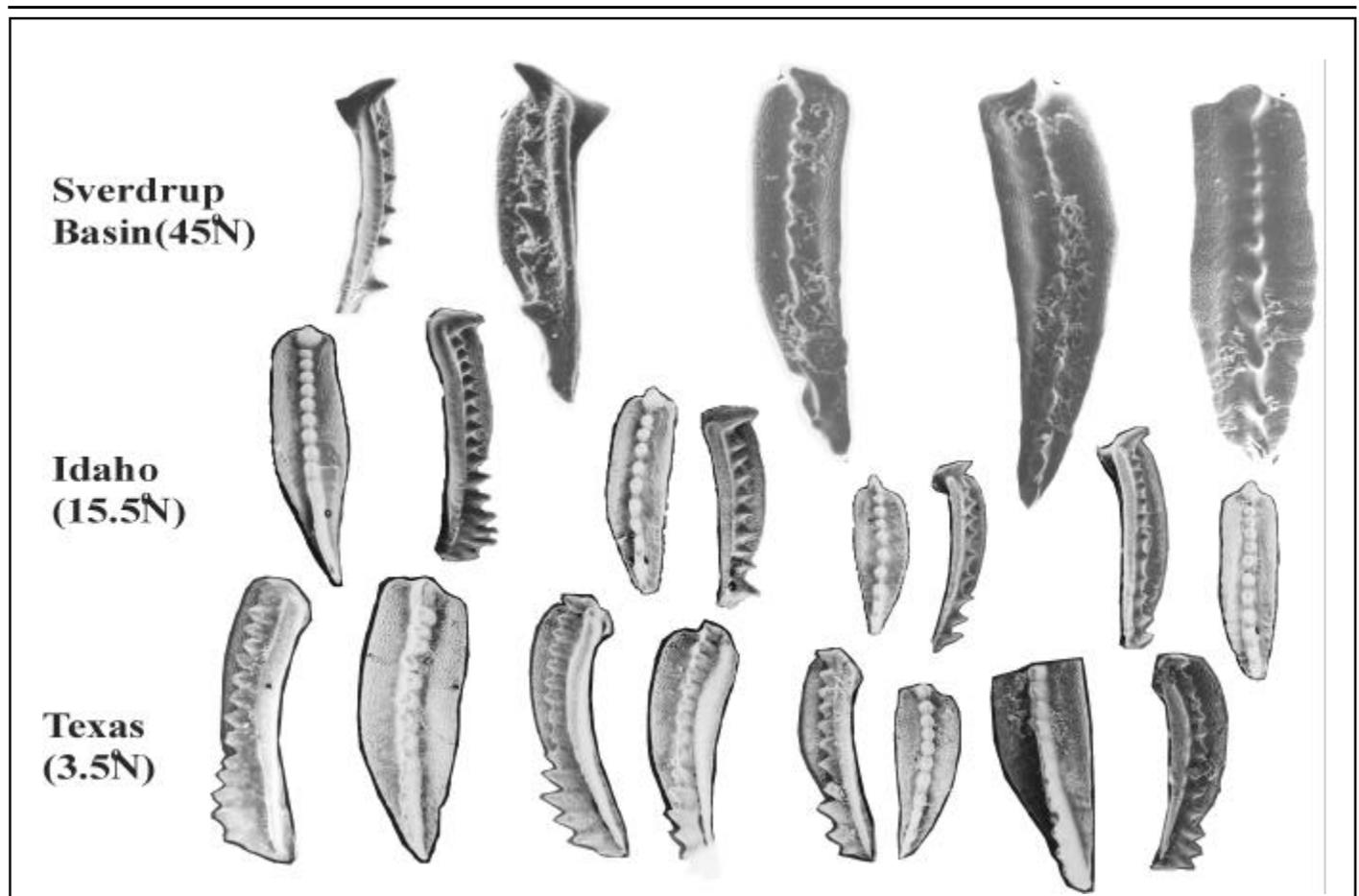


Figure 4. Geographical cline along northwest margin of Pangea. Size of specimens shown in the figure are proportional.

Acknowledgements

Charles M. Henderson and Shilong Mei acknowledge funding from the industry supported Applied Stratigraphy Research Group at the University of Calgary. Shilong Mei acknowledges support from the Open Laboratory of Modern Stratigraphy and Paleontology in Nanjing Institute of Geology and Paleontology, and funding from a key state project funded by the State Science and Technology Commission of China.

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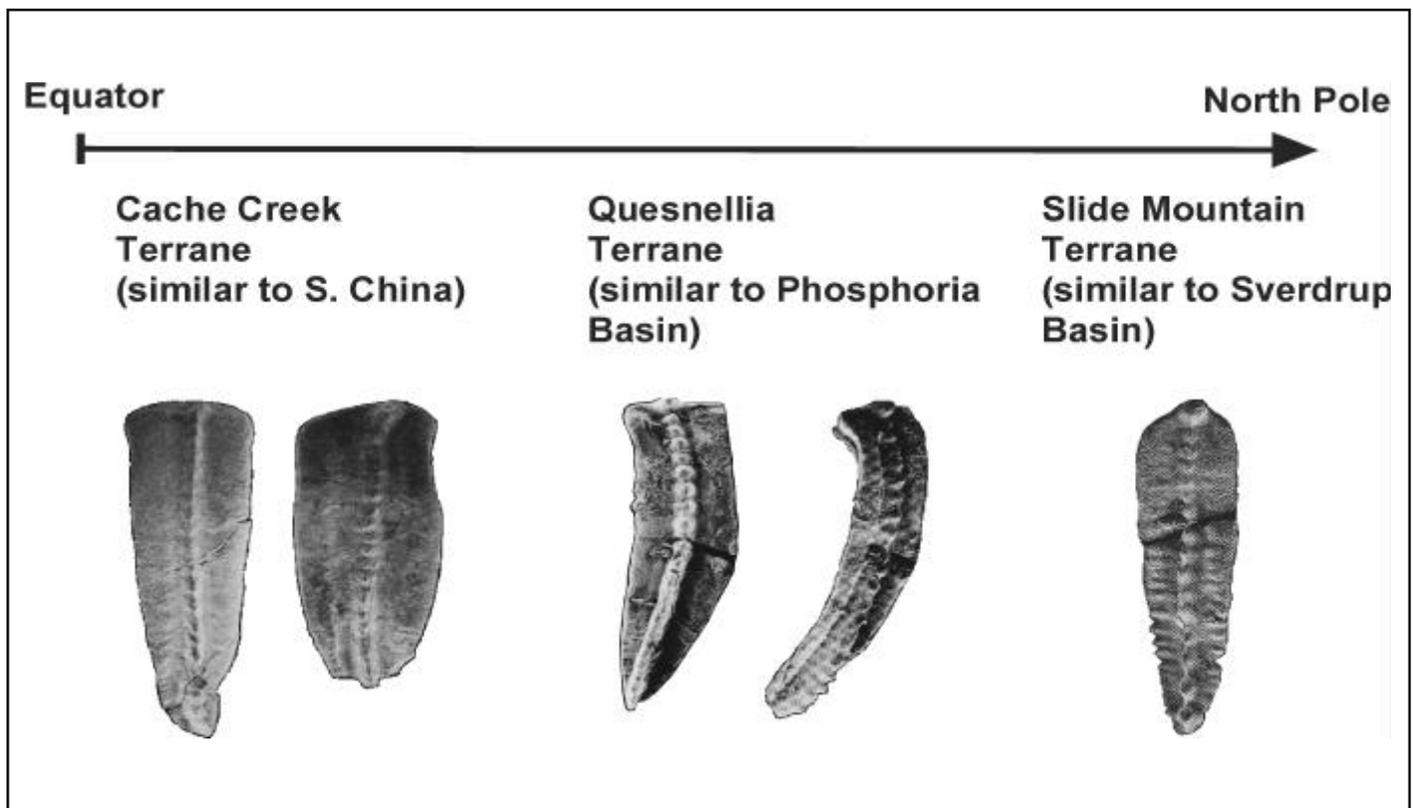


Figure 5. Geographical Cline of Conodonts around Cisuralian-Guadalupian Boundary in western Canadian Cordilleran Terranes. Illustrations are adopted from Beyers and Orchard (1991) for Cache Creek, Orchard and Foster (1988) for Quesnellia and Orchard (1987) for slide Mountain.

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Conodont definition on the basal boundary of Lopingian stages: A report from the International Working Group on the Lopingian Series

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with a report from Charles Henderson and a second from Bruce Wardlaw and Shilong Mei

A. The base of the Wuchiapingian Stage.

In *Palaeoworld* No 9 (Jin *et al.*, 1998), three papers were published on the Penglaitan Section in South China and the conodonts from this section and its equivalents in SW USA. Two papers discussing the potential stratotype points at the Penglaitan section, which reflect controversy over the stratotype point that occurred during discussion at the Calgary meeting, were published in March (Wang, 2000; Jin, 2000a). We feel that a real picture of the stratigraphic distribution of the conodonts is primarily important, and the selection of a boundary level is secondary because the difference between two proposed points is trivial and a GSSP is internationally conventional. In order to clarify the confusion it was necessary to make an examination on relevant samples in a third laboratory. We sent samples from the Penglaitan Section, which are much larger in size than previously studied to Dr. Henderson. Thanks to his cooperation, the first report on the results of studying samples from the beds around the potential boundary level of the Penglaitan Section was provided in March. Clearly, the results are consistent with those made by Dr. Mei and Wardlaw in 1994 and 1998.

Meanwhile, Dr. Wardlaw's revised scheme of Permian chronostratigraphic subdivisions in Permophiles 35 surprised many colleagues because he ignored the official decision of the subcommission. The subcommission passed the decision in 1996 that the indicative fossil is *Clarkina postbitteri*, not *C. dukouensis*, for the base of the Lopingian Series. In addition, recently, the subcommission voted a proposal that *J. nankingensis*, not *J. nankingensis* and *Neostreptognathodus newelli*, for the base of the Guadalupian Series. In his scheme, Wardlaw uses the *altudaensis* Zone instead of several zones that he and Mei recognized in the Penglaitan Section.

B. The base of the Changhsingian Stage.

In 1981, Zhao *et al.* recommended formally Section D in Meishan, Changxing County, Zhejiang Province of China as the stratotype of the Changhsingian Stage, while the base of the stage is located at the base of bed 2, the horizon between the *Clarkina orientalis* Zone and the *Clarkina subcarinata* Zone. Last June, I received a proposal from Drs. Wardlaw and Mei in which the FAD of *Clarkina subcarinata (sensu strictu)* at 13.71 m above the base of the Changxing Limestone at the Meishan (D) Section is recommended as the indicator of the basal boundary of the Changhsingian Stage. However, Mei suspected that there should be a cline from *C. orientalis/inflexa* to *C. wangi/subcarinata* around the base of the Changxing Limestone.

This proposed boundary level is 38 cm below the top of Bed 8

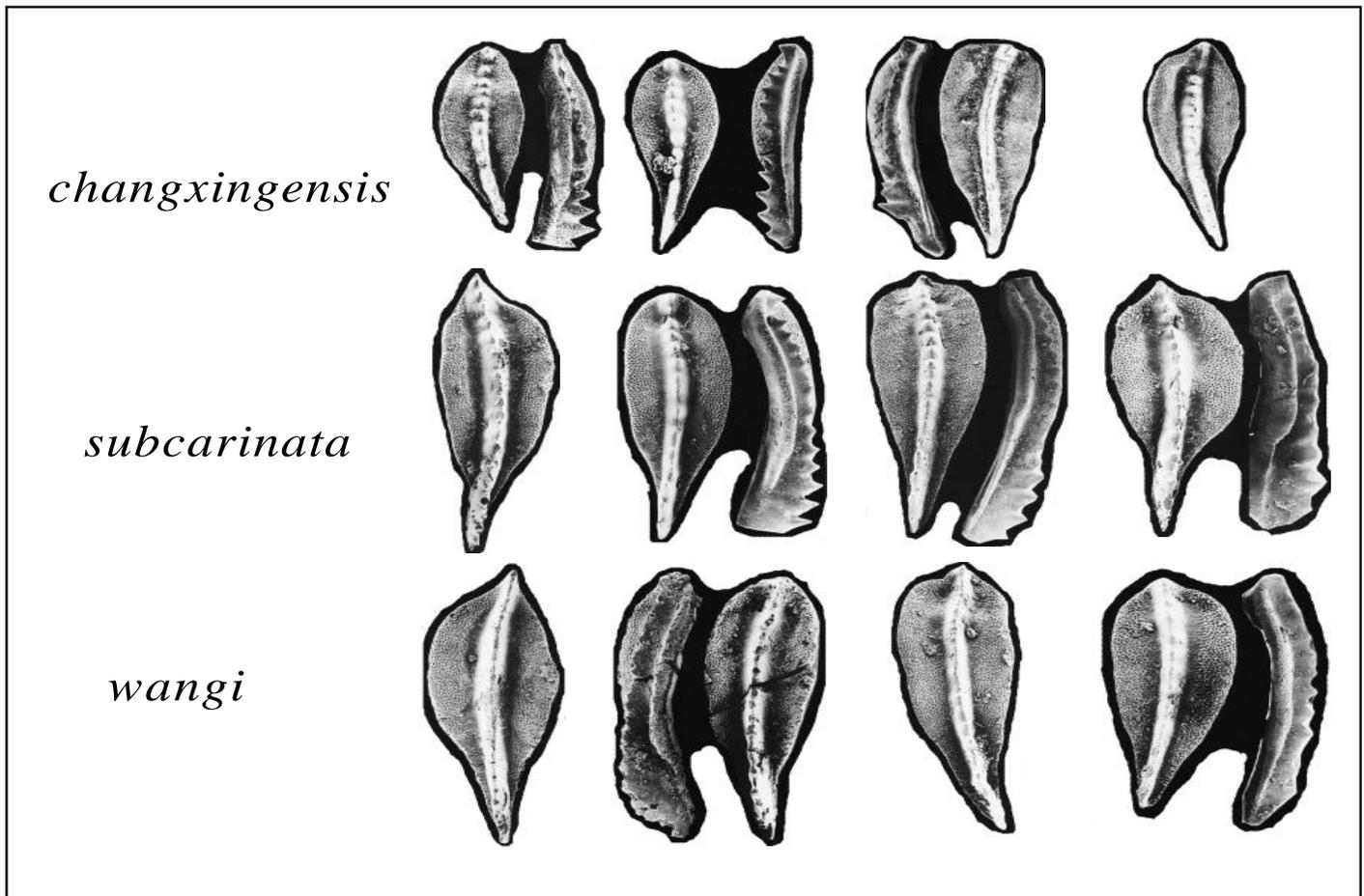


Figure 1. *Clarkina* species that characterize the Changxing Limestone at Meishan, in ascending stratigraphic order. Photos from Mei *et al.* (1998).

(Sheng *et al.*, 1984). The occurrences of some important fossils that used to be referred to as Changhsingian age are as follows. Ammonoids of the *Tapashanites* Zone occur in the top 50 cm of Bed 8, including *Changhsingoceras* sp., *Rongjiangoceras* sp. The fusulinid *Palaeofusiella simplex* appears 4.20m below the level, and the advanced forms of *Palaeofusiella*, such as *P. sinensis*, which are indicative of the Changhsingian Stage, appeared significantly later in this section than in other sections. The foraminifer *Colaniella nana* comes out 3.0 m above the level, and *C. minima*, 3 m below it. Bed 7 is a clay bed with an isotopic age (TIMS) of 253.4 ± 0.2 (Bowring *et al.*, 1998). Magnetostratigraphically, the suggested boundary level locates in the top of a reversed polarity bed of N2P magnetopolarity Zone (Li and Wang, 1989; Jin *et al.*, 2000b).

The following is a report from Dr. Henderson on the conodonts from the beds around the Guadalupian- Lopingian Boundary in the Penglaitan and Tieqiao sections, Laibin County, Guangxi of China, and a proposal from Drs. Wardlaw and Mei on the conodont definition of the basal boundary of the Changhsingian Stage.

The conodonts from the beds around the Guadalupian- Lopingian Boundary in the Penglaitan and Tieqiao sections, Laibin County, Guangxi of China (Henderson)

This report provides the results of samples 116-4f, P6i (lower and upper parts) from Penglaitan and TA6h from Tieqiao. Other samples from these sections are currently being processed or picked, but these three samples are perhaps the most important. Shilong Mei and I looked at these samples independently and then compared notes. Our opinions are exactly the same and are indicated

below.

Tieqiao TA6h Sample

Sample weight = 12.02 kg

Lithology = packstone, perhaps slightly dolomitized which accounts for slightly poorer preservation compared to Penglaitan.

Fauna: All specimens are *Jinogondolella granti*. We did not find any "*Sweetognathids*" as reported previously by Bruce. There are no specimens referable to *Clarkina*; there is no overlap of *Jinogondolella* and *Clarkina*. About 2% of the specimens are somewhat transitional between *J. granti* and *C. postbitteri*, but the lower blade and more fused carina are clearly *J. granti* characters despite the smoothness of the platform outline. Additional organic residue includes fish teeth.

Penglaitan 116-4f Sample

Sample weight = 22.5 kg

Lithology = crinoidal packstone

Fauna: Over 400 specimens of *Jinogondolella granti* Pa elements. Includes all growth sizes as well as numerous parts of the rest of the apparatus. Additional organic material include fish teeth and foram internal molds.

Comments: A few specimens are transitional to *J. xuanhanensis* or are *J. xuanhanensis*. Most specimens have various degrees of serration. Some specimens (less than 5%) have relatively smooth anterior platform margins, but these all have the denticulation of *J. granti* (mostly fused carina with low and somewhat discrete, but closely spaced denticles on the anterior blade). These smooth specimens would be referred to *Mesogondolella altudaensis* or *Clarkina altudaensis* by some other authors, but they are clearly

part of the *J. granti* population in my opinion if you consider carinal characteristics as the primary taxonomic character. Specimens of *Jinogondolella altudaensis* from its type locality are typically wider and shorter. There are no specimens that even come close to that figured recently by Wang (2000; Pl. 1, fig 13; the sample number on his Fig. 1 chart and plate description is labeled as 117-4f, but this is actually 116-4f). His specimen is clearly *C. postbitteri*, but it is totally different from any specimen that we have from the same sample. There is no overlap of *Clarkina* and *Jinogondolella* in this sample on the basis of my analysis.

Penglaitan P6i Sample; lower part

Sample weight = 8.26 kg

Lithology = coarse crinoidal grainstone

Fauna: No conodonts were recovered; not even a fragment. Additional organic residue includes fish teeth, shark dermal denticles, a biserial foram internal mold (nodosarid?). Small pyrite spheres also noted.

Penglaitan P6i upper part; sample was subdivided into two components on the basis of lithology variation.

P6i upper part (a)

Sample weight = 10.27 kg

Lithology = mostly packstone, some grainstone with some carbonate mudstone intraclasts.

Fauna: Abundant specimens of *Clarkina postbitteri*. There are no specimens of *J. granti*; there is no overlap. However, about 4% of the specimens are somewhat transitional with *J. granti* by having more closely spaced denticles and less reduced anterior platform. However, the anterior blade and other carinal characteristics are that of *C. postbitteri*. We also recovered 4 specimens of *Iranognathus cf. movschovitschi*. Fish teeth, shark denticles, and gastropod internal molds were also found.

P6i upper part (b)

Sample weight = 5.32 kg

Lithology = mudstone intraclastic breccia and some packstone

Fauna: Fairly abundant specimens of *C. postbitteri*. No Sweetognathids and no *Jinogondolella*. Numerous solitary rugose corals recognized.

Interpretation: P6i (lower part) is the top of a sequence where very shallow grainstone carbonate forms the top of a HST or lower LST. P6i (upper part) is the beginning of the succeeding sequence (upper LST or early TST; I prefer to call these rocks the "intersequence" as they are deposited during the time between the youngest rocks beneath the sequence boundary and the oldest rocks above the sequence boundary where the sequence boundary is clearly unconformable). The sample contains numerous carbonate mudstone intraclasts which give the limestone a breccia appearance when etched. The same thing was noted in a sample from Tieqiao that I collected with Bruce last year (bed 8C; which should be an equivalent bed and contains only *C. postbitteri*). These are not old reworked clasts, but rather intraclasts ripped up from an adjacent environment (probably by storms or slight sea level fluctuations during the early TST or upper LST); the clasts contain the same conodont fauna as the surrounding matrix. The breccia nature is not obvious until the samples are etched during processing.

There is no overlap between *Jinogondolella granti* and *Clarkina postbitteri* in the reported samples, although rare transitional forms suggest that these taxa represent ancestor and descendant. I was not certain of this relationship previously, but

after considerable discussion with Shilong Mei I have become convinced of this and can see it in the specimens. Furthermore, during our discussions I have become convinced that the end of the Guadalupian marine basin in West Texas is during *J. xuanhanensis* time (= *J. crofti*). These latter two taxa are clearly older than *J. granti*. I believe it is very unlikely that either of these taxa are the direct ancestor to *C. postbitteri*. The time represented by the unconformity above the Altuda Formation is almost certainly equivalent to the time of deposition of the LST/early TST Laibin Limestone. This is why *J. granti* is found only in S. China. It could be argued that the abrupt change from *J. granti* to *C. postbitteri* is indicative of an unconformity and that the breccia could support this (*I agree with you that the term diastem is very appropriate for this bedding plane contact between 6i lower and upper. Shilong Mei would probably regard this as the correlative conformable surface associated with the G/L sequence boundary on the shelf/platform. I don't believe that there is any one correlative conformable surface, but rather an interval. However, it seems clear that there is a turn-around in sea level at this point and applying the Transgressive-Regressive sequence model of Embry, this point could be viewed as the beginning of a new sequence in a conformable succession.). We would argue that if it is an unconformity, it is of very small duration at Penglaitan given the lithologic succession and interpreted sequence stratigraphy. I think we are simply seeing very minor sea level fluctuations in "a complete as you can get" LST and early TST succession (the intersequence). I would argue that the sudden change is more indicative of a biotic signature indicating a major evolutionary event (a punctuated event). Previous history of *Jinogondolella* and subsequent history of *Clarkina* is one of transitional morphotypes. I bet that no one can consistently demonstrate the exact point at which *postbitteri* becomes *dukouensis*; Shilong Mei agrees. There is a change, but how do you pick the consistent point of change. An arbitrary point in a morphologic continuum, as is becoming the trend in Permian chronostratigraphy, is exactly that, arbitrary, and almost certainly inconsistent. It is very likely that this *Jinogondolella* to *Clarkina* evolutionary event is triggered or controlled by the lowstand of sea level. Shilong Mei and I believe that the FAD of *C. postbitteri* is the clearest possible boundary position for the Guadalupian/Lopingian boundary in terms of biologic evolution and from a sequence stratigraphic perspective.

Finally, I would like to make it clear that we looked at the samples independently and came to the exact same conclusion that there is no overlap between the two key taxa. The interpretations about evolution are a result of our common discussions. I was initially very reluctant to see *granti* as the ancestor of *postbitteri*, but I have become convinced from our discussions.

* From a later comment by Dr. Henderson in reply to Jin Yugan.

Conodont Definition for the basal boundary of the Changhsingian Stage (Wardlaw and Mei)

There is a continuous morphocline expressed by the Pa elements of *Clarkina* in the lower part of the Changxing Limestone that provides an appropriate evolutionary point to define the base of the Changhsingian Stage.

Previously, Mei *et al.* (1998), in an attempt to consolidate the disparate morphologic form taxa that have been identified as "spe-

cies” recognized several assemblage zones within the Changxing Limestone based on the evolving change in denticulation and noting four “shape classes” in each zone. The shapes were round-morphotype, square-morphotype, narrow-morphotype, and transitional morphotype (transitional between square and round). Typically names applied to these morphotypes are “*deflecta*” for the square-morphotype, “*changxingensis*” for the round-morphotype, “*wangi*” for the narrow-morphotype, and “*subcarinata*” for the transitional morphotype. All four morphotypes are in every sample throughout the entire Changxing Limestone and clearly do not serve as valid species identifiers. Based on the study of many topotypes to each morphospecies and our abundant new material from the Changxing Limestone, we would like to now abandon these species concepts and base species on the clear evolutionary progression of denticulation in the Pa elements to provide a powerful boundary definition based on a phyletic morphocline rather than platform outline morphologies that provide little variation throughout the Changxing Limestone.

The evolution of the denticulation in the lower part of the Changxing Limestone can be characterized in adult forms. Lambert (1994) discussed a methodology for using size as a proxy of relative maturity by using carina length in neogondolellid platform elements. Small, juvenile forms generally show more discrete denticles than large, adult forms, and then again, very large, gerontic forms display excessive fusion and commonly pathologic, bizarre characters. The evolution in adult Pa elements of *Clarkina* shows a highly fused, high carina, with a cusp that is not clearly separated from the carina and in lateral view looks like a high “wall”, that reduces in height posteriorly, denticles become more discrete, and the denticle clearly separates from the carina, showing a posteriorly declining carina and separated cusp in lateral view, and then, further reduces so that the posterior most denticles are completely discrete and depressed and there is a shallow depression in the platform, the cusp is completely separated and the depression that is quite noticeable in lateral view (figure 1). Based on the holotypes of morphospecies we apply the names *Clarkina wangi* to the forms with the high, wall-like carina, *C. subcarinata (sensu strictu)* to the forms with the reduced, partially discrete denticles, and separated cusp; and *C. changxingensis* to the forms with the depressed, discrete denticles, and separated cusp. The succession is an evolutionary continuum and the distinctions of the species can be arbitrarily picked to define an accurate point and definition for the boundary. We pick the point at the first appearance of adult forms with a clearly separated cusp, and partially discrete posterior carinal denticles as the first occurrence of *Clarkina subcarinata (sensu strictu)* which is at 13.71 m above the base of the Changxing Limestone at the Meishan (D) section, Changxing County, China. It should be noted that the new phylogenetic species concept wholly includes the holotype and topotypes of *Clarkina subcarinata* (Sweet).

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Has your address changed since you last received Permophiles?

Please email or send any address changes to:

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Mailing Address:
Dr. Charles Henderson
University of Calgary
Department of Geology and Geophysics
Calgary, AB T2N 1N4 Canada

CORRESPONDENCE

Re: General Management Plan & Environmental Impact Statement for Guadalupe Mt. National Park

Dear Ellis:

We regret that we were at our national geological convention in New Orleans and missed your Park public hearing at Odessa. In addition to the general comments on your enclosed questionnaire, I would like to address some special concerns to geologists, which you are probably already aware of.

1. No collecting of geologic specimens, fossils or rocks should be permitted along the Geology Trail. What has already been sampled should be archived at The Wallace Pratt Ship-On-The-Desert Research Center or at the Texas Bureau of Economic Geology for study by interested geologists. Access to these rock collections could be through the resident NPS Geologist and/or the Park Superintendent.

2. In keeping with NPS rules- rock collecting in the Park by the general public should be prohibited.

3. It is desirable for the rocks of Guadalupe Mountains to be designated as Type Sections for the Middle Permian by the International Commission on Stratigraphy. An important consideration of such designation is that there should be adequate access and adequate sampling of rocks by members of the ISC and its Permian subcommittee. I propose that

A. Future sampling of rocks by, ISC members or any others should be under the supervision of the NPS resident geologist. They certainly should be granted permission to study and sample the Type Sections in Stratotype Canyon and Nipple Butte.

B. The GMNP resident geologist should catalog existing Guadalupian age rock and fossil collections (e.g. by Bruce Wardlaw at the USGS in Reston, Virginia, by Charlie Kerans at the Texas Bureau of Economic Geology in Austin, and by petroleum industry geologists, etc.) Students and other geologists desiring to sample rocks within Park Boundaries should be referred to study these available collections before additional rock sampling is permitted within Park Boundaries. Future sampling by geologists or others who are not members of the ISC should be at the discretion of the Park Superintendent and under the supervision of the resident Park Geologist.

C. Most of the rock formations of the Backreef Facies are present in abundance on BLM land adjacent to GMNP. Most of the rock formations of the Forereef Facies are present on private ranches to the south in Texas. Some reef rock exposures are also present in these areas. Future students and geologists should be encouraged to collect rocks in these areas after securing permission from the BLM office in Carlsbad, New Mexico or from private property owners rather than grant them permission to sample rocks within the boundaries of GMNP

D. Whether on GMNP, BLM or private land, rock-sampling permits should be denied along highway roadcuts because geologists and professors on fieldtrips

use these extensively and constantly where time constraints prohibit the use of more remote outcrops.

4. The GMNP resident geologist should assemble a collection of polished rock samples representative of the major facies of all formations and important stratigraphic sections in the National Park. This collection could be housed in the Wallace Pratt Ship-On-The-Desert Research Center for study by geologists interested in Permian stratigraphy and/or reef, forereef and backreef architecture. If time does not permit the staff geologist to do this, it would be an excellent thesis, dissertation or Summer Ranger project. Industry funding could probably be secured for such an undertaking.

We all recognize that the rocks of the Guadalupe Mountains form one of the world's greatest textbooks of reef morphology and Permian stratigraphy. It is imperative that vandalism and uncontrolled collecting must not be permitted to mar the outcrops of this textbook. We are pleased that the National Park Service is the custodian and watchdog of this internationally important treasure. We wish you well as you continue the task you are superbly accomplishing on our behalf. n

Your Fiend,
Jim W. Adams
Certified Petroleum Geologist #647

Abadeh Section Accessibility

Dear Permophiles Colleagues,

In a very recent communication with the Deputy Director of the Geological Survey of Iran, he said that "Contrary to the statement expressed in item 7, page 24, Permophiles #35, Abadeh Section is universally accessible to every visitor, including "qualified scientists", and we welcome anybody who is interested to study that Section. Geological Survey of Iran will provide guidance and help, but NOT financial undertaking."

The interested scientists who want to visit or study Abadeh Section should contact:

Dr. A. Aghanabati
Geological Survey and
Mineral Exploration of Iran
P. O. Box 13185-1494
Tehran, IRAN

Sincerely Yours,
Hooshang Taraz, Ph.D.
6836 Hyde Park Dr.9 Apt. A
San Diego, CA 92119 1 USA

Gentlemen,

First let me state that I am extremely proud of the progress made by SPS in recent years, largely because of our individual and collaborative contributions. The Carboniferous and Permian each have a “roof”, the three Permian series have received initial approval, and the Guadalupian and component stages will go through final approval at the August meeting of IGC in Rio de Janeiro. However, I am most disappointed at our failure to bring the GSSP for the base of the Lopingian to a formal vote. This is especially unfortunate because leadership of ICS will change at the IGC, and we may well lose the type of enthusiastic support offered previously by Jürgen Remane.

The differences in opinion revolve about ONE METER in the Penglaitan section. Cogent arguments have been advanced on each of the several horizons preferred within this interval, and I am familiar with them all. BUT 1m! Irrespective of where the GSSP is placed within this interval, it will be fully functional, and this will remain one of the most intensely studied sections in the world.

My plea to you all is for compromise. With adequate interpersonal relations, we could settle this arbitrarily, progress beyond the mechanics, and move on with the science. I look forward to publication of new comprehensive accounts of the Lopingian sequence, although this will remain an ongoing challenge. But now, let's reach early agreement on a compromise horizon so that we can then progress to collaborative science focus.

My high esteem and best wishes to each of you

Brian

June 15, 2000

Editorial note:

This letter was submitted by Brian F. Glenister, specifically requesting that the SPS secretary forward it to Charles Henderson, Heinz Kozur, Jin Yugan, H. R. Lane, Shilong Mei, Jürgen Remane, Wang Cheng-yuan, and Bruce Wardlaw and that it be included in this issue of Permophiles. For a response to this letter from Charles Henderson, Jin Yugan and Bruce Wardlaw, see page 3 of this publication.

ANNOUNCEMENTS

Oman Pangea Symposium and Field Meeting

Dates: January 8 - 11, 2001

Cost: US\$500

Information and Inscription directly on web site:

<http://www.geoconfoman.unibe.ch/symposium1a.html>

On the occasion of the International Conference on the Geology of Oman organised at Sultan Qaboos University, Seeb/Muscat, January 12 to January 16, 2001, an Oman Pangea Symposium and field meeting is scheduled. This Oman Pangea Symposium and field meeting will be co-sponsored by the Global Sedimentary Geology Program (chairman Dr. Benoit Beauchamp), by the International Subcommission on Permian Stratigraphy (chairman Dr. Bruce R. Wardlaw) and by the International Subcommission on Triassic Stratigraphy (chairman Prof. Maurizio Gaetani). The symposium will take place within the Southern Tethys and Arabian Continental Margin topic of the Conference (Prof. Alastair Robertson).

Scientific Organisers of the Symposium and Field Meeting

Dr. Aymon Baud and Prof. Jean Marcoux, with the help of the BRGM and other experts.

Objective

With the presentation of new and recent results on Permian and Triassic sediments of Oman, the aim of the Symposium and the three fieldtrips are to provide a forum to geologists who are interested in the time interval of Pangea for discussing global changes related to Pangea integration, North Gondwana and Central Tethys evolution; It will be an unique opportunity for sedimentologists, stratigraphers and paleontologists who are working within Permian and Triassic time interval, biotic crisis, extinction, recovery and evolution at the Paleozoic- Mesozoic transition to discuss, to look and to sample at the spectacular Permian and Triassic outcrops belonging to the Oman former continental margin, from shallow shelf to deep marine sediments and seamounts. For the petrograph-geochemists, Oman is a key area for the study of the magmatism linked with the Permian Neotethys opening and with the Triassic intra-oceanic seamounts.

General Themes

Pangea and Tethys, moving Plates and environmental Changes.

Secondary Themes

Progress in the Permo-Triassic Stratigraphy and Palaeontology of the Central Tethys and its Gondwana margin.

Comparison between the Permo-Triassic continental margins of Oman, Arabia, Iran, N India (Himalayas) and N Australia.

Further Informations by Aymon Baud, Geological Museum, UNIL-BFSH2, CH-1015 Lausanne, Switzerland, tel.: xx41 21 692 44 71, fax xx41 21 692 44 75, e-mail aymon.baud@sst.unil.ch

Pre-Conference Excursion No. A01

Permo-Triassic Deposits: from the Platform to the Basin and Seamounts

Leaders: A. Baud, F. Bechennec, F. Cordey, L. Krystyn, J. le Métour, J. Marcoux and R. Maury

The mountainous belt located in the eastern part of the Arabian Peninsula, the Oman Mountains, expose a segment of the Gondwanian margin interpreted as a flexural upper plate. During the end of the Cretaceous, this segment was sliced and brought on the Arabian continent with the obduction of the ophiolite, part of the Tethyan ocean. Following a lower Permian rifting phase and middle Permian break-up (birth of the Neotethys), a wide carbonate platform developed during late Permian and Triassic times on the inner part of the margin. This Permian-Triassic sequence is exceptionally well exposed in the Jebel Akhdar Mountains, as part of the «autochthonous» which crops out in a large tectonic window. The Permian and Triassic shallow water carbonate rocks occurring in this area belong to the Akhdar Group, with two main lithologic units: the Saiq and Mahil Formations. The Saiq Formation, about 700 m thick and made up of three transgressive - regressive cycles unconformably overlies Precambrian strata, documenting the upper Permian marine transgression. The following 800 m thick Triassic dolomitic Mahil Formation confirms the cyclic and restricted shallow marine environment upward. Carbonates derived from the platform represented the major source for the thick sequence of slope carbonates deposited near the platform margin. On more distal parts, the basinal and oceanic sedimentation resulted in various types of carbonate, cherts and siliciclastic deposits, presently found in the Hawasina Nappe. Middle Permian radiolarites and red ammonoides limestones as Middle Triassic black marls and limestones deposited on lavas are cropping out as blocks of various dimensions, the Oman Olistolits, both sides of the «autochthonous» tectonic window. Also new results on Permian and Triassic magmatism will be presented.

Spectacular and recently studied outcrops in Wadi Wasit, Ba'id, Aq Quil, Jebel Misfah, Jebel Misht and Jebel Akhdar areas allowed to reconstruct the former geometry of the margin during Late Permian and Triassic times.

Pre-Conference Excursion No. A02

Lower to Middle Permian Sedimentation on the Arabian Platform: the Huqf Area (S. Central Oman) and the Jebel Akhdar (Oman Mountains)

Leaders: L. Angiolini, J. Broutin, S. Crasquin and J.-P. Platel

Dates: January 7 - 11, 2001

Cost: US\$625

This excursion will provide a unique opportunity to see and sample the Peri-Gondwanan Permian successions of the Sultanate of Oman. In the spectacular scenarios of the mountains and the desert, different faunal and floral associations and depositional environments from platform to shallow basin will be visited.

Starting in the desert of the Interior Oman, the excursion will visit the Huqf area, a region marked by gentle deformed and uplifted Palaeozoic formations. Here, the Early to Middle Permian is

represented by two mega-sequences separated by a regional unconformity, recording two major transgressive events respectively controlled by the last phase of the Gondwanan deglaciation and by the opening of the Neotethys. The first sequence consists of Lower Permian glacio-lacustrine deposits of the Al Khlata Formation succeeded by the transgressive marine deposits of the Saiwan Formation, marking the complete deglaciation of the region. The latter unit, of late Sakmarian age, yields a rich and well preserved brachiopod (*L. Angiolini*), bivalve, gastropod, crinoid and bryozoan fauna.

Resting unconformably, the upper sequence is composed at the base of a thick fluvial terrigenous unit, the Gharif Formation. This sequence terminates with the highly fossiliferous [brachiopods, ostracodes, conodonts, bivalves, gastropods, cephalopods, trilobites (*L. Angiolini* & *S. Crasquin*)] transgressive marls and bioclastic limestones of the Khuff Formation, of which only the Wordian part, are exposed below the angular unconformity of the Triassic continental Minjur Formation.

The Huqf succession represents a key-section for the intercalibration of Early to Middle Permian marine and continental biostratigraphical scales. In fact, if on one hand the fauna shows a marked transitional character, being represented by cosmopolitan, Gondwanan, Tethyan and endemic taxa, on the other the newly named "Gharif Paleoflora" (*J. Broutin*) is erected as a standard for the Arabian Peninsula. This warm humid assemblage is of outstanding palaeogeographic significance, because it comprises associated Gondwanan, Cathaysian and Laurasian floral elements.

Moving to the the Oman Mountains, this excursion will examine together with the excursion A01 the Permian succession cropping out in the north-western part of the Jebel Akhdar window, along the Wadi Sahtan. Here, the Permian is represented by the Wordian marine Saiq Formation, lying with a spectacular angular unconformity on the Proterozoic-Lower Paleozoic autochthone series. The Saiq Formation consists of conglomerates at the base overlain by bioclastic limestones and reef limestones which capped by dolomites. This unit marks the transgression on the newly formed Neotethyan margin.

Post-Conference Excursion No. B01

Permo-Triassic Deposits: from Shallow Water to Base of Slope and Basin

Leaders: A. Baud, F. Bechennec, F. Cordey, and J. Marcoux

Dates: January 17 - 20, 2001

Cost: US\$500

The mountainous belt located in the eastern part of the Arabian Peninsula, the Oman Mountains, expose a segment of the Gondwanian margin, interpreted as a flexural upper plate. The Permian-Triassic sequence deposited on the inner part of this margin is exceptionally well exposed in the Saih Hatat Mountains, as part of the «autochthonous» which crops out in a large tectonic window. The Permian and Triassic shallow water carbonate rocks occurring in this area belong to the Saiq and Mahil Formations. The Saiq Formation, about 400 m thick, consists of transgressive - regressive cycles of shallow carbonate and lava flows unconformably overlying Precambrian strata and documenting the upper Permian marine transgression and rift opening. The following Triassic dolomitic Mahil Formation confirms the cyclic

and restricted shallow marine environment upward.

Carbonates derived from the platform represented the major source for the thick sequence of slope carbonates (the Sumeini Group) deposited near the platform margin, cropping out in the Sumeini area near the border between Oman and the United Arab Emirates. The lower part of this group (about 1700 m thick) is included in the Maqam Formation, late Permian to late Triassic in age. Key section of the Oman margin architecture, the Wadi Maqam has been re-investigated in terms of biochronology, sequence and isotope stratigraphy. On more distal parts, the basinal and oceanic sedimentation resulted in various types of carbonate, cherts and siliciclastic deposits, presently found in the Hawasina Nappe. Middle Permian radiolarites and red ammonoides limestones as Middle Triassic black marls and limestones deposited on lavas are cropping out as blocks of various dimensions, the Oman Olistolits, both sides of the «autochthonous» tectonic window. Also new results on Permian and Triassic magmatism will be presented.

Spectacular and well studied outcrops in Saih Hatat Rustaq, Buday'ah Wadi Maqam and Jebel Sumeini areas allowed to reconstruct the former geometry of the margin during Late Permian and Triassic times.

Excursions Information and Inscription directly on web site:

<http://www.geoconfoman.unibe.ch>

Further Information:

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31st International Geological Congress

International Standard References for the Permian System: Cisuralian of Southern Ural Mountains, Guadalupian of Southwestern North America, Lopingian of South China

Conveners: Tamra A. Schiappa (BSU), Bruce R. Wardlaw (USGS), and Brian F. Glenister (University of Iowa)

Date: August 6th through 17th, 2000
Venue: Riocentro Convention Center
Rio de Janeiro - Brazil

Subject: The International Commission on Stratigraphy and Subcommission on Permian Stratigraphy is sponsoring an international symposium at the 31st IGC meeting in Rio. The symposium will highlight progress on final recommendations for Permian series and stage definitions. The symposium will consist of a poster session highlighting all the volunteered contributions (afternoon) followed by an oral session with the convener's address and 5 keynote presentations. The keynote speakers selected are:

- Boris Chuvashov presenting "Cisuralian (Lower Permian) Series: History, Current Status and Proposed Stage Definitions"
- Brian Glenister presenting, "Guadalupian Series: International Standard for the Middle Permian"
- Jin Yugan presenting "Lopingian Series: International Standard for the Upper Permian"
- Heinz Kozur presenting "Importance of Different Microfaunas for Definition and Correlation of Permian Stage Boundaries"
- John Utting presenting "Palynostratigraphic Correlation and Dating of Marine and Continental Permian Successions". Proceedings of the symposium will be published as a special issue on the Permian System.

Permophiles #37 will contain extended abstracts of all the papers presented at the SPS symposium.

International Subcommission on Stratigraphic Classification of IUGS International Commission on Stratigraphy

INTERNATIONAL STRATIGRAPHIC GUIDE AN ABRIDGED VERSION

Edited by Michael A. Murphy and Amos Salvador
Covered Reprint
Episodes, December 1999
Volume 22, No. 4, pp. 255-271

The second edition of the *International Stratigraphic Guide* (1994) made a significant contribution to international agreement on the principles of stratigraphic classification, terminology, and procedure, and to improve communication and understanding of these principles worldwide.

Despite the wide acceptance and distribution of the second edition of the *Guide*, stratigraphers and students of stratigraphy around the world have reported difficulties in getting access to the full *Guide* mainly for reasons of non-availability or cost. This Abridged Version is an attempt to overcome these difficulties.

The Abridged Version is not a revision of the substance of the *Guide*; all essential tenets of the full second edition concerning stratigraphic classification, terminology, and procedures have been retained. The same organizational framework, to the level of chapters, headings, and subheadings, has been maintained, so that the user can readily refer to the full version of the *Guide* for more complete information.

The principal victims of the abridgement have been some explanatory text, examples of stratigraphic procedures, the Glossary of Stratigraphic Terms, the List of National or Regional Stratigraphic Codes and the extensive Bibliography of Stratigraphic Classification, Terminology, and Procedure.

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