

# *Permophiles*

International Commission on Stratigraphy  
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Close-up views of the GSSPs for the Guadalupian, arrows pointing to GSSP. Top left and right, GSSP for the base of the Guadalupian; Middle, GSSP for the base of the Wordian; bottom left and right, GSSP for the Capitanian. Purple scale is 15 cm. Aluminum tags, clearly visible in both right photos mark sample site with defining conodont FAD.

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# EXECUTIVE NOTES

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## Notes from the SPS Secretary Charles Henderson

### Introduction and thanks

I want to thank those individuals who contributed articles for inclusion in the 38<sup>th</sup> issue of Permophiles and those who assisted in its preparation. Bruce Wardlaw and I did some of the editorial work for this issue during a hectic 3.5 days in Calgary. We thank William MacDonald, Thomas Yancey, Rex Hanger, Brian Glenister, Donald Boyd, Yukio Isozaki, Tetsuo Sugiyama, Prof. Dr. G.H. Bachmann, Yusuihiro Ota, Masatoshi Sone, Dr. Eberhard Sittig, Maria Cristina Perri, Keith Knabe, and Dr. Georges Gand for financial contributions to the Permophiles publication fund in support of this issue. We also thank Sharron Kaser (Department of Geology and Geophysics, University of Calgary) for handling the donations. Continuing publication and mailing of Permophiles requires additional contributions; readers are referred to the last page of this issue. Please remember to specify Canadian or USA dollars (\$25US = \$39Can.). Permophiles is recognized by the ICS as an exceptional newsletter and the support of our readers is necessary to maintain that quality.

### Previous SPS Meetings and Minutes

The subcommission met during the NAPC meeting in Berkeley, California from 5 to 6:30pm on June 27<sup>th</sup>, 2001. There were no changes to the composition of the subcommission. The SPS executive includes SPS Chair (Bruce R. Wardlaw), First Vice-Chair (Ernst Ya. Leven), Second Vice-Chair (Clinton B. Foster), and the Secretary (Charles M. Henderson). The individuals in attendance at this meeting included Bruce Wardlaw, Charles Henderson, Jin Yugan, Diane O'Connor, H. Richard Lane, Shuzhong Shen, Yukio Isozaki, Charles Ross, and Erik Katvala.

Bruce Wardlaw indicated the progress toward GSSP establishment of Permian stages including the ratification of the Middle Permian Guadalupian stages as well as for the top of the Permian (the Permian-Triassic boundary). Yugan Jin provided a slide presentation regarding the Guadalupian-Lopingian boundary that was followed by considerable discussion. It was indicated that a vote on the boundary should follow in the near future. Jin *et al.* provide the status of this proposal within a report elsewhere in this issue. It was also suggested that consensus for the base of the Changhsingian may be possible and Bruce Wardlaw and Charles Henderson were directed to consider this issue during our Permophiles preparation meeting in Calgary. A report by Mei *et al.* can be found in this issue, which outlines our current position on that boundary. Finally, H. Richard Lane (First Vice-Chair of ICS) pointed out that the SPS is a model of how the ICS would like to see progress within the various subcommissions.

### Future SPS Meetings

The next scheduled SPS meetings will be held at Changxing County, China (The International Symposium on the Global Stratotype of the Permian-Triassic Boundary August 10-13, 2001) and in conjunction with the European Conodont Sym-

posium (ECOS VIII) to be held June 22 to June 25, 2002 at Toulouse and Albi, France. The SPS will conduct a business meeting and may conduct a conodont workshop on Permian conodonts at the ECOS meeting. Abstract deadline is December 1, 2001. Please visit the ECOS site for details: [http://www.le.ac.uk/geology/map2/con-nexus/ECOS/ECOS\\_VIII.html](http://www.le.ac.uk/geology/map2/con-nexus/ECOS/ECOS_VIII.html)

### Future Issues of Permophiles

Issue 39 will be finalized in March 2002 and we request that all manuscripts be sent such that Charles Henderson receives them no later than February 18, 2002. Issue 39 will be compiled at the USGS in Reston, Virginia. Please see the attached note regarding the preferred method of manuscript submission and format. Following the format as closely as possible makes our job of preparing Permophiles easier. Bruce and I ask you to **please follow the format (especially for references)**! Although Permophiles is not an official publication it is increasingly referred to in many papers, which means that our reports should be professional and address scientific rather than personal issues. The primary function of Permophiles is for discussion of Permian issues so we are always interested in replies to the various contributions. These must also follow the format as outlined elsewhere.

We invite the Chairs of all SPS working groups to submit reports for the next issue of Permophiles. We also invite final proposals for the establishment of Lopingian GSSP's (see report by Jin Yugan). Our database is missing a number of e-mail addresses so if you haven't written to me recently I would appreciate receiving a very short e-mail after receiving Permophiles 38 so that I can check my records for addresses, phone numbers, and e-mail addresses. Send to [henderson@geo.ucalgary.ca](mailto:henderson@geo.ucalgary.ca).

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## Notes from the SPS Chair

### Bruce Wardlaw

The Subcommission made great progress in marine-continental correlations (see working group report) and on settling the boundary disputes of the Lopingian. We anticipate dedicating the next issue of Permophiles to the formal definitions of both the Lopingian and Changhsingian boundaries. The Subcommission actively supported participation in both the Sienna and Oman meetings (covered in this issue) and will be well represented at the important meeting in Changxing. Please send in suggestions for future meetings that you feel that the subcommission should participate in over the next few years.

## SUBMISSION GUIDELINES FOR ISSUE 39

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 or as CorelDraw or Adobe Illustrator files. Do not include figure captions as part of the image; include the captions as a separate section within the text portion of the document. If only hard copies are sent, these must be camera-ready, i.e., clean copies, ready for publication. Typewritten contributions may be submitted by mail as clean paper copies; these must arrive well ahead of the deadline, as they require greater processing time. Any versions that require translation must also be submitted well ahead of the deadline. All paper versions of articles for Permophiles will be destroyed after the deadline of the subsequent issue, unless a request is made for return.

Please note that 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 2000 PC with Corel Word Perfect 10, Corel Draw 10, Adobe Page Maker 6.5, Adobe Illustrator 9, and Microsoft Office 2000 programs; documents compatible with these specifications will be easiest to work with.

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**SUBMISSION DEADLINE FOR  
ISSUE 39 IS FEBRUARY 18, 2002  
This will be a firm deadline.**

## Report of the Working Group "The Continental Sequences of the Permian"

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Since our last report, the highlights are firstly the field workshop on the late Paleozoic basins in Morocco, organized by the very active French "Association des Géologues du Permien" in cooperation with the universities of Marrakech and Rabat as well as the "Groupe Marocain du Permien et du Trias", and secondly the International Congress on the "Stratigraphic and structural evolution of the Late Carboniferous to Triassic Continental and Marine Successions in Tuscany (Italy); Regional Reports and General Correlation". The latter was optimally organized by the Dipartimento di Scienze della Terra, Siena University, Italy. A summary follows below.

After a general outline by G. Stampfli on the plate tectonics of the Western Tethys, a number of contributions about the Late Paleozoic to Triassic successions and events of Italy, and other European and non-European regions were given. In particular, among the latter, Pascucci & Gibling highlighted that Acadian terrane boundaries and other lineaments were reactivated in Eastern Canada during a compressive tectonic episode, probably during the Permian; rifting associated with the breakup of Pangea commenced in Late Permian to Triassic times, resulting in a suite of extensional basins along the continental margin south of the Maritime Basin. Furthermore, the palynological assemblages recorded in the Sverdrup Basin have been compared by Spina, Cirilli & Baud with those documented in the literature from some independently dated P/T successions in the Boreal Domain and in other territories (e.g. Europe, East China, Pakistan). By this correlation the following results can be stressed: 1) the range of some sporomorphs considered as exclusively Early Triassic forms, among which *Endosporites papillatus*, *L. brevicula*, *D. nejburgii*, must be extended downward to the uppermost Permian, and 2) the bloom and the differentiation of cavate spores in assemblages with acavate

key species occur close to the FAD of *Hindeodus parvus*, that is the newly adopted base of the Triassic.

In Italy, research dealt with Carboniferous to Triassic continental and locally marine deposits. In Southern Tuscany, outcrops were intensively investigated, due to the complicated palaeogeographical and structural framework of the region. Aldinucci emphasized a Carnian transgression in the Verrucano Group of the Monticiano-Roccastrada Ridge, and with other contributors from the Siena and Florence universities also focussed on the lowermost Civitella Formation. On the basis of general research carried out by Spina, Cirilli, Decandia & Lazzarotto, palynological data from the Poggio al Carpino Sandstones in the Monticiano area exhibited *Endosporites papillatus*, *Densoisporites* spp., *Lundbladispota* spp. and other forms, along with marine acritarchs (*Michrystidium* spp. and *Veryhachium* spp.). According to Cirilli *et al.* (2001), the microfloral assemblages show analogies with those found in the Mt. Argentario Sandstones and they are referable to the Late Permian-Early Triassic time interval. This interpretation provides Lazzarotto *et al.* with the basis for an original hypothesis on the significance of the Tuscan Palaeozoic formations within the palaeogeographical framework of the future Western Mediterranean domain during Carboniferous time. The Monticiano-Roccastrada stratigraphical-structural Unit (from Mt. Argentario to Iano village, *i.e.* to the northern extremity of the Mid-Tuscan Ridge), can be further subdivided into two main tectonic slices stacked along a low-angle thrust. The Paleozoic portions of both these subunits, of which the second one crops out only to the east in the Farma torrent and the Montagnola Senese, show remarkable differences, in contrast with the uniform Middle-Upper Triassic part. According to the authors of this presentation, the Paleozoic formations of Southern Tuscany were deposited within an evolving belt-foredeep-foreland system. In the framework of this evolutionary scenario, the southern boundary of Paleozoic contractional deformation would represent the front of the Hercynian belt during Early-Middle Carboniferous time, whereas the Farma flysch could have been deposited in an adjacent, foredeep flexural basin. The Farma, Apuane and Elba areas were also subject to specific investigations by other authors. In Southern Calabria, an exhumation path of a late-Carboniferous granitoid near Stilo was carefully examined by Festa *et al.*

Sardinia was the topic of a detailed sedimentologic and lithostratigraphic analysis of the Late Carboniferous S. Giorgio Basin (Sulcis), and a general revision of the Triassic deposits cropping out on the island (Barca & Costamagna). Cassinis, Cortesogno, Gaggero & Ronchi focussed on the depositional history and the very interesting volcano-tectonic evolution of the Early Permian Seui Basin (Barbagia). Traversa *et al.* emphasized the transition from orogenic calcalkaline to anorogenic alkaline magmatism in the late to post-Hercynian dyke activity of Sardinia-Corsica. Stratigraphical correlations and palaeogeographical reconstructions between the Permian-Triassic continental successions of Northwest Sardinia (Nurra) and Southeast Provence (Toulon-Cuers) have also been depicted by Cassinis, Durand & Ronchi.

In the Southern Alps, Sciunnach points to a short duration marine transgression in the Early Permian continental Collio Basin of western Orobian chain. Rare calcareous foraminifers (Miliolacea) were found in a single sandstone interval that also contained phosphate nodules; the unit underlies by 30 m the angular unconformity between the Collio Formation and the superposed Upper Permian

red beds (Verrucano Lombardo). According to the author, this discovery implies that 1) the late Collio lake was not only an intramontane, as commonly held, but also a coastal lake, and 2) its altitude did not exceed the amplitude of a first-order sea-level rise, *i.e.* about 100 m. After evaluation of the possible source of the aforementioned organisms, the resulting paleogeographic scenario, along with striking similarities as to the tectonic context, accumulation rates and geochemical signatures, suggest that the Orobian Collio Basin was a California-type basin, resembling in particular the present-day Salton Sea. Furthermore, Santi highlighted the finding of tetrapod footprints (*Amphisauropus latus*, *A. imminutus*, *Dromopus lacertoides*, *Batrachichnus salamandroides*, and other forms) in the same basin and also remarked on their affinity with those of the typical Collio Formation in the Brescia area. Stratigraphical-petrographical study of Montecampione subvolcanic bodies, intruded into the Upper Permian-Lower Triassic sedimentary succession of eastern Lombardy and radiometrically dated  $231 \pm 5$  and  $226 \pm 4$  Ma, could be related to a shallow magma chamber that fed a Ladinian-Carnian edifice, as witnessed by some feeding conduits recognized in the field. The authors (Armienti *et al.*) ascribe the alkaline composition of these magmatic injections to rifting, connected to the Triassic lithospheric extension.

Outside Italy, Spanish researchers from the Zaragoza and Pamplona universities provided very interesting data on the Early Permian magmatism of the Iberian Range and the Atienza area (Central System), as well as on the Permian alkaline manifestations of the central Pyrenees. In France, the Permian Lodève Basin, in Languedoc, was highlighted by German and French authors (Körner *et al.* 2001; see also below). Based on the detailed lithological documentation in decimetre scale of the 1,800 m thick succession consisting of pure continental playa deposits as well as extensive geochemical (*e.g.*, Chemical Index of Alteration), mineralogical (clay mineralogy, Oxygen and Carbon isotopes) and paleoecological investigations, the climatic development of this area close to the northern rim of the Tethys has been reconstructed. The most remarkable result of the project is the documentation of a rapid climatic turnover. The measured sections reflect a long period of aridity, suddenly exhibiting characteristics of high precipitation rates in their upper parts. This change in facies is paralleled by the sudden appearance of a very diverse tetrapod track assemblage with captorhinomorphs, edaphosaurs, pelycosaurs, eosuchids, therosaurs and the large footprints of caseomorphs or therapsids. Similar phenomena are known from the Upper Permian post-Illawarra dune sandstones shortly below the Zechstein transgression in Scotland and Germany and also underlying the Bellerophon Transgression in the Upper Permian of the Southern Alps. Therefore, this facial and faunal change could be an effect of Upper Permian transgressions. Isotopic ages of newly discovered pyroclastic horizons are in preparation. Yanev described the Carboniferous stratigraphy, environments and paleogeography of Bulgaria. A general review on widespread tectonomagmatic areas was carried out by Deroin & Bonin. They gave evidence, throughout the late Variscan activity in Europe and surrounding regions, to a Mid-Permian episode (MPE). This is reflected by the magmatics at 270 Ma and is also generally marked in the intracontinental basins by a regional angular unconformity. Basically, the MPE appears as a subdivision of the more prolonged epoch of Hercynian orogeny, namely a part of the late Hercynian tectonics, characterized by minor deformations. In fact, the MPE is the last tectonic

event or pulsation linked to the Variscan orogeny. This tectonic pulsation has been notably illustrated in the Southern Alps, the French Massif Central, Central Europe, the North German Basin, Saar-Nahe and Lorraine, etc. In Africa, the Permian tectonics have been notably recognized in Morocco, the Mauretides, the Bassarides, Niger, Mali, Sudan, etc. Furthermore, the contrasted magmatic episodes (the early, mainly high-K calcalkaline with significant crustal component; the second, alkaline in nature, showing a large-scale distribution) are linked to different settings. The Late Permian to Triassic episode is markedly anorogenic and was related to an incipient rifting regime in Corsica, Estérel, Catalonia and other areas. It heralds the Mesozoic evolution of the Western Mediterranean region and can be considered as the beginning of the Alpine era. A further presentation by Virgili *et al.* on the Permian to Triassic successions and events from selected continental areas of Southwestern Europe showed their sedimentary, magmatic and tectonic evolution. Widespread territories of Italy, France and Spain testify, as in the previous work, to the presence of two cycles, which were connected to a marked geodynamic change of the present Mediterranean area, probably in the frame of a larger-scale evolution. At the Siena conference, four other abstracts were presented. They dealt with the first occurrence of fossil freshwater jellyfishes from the Tambach Sandstone (Rotliegend of Thuringia, Germany, by S. Voigt), the Permian of Caucasus (Sh. Adamia *et al.*) and Australia (J.M. Dickins), as well as the Triassic of Turkey (Göncüoğlu *et al.*).

The contents of these papers, which have not been the subject of oral or poster presentations, can be directly examined in the abstract volume of the meeting, which can be requested from the Dipartimento di Scienze della Terra dell'Università di Siena, Via Laterina 8, 27100 Siena, Italy.

The meeting was followed by interesting field trips, leading to the Late Paleozoic-Triassic sequences of Southern Tuscany (Northern Apennines), the continental Permian-Triassic Series of Provence (Southeast France) and the Carboniferous of the Graissessac basin and the Permian-Triassic deposits of Lodève (Languedoc, South France).

The activity of the WG Chairman (V. Lozovsky) focussed on long distance correlations of the continental Permian (see abstract that follows). The results have been presented during the Siena meeting in the following way. Adoption of the three-fold subdivision for the Permian System involved correlation problems between the stages of Guadalupian-Lopingian series and the traditional Ufimian, Kazanian and Tatarian of European Russia. The Kazanian marine fauna permits direct correlations. Ufimian and Tatarian are represented by redbeds with different continental biota. Conodonts correlate the Kazanian with the Upper Roadian and lowermost Wordian (Kozur *et al.*, 1998); according to T. B. Leonova, this connection is also highlighted by the latest discoveries of the Roadian ammonoids in Upper Kazanian (Esaulova *et al.*, 2001). North American and European sections with interbedded marine and continental facies are very important for world-wide Permian correlations. Tetrapod associations play a primary role. Paleomagnetic data can also be used as an independent and objective control.

Three distinct stages in the evolution of Permian tetrapods ("Edaphosaurid", "Tapinocephalid" and "Dicynodontid" empires of Anderson & Cruickshank, 1978) were defined by Romer (1966) and later specified by Lucas (1998). The records of the first stage

came from the Upper Pennsylvanian to Lower Permian of western USA. Analogous faunas are found in the Rotliegend of Western Europe, the Southern Alps of Italy, and red beds of the Caucasus. Leonardian tetrapod bearing formations of Arizona (Lucas & Heckert, 1995) are overlain by the Guadalupian Kaibab Limestone, including Roadian ammonoids. The Eryopoid supercomplex from Inta Formation (Ufimian) of the Timano-Petchora basin (Ivachnenko *et al.*, 1997) is very similar to the European Early Permian. Therefore the Ufimian-Kazanian boundary corresponds approximately to the Leonardian-Guadalupian boundary (Lozovsky, 1992).

The transition from the first stage to the second is marked by the appearance of therapsids, anomodonts, which co-existed with the persisting pelycosaurids, seymouriamorphs, captorhinids and temnospondil amphibians. East European Kazanian and Lower Tatarian records are the most complete, where five tetrapod faunas, including Mezenian, were distinguished by Ivachnenko *et al.* (1997). Recently, typical forms of the Mezen fauna were discovered in the Chikasha Formation (Guadalupian), in particular *Macroleter*, a form similar to *Mesenosaurus*, but much bigger and more close to caseids as *Ennatosaurus* (written communication of R.R.Reisz, Toronto University, Canada). Thus, the same animals are present in North America and European Russia as well. The Chikasha Formation is correlated with the Wordian. The position of the Illawarra Reversal Megazone near the Capitanian-Wordian boundary (Glenister *et al.*, 1999) demonstrates the plus/minus synchronicity of the tetrapod bearing beds on both continents. The absence of deinocephalian tetrapods in Western Europe can be explained by the break in sedimentation during the post-Variscan movements, well evident in the Southern Alps (Cassinis & Neri, 1999).

The third stage is characterized by widespread herbivorous anomodonts (*Dicynodon*), parareptilian pareiasaurids, carnivorous theriodont gorgonopsoids, and by the first appearance of archosaurids and cynodonts. This fauna characterizes the Upper Tatarian of East Europe, which magnetostratigraphically corresponds to the Illawarra Megazone. A similar ichnofauna is reported from the Val Gardena Formation (Dolomites), where the Pareiasaurs *Pachypes dolomiticus* and Gorgonopsians (Ceoloni *et al.*, 1986) are the most typical forms. The overlying Bellerophon Formation contains a Changhsingian marine fauna. The trackway of a large Pareiasaurian similar to *Pachypes* (Bulanov *et al.*, 2001) was found in the Upper Tatarian of European Russia. Some elements of this fauna are also known from Western Europe. Dicynodontids are unknown in North America.

Thus, during the Permian a broad exchange between the North American and European tetrapod faunas took place. The tetrapod biochronology provides a threefold division of the Permian; however, their boundaries do not correspond with the CisUralian, Guadalupian and Lopingian series. The most distinctive changes occur at the Ufimian-Kazanian boundary, which corresponds approximately to the Leonardian-Guadalupian boundary of North America. The adopted Guadalupian-Lopingian boundary is clearly younger than the Lower-Upper Tatarian one, where the transition between the "Tapinocephalid" and "Dicynodontid" empires and the Illawarra Reversal Megazone are registered.

The activity of German, French and Czech workers is focussed on joint research in the classical Autunian of the French Massif Central. Just now the uppermost Carboniferous/Lower Permian fossil-site of Buxières-les-Mines, Bourbon l'Archambault Basin,

is under investigation (coordinated by J.M. Pouillon and J.W. Schneider). This site provides the opportunity for the calibration of different methods - biostratigraphic dating based on shark teeth, palaeoniscids, amphibians, insects and palynomorphs and the isotopic dating of pyroclastics as well (Steyer *et al.* 2000).

In the course of the DFG (German Research Foundation) project "Evolution of the System Earth" one of the most complete middle/upper Permian profiles in Europe is being studied by German and French colleagues (coordinated by G. Gand and J.W. Schneider) - the unusual fossiliferous continental red beds of the Southern French Lodève Basin (Körner *et al.* 2001 - see there for further references). Conchostracans occur in the whole profile, more than ten orders of insects were found. Preliminary biostratigraphic results (J.W. Schneider, G. Gand, A. Nel, O. Bethoux, J. Lapeyrie, J. Goretzki in progress) point to an Artinskian to Capitanian or ?Changhsingian age for the red beds. The first magnetostratigraphic data (Bachtadse) could indicate the Illawarra reversal in the higher part of the profile.

Supported by the same research project are correlation charts of continental Permian basins that were compiled by J.W. Schneider and M. Roscher. Congresses and meetings during the last years have shown the strong demand for such compilations and the correlation with marine standards. But if compiled by single individuals, these tables often contain errors or fail in the details. Nobody has the overview on the amounts of data produced by local and regional workers. To activate them for cooperation, a www-publication of such charts has been started - see [www.geo.tu-freiberg.de/~schneidj](http://www.geo.tu-freiberg.de/~schneidj) (special topics). Each local section of the interregional chart should be accompanied by comment and more detailed local section (see "special topics", example Saale basin). Every contributor will be indicated as the author of his profile; everybody using this profile(s), should cite the author(s). M. Menning, who is known for his famous calibration of biostratigraphic and isotopic ages of the Carboniferous and Permian, has applied for a DFG-project: Menning and Schneider, Integrative calibration of the Silurian to Permian time scale. One part of this project should focus on the marine/continental correlation of the Permian.

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# REPORTS

## Some Problems and New Achievements in the Long Distance Correlations of the Continental Permian of Pangea

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Adoption of the three-fold subdivision for the Permian System intensifies the problems of correlation between the stages of Guadalupian and Lopingian series with the traditional Ufimian, Kazanian and Tatarian of the European Russia. The marine fauna of the Kazanian allows direct correlations to be made. Ufimian and Tatarian are represented by the redbeds with diverse continental biota. The finding of conodonts date the Kazanian as the Upper Roadian and lowermost Wordian (Kozur *et al.*, 1998), that is a very good co-ordinate with the latest discoveries of the ammonoids. North American and European sections with interbedded marine and continental facies are very important for world-wide Permian correlations. Tetrapod complexes play a primary role. Paleomagnetic data can also be used as an independent and objective control. Three distinctive stages in the evolution of Permian tetrapods ("Edaphosaurid", "Tapinocephalid" and "Dicynodontid" empires of Anderson and Cruickshank, 1978) were first defined by Romer (1966) and then well developed by Lucas (1998). The records of the first stage come from the Upper Pennsylvanian to Lower Permian of the western USA. Analogous faunas are known from Rotliegend of Western Europe, Dolomite Alps and Caucasus. Leonardian tetrapod bearing formations of Arizona (Lucas and Heckert, 1995) are overlain by the Guadalupian Kaibab Limestone. Aquatic Eryopoid supercomplex from Ufimian of Timano-Petchora basin (Ivachnenko *et al.*, 1997) is very close to the European Early Permian. The Ufimian-Kazanian boundary approximately corresponds to the Leonardian-Guadalupian boundary (Lozovsky, 1992). The transition from the first stage to the second is marked by the appearance of therapsids, anomodonts and parareptilians, which coexisted with the holdover pelycosaurids, seymouriamorphs, captorhinids and temnospondil amphibians. East European records from the Kazanian and Lower Tatarian are the more complete, where five tetrapod faunas were distinguished, including the Mezen one (Ivachnenko *et al.*, 1997). Recently the typical forms of the Mezen fauna were discovered in the Guadalupian Chikasha Formation, in particular *Macroleter*, a form like *Mesenosaurus*, but much bigger, and caseids like *Ennatosaurus* (written communication of R.R.Reisz, Canada). So not only are the same animals present in North America as in European Russia, but also similarities in faunal composition support that they are contemporaneous. The Chikasha Formation is correlated with the Wordian. The position of the Illawarra / Reversal Megazones is approximately near the Capitanian-Wordian level (Glenister *et al.*, 1999) and demonstrates the analogy of this paleomagnetic marker in comparison with the tetrapod-bearing beds in both continents. The absence of deinocephalian tetrapods in Western Europe can be explained by the break in sedimentation during the Variscan movements, well proved in Southern Alps (Cassinis and Neri, 1999).

The above mentioned facts of the broad exchange between the North American and European faunas refute the wide-spread opinion about the complete isolation of the North American continent from the European one. The third stage is characterized by the widespread distribution of herbivorous anomodonts (*Dicynodon*), parareptilians Pareiasaurids, carnivorous theriodonts, gorgonopsoids and by the first appearance of archosaurids and cynodonts with some holdover. This fauna characterizes the Upper Tatarian of East Europe, which paleomagnetically corresponds to the Illawarra Megazone. The close composition has the ichnofauna from Val Gardena Formation (Dolomites), where the most typical are the Pareiasaurs *Pachypes dolomiticus* and Gorgonopsians (Ceoloni *et al.*, 1986). The overlying Bellerophon Formation contains the Changhsingian marine fauna. Last year a trackway of large forms, very close to *Pachypes*, was found by Petukhov S.V in the Upper Tatarian of European Russia. Some elements of this fauna are known from Western Europe. There are no the finds of the Dicynodontid fauna in North America.

### Conclusions

During the Permian period broad exchange between the North American and European tetrapod communities took place. The tetrapod biochronology provides a threefold division of the Permian, however their boundaries do not correspond with the CisUralian, Guadalupian and Lopingian series. The more distinctive changes occur at the Ufimian-Kazanian boundary, which approximately corresponds to the Leonardian-Guadalupian of North America. The current Guadalupian-Lopingian boundary is clearly younger than Lower-Upper Tatarian one, where the transition between "Tapinocephalid" and "Dicynodontid" empires and the Illawarra/Reversal Megazone are registered.

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## Oman Pangea Symposium and Field-meeting Report, Muscat, Sultanate of Oman, 7-20 January, 2001

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The preparation of the International Conference on the Geology of Oman organized by the Oman Ministry of Commerce and Industry in cooperation with Sultan Qaboos University and the Mineralogical Institute of Bern University was a unique opportunity for a Pangea Symposium proposal in this part of the world. This was done in 1999 by A. Baud and J. Marcoux and accepted the same year by the Organizing Committee.

With the presentation of new and recent results on Permian and Triassic sediments of Oman, the aim of the Symposium and field-meeting was to provide a forum to geologists who are interested in the Pangean time interval for discussing global changes related to Pangea integration and North Gondwana and Central Tethys evolution. Members of the International Subcommissions on Permian and on Triassic Stratigraphy were invited. Sedimentologists, stratigraphers and paleontologists working within the Permian and Triassic time interval and interested by topics as diverse as biotic crisis, extinction, recovery and evolution across the Paleozoic-Mesozoic transition used the opportunity to discuss, observe and sample the spectacular Permian and Triassic outcrops of Oman's former continental margin, from shallow shelf to deep marine sediments and sea mounds and to participate in the Pangea Symposium.

### Two field excursions were organised before the Conference

The thematic of the *Pre-Conference Excursion No. A01*, from January 8 - 11, 2001, was «Permo-Triassic Deposits, from shallow platform to Basin and Seamounts». It was led by A. Baud, F. Bechennec, L. Krystyn, J. Marcoux, R. Maury and S. Richo. Sixteen participants attended this fieldtrip with great interest and took part in lively discussions on the outcrops.

Firstly, the geology of the belt located in the eastern part of the Arabian Peninsula, the Oman Mountains was introduced. Briefly, 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. Carbonates derived from the platform represented the major source for the thick sequence of slope carbonates deposited near the platform margin. In the more distal areas, basinal and oceanic sedimentation resulted in various types of carbonate, chert and siliciclastic deposits, presently found in the Hawasina Nappe. Middle Permian radiolarites and red ammonoid limestones and Middle Triassic black marls and limestones deposited on lavas (seamounts) are cropping out on both sides of the "autochthonous" tectonic window as blocks of various dimensions, the Oman Exotics. New results on Permian and Triassic magmatism were also presented. Spectacular and recently studied outcrops in Djebel Akhdar, Rustaq, Wadi Wasit, Ba'id, Musjah, Aq Quil, Jebel Kawr and Misfah areas allowed to reconstruct the former geometry of the margin during Late Permian and Triassic times.

The thematic of the *Pre-Conference Excursion No. A02*, from January 7 - 11, 2001 was the Lower to Middle Permian Sedimentation on the Arabian Platform in the Huqf Area (S. Central Oman) and the Jebel Akhdar (Oman Mountains). It was led by L. Angiolini, A. Nicora, J.-P. Platel and J. Roger and attended by 14 participants. This excursion provided the opportunity to see and sample the Peri-Gondwanan Permian succession of the Sultanate of Oman. Against the spectacular background of mountains and desert, different faunal and floral associations and depositional environments from platform to shallow basin were shown.

Starting in the desert of the Oman Interior, the excursion visited 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 fauna studied by L. Angiolini, in addition to bivalve, gastropod, crinoid and bryozoan faunas.

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 transgressive marls and bioclastic limestones of the Khuff Formation containing brachiopods, conodonts, ostracodes, (studied respectively by L. Angiolini, A. Nicora & S. Crasquin), in addition to bivalves, gastropods, cephalopods and trilobites. Only the Wordian part is exposed below the angular unconformity of the Triassic continental Minjur Formation in the studied outcrops.

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 paleogeographic significance, because it comprises associated Gondwanan, Cathaysian and Laurasian floral elements.

Moving to the Oman Mountains, this excursion examined 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 autochthon series. The Saiq Formation consists of conglomerates at the base overlain by bioclastic limestones and reef limestones, which are capped by dolomites. This unit marks the transgression on the newly formed Neotethyan margin. About 400m higher, near the top of the Saiq Formation a group of participants led by A. Baud were looking on the Permian-Triassic boundary in dolomite facies. The other participants went to the key Rustaq outcrop to sample the middle Permian red ammonoid limestones lying on pillow lava and containing abundant *N. siciliensis* conodonts.

### The Conference

Between Jan. 12-16, 2001, the Conference on the Geology of Oman has attracted about 400 scientists from all over the world. As part of the Conference, the 2-day **Pangea Symposium** started on Jan. 14 in which 18 oral communications and 5 posters were presented. Between 50 and 100 scientists followed the Symposium. In their introduction, A. Baud and B. Beauchamp stated the general purposes of the Pangea project and emphasised the international cooperation. The main items of scientific progress are summarized below.

### Stratigraphy and depositional models of the Permian and Triassic sediments in Oman

A series of presentations on new results on the Permian and Triassic stratigraphy and correlations were given by Angiolini, L., Balini, M., Garzanti, E., Nicora, A. and Tintori, A. (The Gondwanan deglaciation in Central Oman: paleontological and sedimentological evidence), Broutin, J., Berthelin, M. and Crasquin-Soleau, S. (The Permian «Gharif paleoflora» and the ostracodes from the Khuff Formation (Huqf area, Sultanate of Oman), Archbold, N. W. (Oman to Western Australia: Correlation of the Peripheral Gondwanan Permian), Bernecker, M. (Second-order cycle development of the Arabian platform and Hawasina seamounts: Permian and Triassic outcrop data from central Oman), Cordey, F., Baud, A., Béchenec, F., Gorican, S. Krystyn, L. and Robin C. (Permian-Triassic deep water sediments of the Wadi Wasit revisited),

Recent isotope studies were presented by Richoz, S., Atudorei, V., Baud, A. and Marcoux, J. (Upper Permian to lower Triassic carbon isotope record: review and new data in the Oman Mountains, from the shallow platform to the basin) and Richoz, S., Baud, A., Marcoux, J. and Cordey, F. (Lower Triassic carbon isotope stratigraphy of the Sumeini slope deposits (Maqam C, NW Oman).

New data on Permian-Triassic boundary were the subject of a talk by Baud, A., Cordey, F., Krystyn, L., Marcoux, J., and Richoz, S. (The Permian-Triassic boundary in Oman, a review) and of a

poster by Krystyn, L., Richoz, S. and Baud, A. (A Unique Permian-Triassic Boundary section from Oman): this is the first discovery of a complete dated Griesbachian coquinite limestone succession in Oman. This facies is unknown in other parts of the Tethys.

### Pangea paleoclimates, stratigraphy, magnetic insight and palynofacies

The first presentation was given by MacDonald, W. and Ellwood, B. on «Magnetic Insights into Permo-Triassic Pangea».

Late Permian cooling followed by a global warming was the subject of Beauchamp, B. and Baud, A. in «Demise of Permian biogenic chert along the margins of NW Pangea, Western Tethys and Gondwana: evidence for paleoceanographic disruption and global warming», and a late Permian warming was presented by Wopfner, H. (Late Palaeozoic to Early Triassic climatic transition between Africa and the Southern Alps).

Stratigraphy of Permian or Triassic sediments was presented by Jin Yugan (Lopingian), Bachmann, G.H., Brueckner-Roehling, S., Exner, M., Kedzierski, J. and Szurlies, M. (Sequence Stratigraphy of the Scythian-Anisian Transgression, Triassic Type Region, Germany), Mandl, G. W. (From Triassic Sea to Cretaceous Orogen - The Austroalpine Sector of the Tethyan Shelf (Eastern Alps, Austria), Kozur, H. W. (Ladinian and Carnian palaeogeography of southern Turkey and its importance for the development of the Triassic Tethyan faunal provinces).

Sedimentology, correlations, paleoecology and palynology of the Permian-Triassic boundary interval were the subject of 4 presentations: -Brookfield, M. (Sedimentology of the Permo-Triassic boundary sections in Kashmir, India), - Twitchett, R. J. (High resolution, global correlation of the Permian-Triassic interval), - Twitchett, R. J. and Looy, C. V. (Rapid and synchronous collapse of end-Permian marine and terrestrial ecosystems), - Spina, A., Cirilli, S and Baud, A. (Palynology of the uppermost Permian - basal Triassic successions in the High Arctic (Canada) and comparison with some PTB Gondwanian localities).

All of the abstracts of the Pangea Symposium are available on the Web at <http://www.geoconfoman.unibe.ch/> and have been published in the last issue of GeoArabia.

The Symposium was followed on Jan. 17 by a 4-day *post-conference Excursion (B01)* on the Permo-Triassic Deposits from Shallow Water to Base of Slope and basin led by A. Baud, F. Bechenec, F. Cordey, J. Marcoux, R. Maury, J. le Metour and S. Richoz.

The Oman Mountains display a segment of the Gondwana 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» succession 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. This was the subject of the first day trip. The Saiq Formation, about 400 m thick, consists of transgressive - regressive cycles of shallow carbonate and lava flows unconformably overlying Precambrian to Ordovician 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. During the second day we examined the basinal and oceanic sedimentation with the middle Permian red ammonoid limestones of Rustaq, and the radiolarites of Buday'ah

also deposited on lavas and cropping out as slices of various dimensions.

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, Middle 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: this was the subject of the third and fourth day excursion.

Thanks to the organizing Committee in Muscat, to the Sultan Qaboos University, to the Oman Ministry of Commerce and Industry and particularly to Dr. Hilal bin Mohammed Al-Azri, Director General of Minerals and to Prof. Peters and his collaborators in Bern. All of them made great effort for the complete success of the Conference and the excursions.

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## Middle Permian Conodonts from Oman

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This paper is to report the joint occurrence of *Mesogondolella aserrata*, the conodont index species of the Wordian Stage, and *Mesogondolella siciliensis* in ammonoid-bearing Wordian rocks of the Rustaq and Wadi Wasit sections, Oman.

In the Sultanate of Oman, the best Neotethyan outcrops of the entire Tethys are present. In the Hawasina nappes good Permian and Triassic outcrops are present, which were visited by the excellently guided excursions A01 and B01 on the very successful International Conference on the Geology of Oman, Pangaea Symposium and Field Meeting, January 2001. B.R. Wardlaw as Chairman of the SPS asked H.W. Kozur as one of the participants to sample the ammonoid-bearing red limestones overlying pillow lava in the sections Rustaq and Wadi Wasit. These sections are Wordian based on a well preserved, rich, Sosio-type ammonoid fauna identified by the top specialists of Guadalupian ammonoids and stratigraphy

Prof. Dr. W.M. Furnish, Prof. Dr. B.F. Glenister and Prof. Dr. W.W. Nassichuk in Blendinger *et al.* (1992), Pillevuit (1993) and Baud *et al.* (2001a,b). Preliminary conodont determinations by Kozur and Krystyn in Blendinger *et al.* (1992) and Baud *et al.* (2001a,b) from the ammonoid horizons yielded mainly *M. siciliensis* as in the famous Rupe del Passo di Burgio block of Sosio Valley, Sicily.

The aim of these investigations was to find in a continuous section, a further anchor point for the conodont correlation of the Wordian Sosio type ammonoid faunas (important for the recognition of the Wordian in the open sea Tethys) with the type Wordian in the Delaware Basin. A second aim was to show, again in a continuous section, well dated as Wordian by ammonoids, the typical Wordian conodont fauna of the Tethyan Conodont Province. The Wordian ammonoid dating of Oman is accepted by all Tethyan workers, not only by the ammonoid specialists, and is based on an up to date ammonoid taxonomy, worked out by three top specialists of the Wordian ammonoid taxonomy and biostratigraphy (see above). This second aim is important because Mei *et al.* (1999a, 1999b) and Mei & Henderson (2001) questioned the Wordian age of the Sosio-type ammonoid fauna which is the best anchor point for correlation of the type Wordian with the Wordian in the huge Tethyan area. They correlated the conodont fauna of the Wordian Sosio type ammonoid fauna of Rupe del Passo di Burgio block in different papers with different Kungurian conodont zones from the base to the top of the Kungurian. Mei & Henderson (2001) even questioned the stratigraphic importance of *Waagenoceras* and regarded this genus as a long-ranging late Kungurian to early Lopingian genus. By the dating of the late Wordian ammonoid fauna of Sosio type and the contemporaneous lower Midian fusulinid fauna from the Rupe del Passo di Burgio stratum typicum of the type species of *Waagenoceras* as lower or upper Kungurian, Mei *et al.* (1999a,b) and Mei & Henderson (2001) did not only reject well established Tethyan Guadalupian biostratigraphic correlations, but also caused Leven (2001) to even question the use of the Guadalupian stages for the Tethys. To provide Mei and Henderson with a well dated Wordian conodont fauna from the Tethyan Conodont Province, the sampling by Kozur from the Wordian ammonoid horizons of the sections Wadi Wasit and Rustaq was duplicated by Dr. B. Beauchamp to make sure that Mei and Henderson got the same samples that we have investigated. The sampling by Kozur and Beauchamp was very much supported in the field by A. Baud, F. Béchennec and J. Marcoux, top specialists of the Permian stratigraphy in Oman. By this, it was guaranteed that the conodont samples were taken exactly from the points from where the Wordian ammonoids had been collected.

Both in the Wadi Wasit and in the Rustaq section, a thick pile of pillow lava with interpillow intercalations of red pelagic limestone, partly with Guadalupian ammonoids is overlain by red pelagic limestones, partly in the facies of ammonitico rosso (Rustaq). The Wordian ammonoids in Blendinger *et al.* (1992), Pillevuit (1993) and Baud *et al.* (2001a,b) were from the lower 3 m of these limestones in the Wadi Wasit section and from two 1 m and 1.1 m thick very ammonoid-rich red limestone separated by 1.10-1.80 m thick dolomite in the Rustaq section. In Wadi Wasit the red ammonoid-bearing limestone is overlain by about 30 m of limestones, at first red micritic siliceous limestone, toward the top increasingly grey limestone intercalations, allodapic limestones and shales. All limestones are strongly siliceous. Then follows 5.2 m thick coarse calcarenites with a 3 m intercalation of red and orange shales con-

taining some thin limestone beds. In the upper 5 m red, there are red, subordinately grey or greenish-grey shales, with thick and thin grey, partly graded cherty limestone banks and chert. This sequence is followed by a breccia (Baud *et al.*, 2001a). One sample with ammonoids was taken by Beauchamp 0.5 m above the pillow lava (sample KW 10A/2001) and given half of the sample to Kozur. Kozur has taken a further sample 0.4 m above the pillow lava (sample KW 10B/2001) and 9 further samples from the ammonoid-free part of the section up to 40.4 m above the pillow lava for investigations outside the scope of the present contribution (samples KW 1-9/2001).

In the Rustaq section, the Wordian ammonoids were found in two thick beds of red pelagic limestones with several layers rich in crinoids (Baud *et al.*, 2001b). Numerous, well preserved Wordian ammonoids were found in several levels of both beds. The 1 m thick lower bed begins about 0.5 m above the pillow lava and consist of red pelagic limestones with numerous ammonoids and crinoids. These two beds were sampled by Kozur and the sample points were marked in the field and a few days later re-sampled in exactly the same sampling points by B. Beauchamp. Sample KR 2/2001 was taken from the base of the lower bed, sample KR1/2001 15 cm higher, sample KR3/2001 from the upper 10 cm below the 1.1-1.8 m thick dolomite intercalation. The upper ammonoid-bearing bed is 1.1 m thick and consists of Hallstatt Limestone. It is subdivided into 4 beds, from which the uppermost one is partly flaser-bedded. Sample KR 4/2001 was taken 0.15 m above the base of the limestone, sample KR 5/2001 at 0.35 m above the base, sample KR 6/2001 at 0.7 m above the base, and sample KR 7/2001 at the top of the upper limestone bed immediately below about 10 m of dolomites.

The samples KW 10A,B/2001 from the Wadi Wasit section contains numerous silicified ostracods (Kozur, in prep.). They consist mainly of shallow-water ostracods, such as sculptured Bairdiidae and Kirkbyidae and ostracods that occur both in shallow- and deep-water, such as smooth Bairdiidae. In addition, palaeopsychrosphaeric deep-water ostracods are never dominating but rather common. Such an ostracod fauna indicates water depth below the storm-wave base around 100 m to shallower than 200 m. Furthermore, they indicate that the area had full connection to nearby cold bottom-water currents. The conodont fauna consists almost exclusively of smooth *Mesogondolella*, mainly *M. siciliensis*, with rarer primitive specimens of *M. omanensis* n. sp., transitional from *M. siciliensis*. *M. omanensis* evolved from *M. siciliensis* and is distinguished from this species by the outline either with subparallel sides (in primitive forms) or distinctly triangular (advanced specimens). *M. aserrata* (*J. aserrata*) is rarely present, and is very smooth. The highest occurrence of smooth *M. aserrata* is in sample KW8/2001, about 34 m above the pillow lava. In the entire interval an open connection to cold bottom-water currents is indicated by the ostracods, and by the conodonts because all *Mesogondolella*, including *M. aserrata*, are basically unserrated.

In the lower part of the lower ammonoid-bearing limestone at Rustaq, the same ostracod fauna is present, but with fewer palaeopsychrosphaeric ostracods. The conodont fauna is the same as in KW 10A,B/2001. Also in KR1/2001 and KR2/2001 all conodonts, including a few *M. aserrata* are smooth. The ostracod fauna with fewer palaeopsychrosphaeric forms indicates a little shallower environment than that at Wadi Wasit, but within the

same depth range as indicated for Wadi Wasit. A distinct change is observed in KR 3/2001, immediately below the dolomite intercalation. There, the same species occur, but *M. aserrata* is not so rare and besides the basically smooth forms, serrated forms are common. In rare specimens, weak serration is even developed in *M. siciliensis* and *M. omanensis*. However, in the lower part of the upper ammonoid-bearing limestone, 15 cm above the dolomite (sample KR4/2001), smooth forms dominate again with only one weakly serrated *M. aserrata*. All other specimens of the rare *M. aserrata*, and of the common *M. siciliensis* and *M. omanensis* are smooth. In sample KR5/2001 all *Mesogondolella* (dominated *M. siciliensis* and *M. omanensis* with very rare *M. aserrata*) are smooth and palaeopsychrosphaeric ostracods re-appear. This indicates a re-opening of the connection to the cold bottom water currents and a correlation between palaeopsychrosphaeric ostracods and completely smooth *Mesogondolellas*. Near the upper thick dolomite, the palaeopsychrosphaeric ostracods disappear again and several specimens of both *M. siciliensis* and *M. omanensis* show faint serration of the anterior platform margin. This feature is especially well developed in sample KR7/2001 immediately below the upper thick dolomite. Thus, two times, typically smooth *Mesogondolella* exhibit faint serration when the open connection to the cold bottom water currents was interrupted. In sample KR6 and 7/2001 *M. siciliensis* is progressively more replaced by *M. omanensis*, which is represented by more and more advanced forms with triangular outline.

In addition to the ammonoids, conodonts and ostracods, reef debris is present in the Wadi Wasit section, and some silicified fusulinids were found in the insoluble residues from Rustaq. Colonial reef corals and numerous sculptured Bairdiidae indicate tropical warm-water conditions. This suggests the presence of reefs (close to Wadi Wasit) and a small carbonate platform (Rustaq) similar to deposition near atolls today.

The above mentioned results show the extraordinary importance of the Rustaq and Wadi Wasit sections for the correlation of the Tethyan stratigraphy and above all for the correlation with the type Wordian in the Delaware Basin which make them to a critical anchor point for the Wordian of the Tethys. The main results are: 1) The Tethyan Wordian key ammonoid fauna of Sosio type in the Wadi Wasit and Rustaq sections contains dominantly smooth *Mesogondolella* (*M. siciliensis*, *M. omanensis*), but this conodont fauna is accompanied by very rare to moderately common *M. aserrata* (*J. aserrata*), the index species of the type Wordian in the Delaware Basin. This confirms also by conodonts the Wordian age of the Sosio-type ammonoid fauna which is accepted by all Tethyan Permian stratigraphers since Miller (1933, Heritsch (1933, 1940) and Kahler (1939).

2) The co-occurrence of *M. siciliensis* and *M. aserrata* confirms by conodonts the Wordian age of the *M. siciliensis* conodont fauna within the Wordian Sosio-type ammonoid fauna.

3) Guadalupian conodont faunas of open sea Tethyan environment with open connection to the cold bottom water currents contain in situ only smooth *Mesogondolella*. Even *M. aserrata* in this environment is typically unserrated. When the open connection to the cold bottom water currents is interrupted, *M. aserrata* displays common serrations and generally smooth forms such as *M. siciliensis* and *M. omanensis* also exhibit faint serrations of the anterior platform.

A very interesting parallel evolution can be observed in the

Phosphoria Basin of western North American and in Oman. In the upper Wordian Retort Phosphatic Shale, *M. phosphoriensis* with a platform widest in or around the middle part, in which triangular forms appear very rare in the upper part of its range changes into parallel-sided to triangular forms of *M. retortensis* n. sp. In Oman *M. siciliensis*, with a platform widest in front or around the middle of the platform changed into the parallel-sided or triangular *M. omanensis*. Both new species are very similar to each other. This suggests that *M. phosphoriensis* and *M. siciliensis* are very closely related to each other.

Mei & Henderson (2001, p.252) suggest that the Oman conodont faunas are transitional between *M. siciliensis* and *J. nankingensis* (based on only three samples collected by Dr. Beauchamp). Our material from Rustaq and Wadi Wasit contains only advanced *M. aserrata* without similarity to *M. nankingensis*. *M. aserrata* of the type which we have found in Oman are also in the Delaware Basin and distinctly younger than *M. nankingensis* and do not occur with *M. nankingensis* or its forerunner. *M. siciliensis* belongs to a different lineage than *M. nankingensis* which retains the carina denticulation and the low blade of *M. idahoensis*, whereas *M. siciliensis* and all species of the *M. siciliensis* lineage up to the Capitanian always have a high, highly fused blade and a different denticulation pattern of the posterior carina. Lambert *et al.* (2000) and Lambert and Wardlaw (1996) have clearly shown that *M. (Jinogondolella) nankingensis* evolved from *M. idahoensis* not *M. siciliensis*. Further, a word of caution, our current investigation suggests that faint serrations can develop in many species of *Mesogondolella* given the proper environmental conditions and the presence of just serration does not indicate the presence of *M. (J.) nankingensis*.

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## Joint American-German research effort: Recent studies of the Capitan Reef (Permian: Guadalupian: Capitanian), Guadalupe Mountains, New Mexico-Texas, USA

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### Introduction

Most of the results from a prolonged (1993-1999) joint American-German paleontology-sedimentology research effort on the taxonomic composition, the relative abundance of taxa, their distribution, and the guild structure of the fossil communities involved in building the reefs in the Upper Capitan Limestone have now

been published. In addition, intrinsic and extrinsic control mechanisms on reef formation have been investigated. The most important results are summarized below.

### I. Taxonomic affinities, diversity, and guild structure

Analysis of large acetate sheet tracings, close-up photos, and polished quadrat surfaces at four localities near the base of the Guadalupe Mountains escarpment indicate that the Upper Capitan Limestone reef was built by 34 species of "calcareous" sponges and demosponges, 9 bryozoans, the richthofeniid brachiopod *Sestropoma cribriferum* Cooper and Grant, 1969, the phylloid alga *Eugonophyllum* sp., 4 *Problematica*, and microbes. Demosponge "sphinctozoans" and inozoid calcareous sponges are major constituents of the Middle Permian upper Capitan Limestone. The fauna appears diverse on local scale, but compared to the diversity of assemblages of similar age in Tunisia and in Southern China, the assemblage is species poor. *Gigantospongia discoforma* Rigby and Senowbari-Daryan 1996, a discoidal inozoid calcareous sponge at least 2.5 m in diameter, is the largest described Permian sponge. In addition to previously described reef-builders of other taxonomic affiliation, *Lercaritubus problematicus* Flügel, Senowbari-Daryan, and Di Stefano, 1990, an organism of unknown affinity, was identified in the Capitan Limestone for the first time. A re-evaluation of the Guild Concept highlights the validity of the functional roles of the Constructor, Binder, and Baffler Guilds for reef construction. Although members of the Baffler Guild are abundant, the lack of baffled sediment suggests that the importance of their role in building the upper Capitan reef needs to be reconsidered. Interpretations of the importance of microbes and cryptic biota remain controversial.

#### Publications:

- Rigby, J.K. and Senowbari-Daryan, B., 1996, *Gigantospongia*, new genus, the largest known Permian sponge, Capitan Limestone, Guadalupe Mountains, New Mexico: *Journal of Paleontology*, v. 70, p. 347-355.
- Senowbari-Daryan, B. and Rigby, J.K., 1996a, First report of *Lercaritubus* in North America, from the Permian Capitan Limestone, Guadalupe Mountains, New Mexico: *Journal of Paleontology*, v. 70, p. 22-26.
- Rigby, J.K., Senowbari-Daryan, B. and Liu, H., 1998, Sponges of the Permian upper Capitan Limestone, Guadalupe Mountains, New Mexico and Texas: *Brigham Young Univ., Geology Studies*, v. 42, p. 19-118.
- Fagerstrom, J.A. and Weidlich, O., 1999, Strengths and weaknesses of the reef guild concept and quantitative data: application to the upper Capitan-Massive community (Permian), Guadalupe Mountains, New Mexico-Texas: *Facies*, v. 40, p. 131-156.

### II. Reef types

Of the 10 reef types known from the Permian, algal/cement reefs and sponge reefs formed most of the upper Capitanian framework. Phylloid algal reefs, brachiopod reefs, and calcimicrobe reefs also contributed to the accretion of the platform rim in different paleoenvironmental settings (Fig. 1).

#### Publications:

- Senowbari-Daryan, B. and Rigby, J.K., 1996, Brachiopod mounds not sponge reefs, Permian Capitan-Tansill Formations,

Guadalupe Mountains, New Mexico: *Journal of Paleontology*, v. 70, p. 697-701.

- Weidlich, O. and Fagerstrom, J.A., 1998, Evolution of the upper Capitan-Massive (Permian), Guadalupe Mountains, New Mexico: *Brigham Young Univ., Geology Studies*, v. 43, p. 167-187.

### III. Reef composition and development

The long-running controversy over the origin of the Upper Capitan Limestone concerns different interpretations of the relative importance of its organic versus inorganic components and whether the organic components were capable of building a reef framework. Our quantitative data from the reef maps indicate a need to reinterpret existing models. The most important constructional element is the micro-framework (76.7% average coverage), a consortium of small, low-growing reefbuilders (especially *Archaeolithoporella hidensis* and *Shamovella obscura*) and botryoidal marine-phreatic cements. In contrast to previous interpretations, neither macro-sponges nor syndepositional cement predominated, making the Upper Capitan Limestone a poor analog for both modern well-skeletonized metazoan and Precambrian cement reefs. Quantitative areal cover data were assessed at various scales. Large acetate sheets generally have low coverage of macrobiota (5.4%). By contrast, analysis of small areas in selected acetate sheet quadrats, sub-vertical photographs, and quadrat samples provide detailed insights into the roles of clustered patches of high areal cover (15-21%) in building the reef framework.

Facies relations determined from outcrop studies and photomosaics have been used in conjunction with reef maps, polished slabs, and microfacies data to better understand the depositional facies, quantitative composition, and control mechanisms of the Upper Capitan Limestone which differs from the outer shelf in its biotic composition and unbedded nature. A three-stage model of the seaward shelf is established comprising (1) a sponge reef/algal cement/phylloid algal stage, (2) a *Shamovella* (*Tubiphytes*) stage, and (3) prograding cyclic outer shelf beds with isolated reefbuilders (Fig. 1). Stage 1 is characterized by progressive shallowing as evidenced by a shift from aggradation to progradation, by changes in boundstone composition, and finally by disintegration of the biogenic framework. Stage 2, dominated by *Shamovella*, bryozoans, microbes and small reefbuilders, exhibits a lateral zonation triggered by the seaward dipping outer shelf. Stage 3 is composed of cyclic outer shelf grainstones; scattered sponges and *Shamovella* microbial level-bottom communities are restricted to few horizons.

#### Publications:

- Fagerstrom, J.A. and Weidlich, O., 1999, Origin of the upper Capitan-Massive Limestone (Permian), Guadalupe Mountains, New Mexico-Texas: Is it a reef? *Geological Society of America Bulletin*, v. 111, p. 159-176.
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### IV. Extrinsic control mechanisms

The entire depositional sequence of the Upper Capitan Limestone is controlled by a third-order sea-level fall as evidenced by

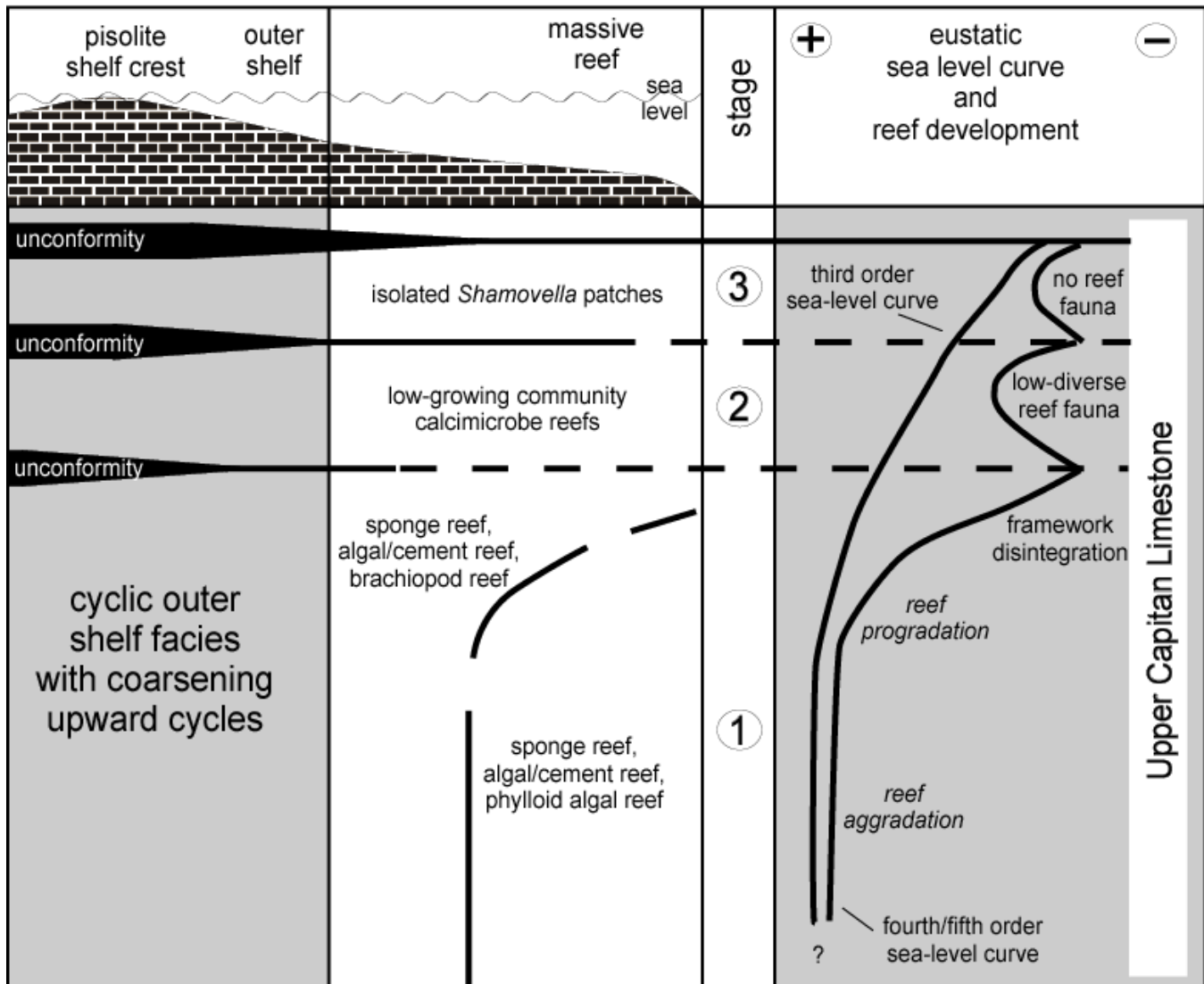


Figure 1. Sequence stratigraphy and evolution of the upper Capitan Limestone based on quantitative field data. exposure horizons. This sequence is in turn superimposed by three high-frequency cycles. Water was only deep enough for typical Permian reef types during stage 1 which produced the thickest depositional unit. Relative water depth decreased significantly during stage 2 leading to a small, tabular reef constructed by an impoverished fauna. During stage 3, water was too shallow for reef communities. In contrast to modern reefs, shallowing beyond a distinct level in subtidal depth limited reef growth. In addition, salinity fluctuations indicated by cyclic cementation caused the demise of the *Shamovella* microbial level-bottom communities.

**Publications:**

Weidlich, O. and Fagerstrom, J.A., 1999, Influence of sea-level changes on development, community structure and quantitative composition of the upper Capitan-Massive (Permian), Guadalupe Mountains, Texas and New Mexico, in Saller, A.H., Harris, P.M., Kirkland, B.L. and Mazzullo, S.J. (eds.), Geologic framework of the Capitan reef: SEPM Special Publication 65, p. 139-160.

**V. Other recent publications**

In addition, the following articles or edited books were addressed to relevant topics of the Capitan Reef during the last years:

Bebout, D. C. and Kerans, C., eds., 1993a, Guide to the Permian Reef Geology Trail, McKittrick Canyon, Guadalupe Mountains National Park, West Texas: Guidebook 26, Bureau of Economic Geology, Austin, Texas.

Harwood, G.M., and Kendall, A.C., 1999, Reef margin collapse, gully formation and filling within the Permian Capitan reef: Carlsbad Caverns, New Mexico, USA: *Sedimentology*, v. 46, p. 443-461.

Kirkland, B.L., Dickson, J.A.D., Wood, R.A., and Land, L.S., 1998, Microbialite and microstratigraphy: encrustations in the middle and upper Capitan Formation, Guadalupe Mountains, Texas and New Mexico, USA: *Journal of Sedimentary Research*, v. 68, p. 956-969.

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## Wang Cheng-yuan and Wang Zhi-hao

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[This paper was very late in coming together. Many inconsistencies probably exist by the way it was edited by Wardlaw. The manuscript was very long for an issue of *Permophiles* and it was severely shortened (again by Wardlaw). Wardlaw takes full blame for these errors and inconsistencies. However, the points of this paper are:

1. The fauna from Rupe del Passo di Burgio is unequivocally Wordian.
2. The misidentification of *M. siciliensis* to beds in West Texas severely jeopardizes age and provincial interpretations.
3. The fauna from Oman (reviewed in a separate paper) clearly shows that the *M. siciliensis* fauna is Wordian
4. The section at Luodian contains reworked material that greatly limits its utility]

The definition of the three Guadalupian stages is based on species of serrated *Mesogondolella* (*Jinogondolella*), which are, unfortunately, strongly facies dependent. They are restricted to warm-water deposits and absent in cool-water deposits of high latitudes, such as in the Boreal Conodont Province, and in the Eastern Gondwana Conodont Province (sensu Kozur, 1995). They are very rare in open sea Tethyan environments, where they are commonly represented by basinal redeposition of shallow upper slope or shelf deposits (Kozur, 1995, 1998). Serrated *Mesogondolella* are also missing from low latitude Panthalassa. Thus, the serrated *Mesogondolella* are common only to low latitude warm-water intraplatform basins which are not connected to the cold bottom-water currents of the open sea, such as the Delaware Basin and the South Chinese intraplatform basins. Serrated *Mesogondolella* invaded the open Tethys sea in a narrow depth interval adjacent to these basins. They are not present in the gondolellid-free shallow-water carbonate platform (widespread in the Tethys) or in water of palaeopsychrosphaeric conditions with cold bottom water which is below 200 m water depth. In greater water depth, the high latitude cool-water conodonts occur within the low latitude Tethys. The narrow depth restriction of the serrated *Mesogondolella* within the open sea Tethys did not allow them to penetrate very far into the open sea Tethys so even the shallow pelagic depth interval is occupied in the western Tethys by smooth *Mesogondolella*. For example, the very rich gondolellid faunas of Roadian, Wordian and Capitanian age at Sosio (Müller, 1956; Bender and Stoppel, 1956; Gullo, 1993; Kozur, 1997) are represented entirely by smooth *Mesogondolella*. Also, Krystyn (pers. comm., 2000) recovered more than 500 specimens of *M. siciliensis* from Rupe del Passo di Burgio and did not find a single specimen of a serrated *Mesogondolella*. The Wordian part of the Sosio Middle Permian is well dated by ammonoids, the Roadian and Capitanian part by radiolarians of these ages and Kubergandinian fusulinids for the Roadian and *Yabeina* fusulinid faunas for the Capitanian in these Guadalupian beds.

During sea-level highstand in the upper Wordian (lower Midian), where *Waagenoceras* ammonoid faunas are common in the entire Tethys and West Texas, the faunal differences between the open sea Tethys and the intraplatform basins decreased prob-

## The Guadalupian smooth *Mesogondolella* faunas and their possible correlations with the international Permian scale

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ably because the water mass exchanges between the open sea with cold bottom water and intraplatform basins with warm bottom water increased. At that time, even in the Delaware Basin and in the South Chinese intraplatform basins, weakly serrated *M. aserrata* (Clark and Behnken) developed. Representatives of this species invaded the open sea Tethys where they are basically smooth (the other features of this species remained unchanged). *M. aserrata* is important for Guadalupian correlations because it seems to be the only serrated *Mesogondolella* to be reasonably widespread and it appears to be very sensitive to water mass. Populations in areas or at times of cold bottom water connections are mostly smooth and populations without cold water influence are mostly serrated (the serrations restricted to the anterior of the platform). In areas or times that *M. aserrata* populations are serrated in the Tethys associated generally unserrated *Mesogondolella* species, such as *M. siciliensis* and its descendant *M. omanensis* n. sp. (will be described by Kozur and Wardlaw in Kozur *et al.*, in prep.) develop faint serrations.

It appears that most Permian and Triassic gondolellid genera with a fully developed platform (*Clarkina*, *Mesogondolella*, *Neogondolella*, *Norigondolella*, *Scythogondolella*) have smooth and serrated representatives. With the exception of *Jinogondolella*, serration has not been regarded as a generic difference, but as a facies-controlled character. *Jinogondolella* (serrated *Mesogondolella*) is a stratigraphic genus that has no real difference from *Mesogondolella* as both *Mesogondolella* and *Jinogondolella* have smooth and serrated representatives, and all other features of the Pa element and the apparatus are identical. If we take only the presence and absence of serration as the taxonomic difference, then the boundary between *Mesogondolella* and *Jinogondolella* runs within several species (*M. aserrata*, *M. gracilis*, *M. siciliensis*, *M. omanensis*, *M. wilcoxi*, *M. bitteri*). For these reasons three of the conodont specialists of this paper (Kozur, Wang Cheng-yuan, Wang Zhi-hao) do not separate serrated forms from unserrated forms at a generic level, whereas the fourth conodont specialist (Wardlaw) continues to use the genus *Jinogondolella* for a species group of mainly serrated forms. For the stratigraphic evaluation of the species these different generic assignments have no importance. However, if the stratigraphic concept for the genus *Jinogondolella* is taken as the controlling factor for stratigraphic correlation and discrimination of conodont faunal provinces without regard to well studied other stratigraphically important groups such as ammonoids, fusulinids and radiolarians, then this has a disastrous impact on the Tethyan Permian stratigraphy and palaeogeography (Mei *et al.*, 1999a,b, Henderson *et al.*, 1999, Henderson and Mei, 2000a, b, Mei and Henderson, 2001). Their application of serration as a generic discriminator seems inconsistent. For instance, in the Great Basin, they recognize that in the *M. bitteri* lineage first serrations appear in the late Wordian and they left the serrated forms (slight serrations in *M. bitteri* and strong serrations in *M. wilcoxi*) in *Mesogondolella*. In the Tethys, however, they regard all first occurrences (not necessarily first appearances) of serrated form as the base of the Roadian in disregard the well established and correlated ammonoid and fusulinid successions, and place underlying beds with the smooth Tethyan Guadalupian *Mesogondolella* into the Kungurian, even if this Kungurian has Wordian or, as in Sicily and Oman, late Wordian aged faunas. This practice has caused Leven (2001) to question the use of the Guadalupian stages

as a world standard. Especially troubling for most Tethyan workers (including all the authors) is the questioning of the Wordian age of the Rupe del Passo di Burgio block in Sosio Valley, Sicily. This small block of massive, light-coloured limestone has the same fauna throughout and all species established from the material not only have the same type locality but also the same stratum typicum. This block within middle Carnian deep-water rocks contains the richest Wordian ammonoid fauna in the world, including the holotype of *Waagenoceras mojsisovicsi*, the type species of *Waagenoceras*, the ammonoid index genus of the Wordian. It has the same stratum typicum as *M. siciliensis*, which has been assigned by Henderson and Mei to the lower Kungurian (Mei *et al.*, 1999a, b, Shi Xiaoying *et al.*, 1999), but now correlated to the upper Kungurian (Henderson and Mei, 2000a, Mei and Henderson, 2001). Both *Waagenoceras* species of Rupe del Passo di Burgio, *W. mojsisovicsi* and *W. stachei*, are advanced *Waagenoceras*, characteristic for the Upper Wordian and this age is also indicated by the lower Midian fusulinid age (Kozur and Davydov, 1996, Leven, 1996). If this fauna is Kungurian, then, of course, also the type Wordian, which also has ammonoids characterised by *Waagenoceras*, should be Kungurian. However, in the type area of the Guadalupian even the forerunner of *Waagenoceras*, *Demarezites*, is Guadalupian (post-Kungurian) in age.

As Kozur was one of the reviewers of Mei and Henderson (2001) he pointed out that the publication of this paper needs a careful consideration of the ammonoid and fusulinid data which basically oppose their age and that Rupe del Passo di Burgio has been considered Guadalupian or Wordian since Heritsch (1933) and Miller (1933). A major part of the problem is the range of *Waagenoceras*. Mei and Henderson (2001) concentrated on *Waagenoceras dieneri*, which is not present in Rupe del Passo di Burgio and came to the conclusion: "The best comparisons for the range of *Waagenoceras dieneri* suggest a correlation in the upper range of *J. nankingensis* (i.e. Upper Roadian), but the species may range down into the Lower Roadian and possibly even upper Kungurian. This suggests that the full range of *M. siciliensis* is Upper Kungurian-Roadian (Upper Kungurian to Lower Roadian at Luodian), not Wordian" (Mei and Henderson, 2001, p. 251). And this needs further discussion. First, Mei and Henderson (2001) point out that according to Kozur the total range of *M. siciliensis* is Wordian. Kozur (e.g., 1995, 1998) gave a range for *M. siciliensis* from (middle) Roadian to upper Wordian. Mei and Henderson point out that Miller (1933) correlated the Sosio ammonoid fauna (which contains not only the upper Wordian of Rupe del Passo di Burgio but also Roadian faunas from other blocks) with the Word Formation. From this they concluded that he correlated the Sosio fauna with an ammonoid fauna from the Upper Kungurian to Wordian because the First Limestone Member of the Word Formation has become the Road Canyon Formation of latest Kungurian and Roadian age. However, the correlation of Miller (1933) was based on the ammonoid fauna described at that time which did not include the ammonoid fauna from the First Limestone Member (Road Canyon Formation), discussed in detail later (e.g., Miller and Furnish, 1957). Heritsch (1940) recognised that the correlation of the Sosio fauna on the basis of ammonoids was made only with the upper Word Formation. Mei and Henderson (2001) wrote that the specimens of *W. dieneri* are identical with those of Rupe del Passo di Burgio. This is a) not the case and b) not only one *Waagenoceras* species was described from Rupe del Passo di

Burgio (see Table 1). Mei and Henderson (2001) discussed then the range of *W. dieneri*. The range of this species is well defined in the Willis Ranch Member (Wardlaw, 1996) which they put in the Road Canyon Formation despite the fact that it is the second member of the Word Formation s.s. (above the China Tank Member of the lower Word Formation). This would be upper Roadian, if the FAD of *M. aserrata* defines the base of the Wordian. This, of course, does not yield a Kungurian age for *M. siciliensis* and, therefore, they quote 4 papers “smaller specimens from the first limestone (Upper Kungurian to Lower Roadian) are probably also *W. dieneri*” (Mei and Henderson, 2001, p. 251). Not one specimen of the cyclobids of the Road Canyon Formation was reported from the Kungurian lower part of the Road Canyon Formation and the forms from the upper Road Canyon Formation does not belong to *Waagenoceras*, but to *Demarezites*, the forerunner of *Waagenoceras* (Spinosa, pers. comm., 1999).

Furnish (1973) from the 4 quoted papers is especially interesting because in this paper both the Roadian and the Wordian were used. There is no word in this paper that small cyclobids of the Road Canyon Formation probably belong to *Waagenoceras dieneri*. In fact, Furnish (1973) did not mention any *Waagenoceras* from the Road Canyon Formation. He mentioned the oldest *Waagenoceras* from the Pipeline Shale of the Guadalupe Mountains. And this rock unit is upper Roadian in age. The taxonomic position of the cyclobids in the Pipeline Shale is disputed. Some belong to *Demarezites*, the Roadian forerunner of *Waagenoceras*. Others are mentioned as *Waagenoceras* n. sp. (Lambert *et al.*, 2000). According to Krystyn (pers. comm., 2001) none of the cyclobids of the Pipeline Shale belong to true *Waagenoceras* as defined in its stratum typicum. Independent from these taxonomic questions, most ammonoid workers agree that the cyclobids of the Pipeline Shale are more primitive than *Waagenoceras* of the Tethys, and regarded them as transition forms between *Demarezites* and *Waagenoceras* (Glenister *et al.*, 1999). Under Wordian Stage, Furnish (1973) wrote: “The best known ammonoid fauna of this age has been found in isolated structural erratics near Rio Sosio, Sicily, where the multitude of species described by Gemmellaro (1888-1889) duplicate the type Word fauna, with some additional forms.” (Furnish, 1973, p. 538).

In the stratigraphic-palaeogeographic concept of Henderson and Mei (2001), in low latitude warm-water environment *Jinogondolella* (in its concept as a stratigraphic genus) totally replaced smooth *Mesogondolella* which continued without *Jinogondolella* in the high latitude cool-water faunas. As the Guadalupian fauna of Sosio is a tropical fauna with many fusulinids, calcareous algae and colonial corals, the *M. siciliensis* fauna with 100 % smooth *Mesogondolella* must be in this concept Lower Permian.

Rupe del Passo di Burgio is one of the anchor points for the correlation of the Guadalupian standard with the fusulinid ages of the Tethys. There, for the first time was shown that the lower Midian corresponds to the upper Wordian (Kozur and Davydov, 1996). Later, this was proven also in Cache Creek Terrane in Canada. The correlation of Rupe del Passo di Burgio with the type Wordian is based on its ammonoid fauna. The lower Midian fusulinid fauna indicate Late Wordian age because the Wordian ammonoid fauna begins in the upper Murgabian which can be, consequently, assigned to the lower Wordian (Leven, 2001).

Rupe del Passo di Burgio (Sosio Valley) with its famous Wordian

ammonoid fauna was the first locality outside the Wordian type area which was put into the Wordian! Heritsch, put it in 1933 in the Word Formation. A few month later, Miller (1933) did the same on the base of new ammonoid studies (see above). And the fusulinid specialist Kahler made the same correlation in 1939. Heritsch (1940) recognised that the ammonoids used for correlation were derived from the upper Word Formation and consequently, he correlated the Sosio ammonoid fauna with the upper Word Formation and therefore definitely for the first time with the Wordian s.s. Subsequently, many other Permian specialists put the ammonoid, fusulinid and other faunas of Rupe del Passo di Burgio into the Wordian or generally into the Guadalupian. Only few names: Miller, Furnish, Glenister for the ammonoids, Grant for the brachiopods, Skinner and Wilde for the fusulinids. Nobody added any evidence for an age older than Wordian! Among all ammonoid workers, the Wordian ammonoid fauna of the Sosio type is a standard term (e.g., Blendinger *et al.*, 1992, Vašíček and Kullmann, 1988). In these papers the Sosio ammonoid fauna of Rupe del Passo di Burgio is assigned also to the Wordian.

In recent years Davydov in Kozur and Davydov (1996) and Leven (1996) established the exact fusulinid age within the Tethyan fusulinid scale and came in both papers to a lower Midian fusulinid age.

On the Guadalupian I Symposium (1991) Kozur pointed out that the conodonts of the open sea Tethys are totally different from the conodonts of the intraplatform basins such as the Delaware Basin and the South Chinese basins, but, can be correlated with the type Guadalupian through joint occurrences with Guadalupian ammonoids or with Tethyan fusulinids which are correlated by ammonoids. Also direct correlation with radiolarians is possible. This view was tested after a joint excursion with Leven and other members of the SPS to the Luodian section in South China. Roadian conodonts (smooth gondolellids, such as *M. saraciniensis*, *M. slovenica* M. n. sp. of the *M. gracilis* group, *Guliodus catalanoi*, and *Hindeodus gulloides*, the latter two species present also in the Roadian of North America) were found exactly in the same level, where Leven (now published in Leven, 2001) determined the base of the Kubergandian with fusulinids. This indicated a coincidence of the base of the Roadian with the base of the Kubergandian which is also indicated by Roadian ammonoids in Tethyan rocks of Kubergandian fusulinid age (Bogoslovskaya *et al.*, 1999, Leven 2001). Wang Zhi-hao (2000) described conodonts across the Cisuralian-Guadalupian boundary. The authors agree with most of his determinations, but the illustrated two specimens of *M. idahoensis* do not belong to this species but include forms from the transition field of *M. idahoensis* to smooth and serrated Guadalupian *Mesogondolella*. For this reason, the *M. idahoensis*-*M. phosphoriensis* A.Z. does not exist, but this short interval with *Mesogondolella* of the *M. phosphoriensis* group but not yet with *M. siciliensis* was also recognised in the studies by Kozur, and assigned to the Roadian (Kozur, 1998). The same level was assigned on the basis of fusulinids to the lower Kubergandian by Leven (2001). A part of this “*M. idahoensis*” belongs to a new species with shorter cusp as in *M. idahoensis* and somewhat higher blade (Wang, 2000, pl. 1, fig. 13). Especially interesting is the form figured by Wang Zhi-hao (2000, pl. 1, fig. 12). It is a transitional form between *M. idahoensis* and *M. nankingensis*. It has a high cusp and low blade, but even in adult forms the anterior platform is slightly

serrated as clearly seen in the illustration by Wang Zhi-hao. Kozur (1998) mentioned these forms from Luodian as transitional forms between *M. idahoensis* and *M. nankingensis*. Exactly the same forms occur in the lower Roadian at the roadcut of US Highway 62-180 in front of the Guadalupe Mountains in the Williams Ranch Member of the Cutoff Formation. In this outcrop numerous Roadian ammonoids with *Paraceltites* are present and also Roadian radiolarians are common in some levels.

A second anchor point was found in the upper Wordian of Oman (Kozur *et al.*, this issue). The correlation of the base of Kubergandian with the base of Roadian convinced finally most of the Tethyan workers to use the Guadalupian stages as world standard and after intensive discussions at the Guadalupian II Symposium, Alpine 1996, also Kotlyar and Leven agreed the use of the Guadalupian stages. This situation changed after the publication of the papers by Mei and others because it questioned the very foundations forged to make an international correlation scheme. Wardlaw strongly disagreed with the assignment of the Wordian *M. siciliensis* fauna of Sosio (Rupe del Passo di Burgio) to the Kungurian because this would make the Wordian a part of the Kungurian (see above) and would make impossible the application of the Guadalupian stages as world standard. He ask Kozur to sample the Wordian ammonoid localities Rustaq and Wadi Wasit (and he and A. Baud, Lausanne, F. Béchenec, Nantes, and J. Marcoux, Paris, very much supported this sampling), from where Wordian ammonoid faunas determined by Furnish, Glenister and Nassichuk were recently described (Blendinger *et al.*, 1992, Pillevuit, 1993). As shown in the following paper, the conodont studies of these localities have shown that the correlations by Mei and Henderson and their consequences for the conodont provincialism are incorrect.

In regards to Luodian, there a special situation is present which is not representative for the Tethys. Already from the literature (Wang Yu-jin *et al.*, 1994) indicates that a pelagic Lower Permian is overlain by pelagic Roadian with the typical Tethyan smooth *Mesogondolella* fauna which is to a large part incorrectly determined. From this level (beginning with Bed 22) Wang Zhi-hao (1994) described *Mesogondolella parasiciliensis* which is a junior synonym of *M. saraciniensis*. This fauna also contains *M. slovenica*, *M. n. sp.* of the *M. gracilis* group (rare) which is also known from the lower Roadian of North America, *Gulldodus catalanoi* which is present in the Roadian and Wordian of Sicily, and *Hindeodus gulloides*, which is also known from the Roadian of its type locality. In Bed 25 at first representatives of the *M. phosphoriensis* group and a little later *M. siciliensis* appears. In the beginning these two species are still accompanied by *M. saraciniensis* which later disappeared. As in the Lower Permian, also in large part of the Roadian the Luodian basin was close to a carbonate platform from which fusulinids were transported into the basin. In the upper Roadian the Luodian basin shallowed to a level, in which only shallow-water conodonts (*Sweetognathus*) occurred and *Mesogondolella* is missing. Still higher, in the upper Murgabian fusulinid faunas (Wordian) several levels with very thick massive breccia appear which indicate strong reworking adjacent to the Luodian section. This is the level, where clearly reworked *M. nankingensis* is found in the Luodian section. In this level and slightly below it, Mei reported *Mesogondolella praenankingensis*. According to Wardlaw, who has seen this form, it is a *Jinogondolella aserrata*. This would agree well with the upper

Murgabian (Wordian) age of this level.

During the excursion, the correlation of Mei was rejected by most participants, both by the Chinese and foreign fusulinid workers (among them Leven) and by the present conodont workers (Kozur and Wardlaw). The photographed specimen of *M. nankingensis* presented at the excursion was a poorly preserved, corroded form that is according to Wardlaw heavily coated with phosphate. Kozur and Wardlaw regarded this form as a reworked form. According to Wardlaw, the pattern of individual crystallite dissolution exhibited on this specimen indicates reaction with fresh water and subaerial exposure. The argument of the fusulinid workers was that the level of the first appearance and range of *M. nankingensis* in the section cannot define the Roadian because this species was reported from the uppermost Murgabian to *Yabeina*-bearing beds of the Midian. *Yabeina* is the only Tethyan fusulinid which occurs in the type Guadalupian within the Capitanian, the base of which is two conodont zones higher than the *M. nankingensis* Zone of the Roadian. All present authors agree with Leven (2001): When the ammonoids show a Roadian age of the Kubergandian and *M. nankingensis* occurs in the Luodian section in the uppermost Murgabian and in *Yabeina*-bearing beds of the Midian, then *M. nankingensis* is there either reworked or it appears in the Tethys so late and ranges so high that it cannot be used for definition of the base of the Roadian and as conodont index species for the entire Roadian. As the reworking is quite obvious by the preservation, we regard *M. nankingensis* is a good guideform which is reworked into much younger beds of upper Wordian to Capitanian age in the Luodian section.

As the lower Roadian (Kubergandian) conodonts of the Luodian section are smooth *Mesogondolella* of the cold bottom-water fauna (Kozur, 1998, Leven 2001), which occur in Sicily together with palaeopsychrosphaeric ostracods without shallow-water ostracods, the water depth must be below 200 m. The adjacent shallow-water shelf with fusulinids was surely not deeper than 50 m. The elevation of the area during the late Roadian brought the former deep-pelagic depositional area in a level, in which only *Sweetognathus*, but no more gondolellids are present. This requires an elevation of at least 200 m and this would bring the former shelf and the adjacent upper slope (the depth interval, where adjacent to the South Chinese intraplateau basins serrated *Mesogondolella* = *Jinogondolella* could have lived in the open sea Tethys) above the sea level. By the subaerial erosion massive breccias were transported into the (in that time shallow) Luodian basin. *M. nankingensis* was transported with this reworked material during the upper Wordian and Capitanian into the Luodian basin. Also the reported *M. aserrata* (not the forms determined as *M. praenankingensis*) must be reworked because they occur exclusively in faunas with Capitanian *Yabeina*. Nowhere in the world *Yabeina* is present before the Capitanian and it is the only Tethyan fusulinid which allow a direct correlation with the type Capitanian because it is present also in the Delaware Basin !

Wardlaw (see this issue) does not recognize *M. siciliensis* in West Texas, and he has worked there for years (please view the figures of *zsuzsannae* in Wardlaw, this issue, which with their high posterior carina are clearly not *siciliensis*!). However, Mei and Henderson created the presence of *M. siciliensis* assuming that *M. zsuzsannae* reported by Wardlaw was a junior synonym of *M. siciliensis* (Mei *et al.*, 1999b, Mei and Henderson, 2001), and by this they recognised automatically in West Texas a lineage of *M.*











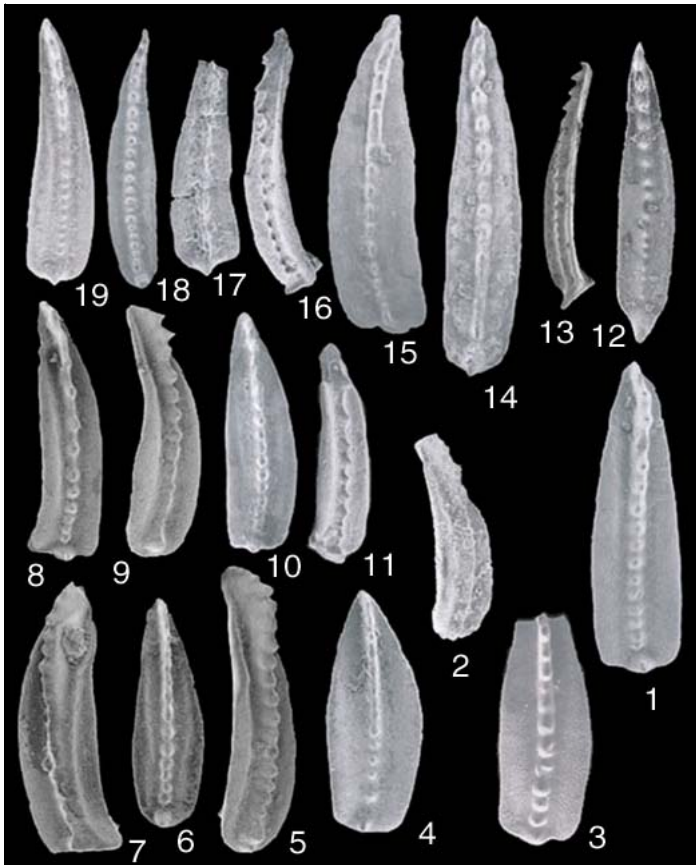


Figure 1. All specimens Pa elements x32.

1. *Mesogondolella intermedia*, from near base, Skinner Ranch Formation, Leonard Mountain, Glass Mountains, Texas.
2. *Mesogondolella gujioensis*, from near base, Skinner Ranch Formation, Leonard Mountain, Glass Mountains, Texas.
3. *Mesogondolella glenisteri*, from middle, Skinner Ranch Formation, Leonard Mountain, Glass Mountains, Texas.
4. *Mesogondolella asiatica*, from middle, Skinner Ranch Formation, Leonard Mountain, Glass Mountains, Texas.
5. *Mesogondolella zszusanna*, from near base Cathedral Mountain Formation, Split Tank, Glass Mountains, Texas
6. *Mesogondolella zszusanna*, from same sample as 5.
7. *Mesogondolella zszusanna*, rare “triangular” morphotype from same sample as 5.
8. *Mesogondolella idahoensis*, rare “triangular” morphotype from middle, Cathedral Mountain Formation, Split Tank, Glass Mountains, Texas.
9. *Mesogondolella idahoensis* from same sample as 8.
10. *Mesogondolella idahoensis* from base, Road Canyon Formation, stratotype, Glass Mountains, Texas.
11. *Mesogondolella idahoensis*, holotype, just below cap rock, Montpelier Canyon, Idaho.
12. *Mesogondolella gracilis*, false cap, Meade Peak Phosphatic Shale, Montpelier Canyon, Idaho.
13. *Mesogondolella gracilis*, from same sample as 12.
14. *Mesogondolella gracilis*, transitional from *gracilis* to *phosphoriensis*, middle silt, Meade Peak Phosphatic Shale, Conda Mine, Idaho.
15. *Mesogondolella phosphoriensis*, large, gerontic specimen, from rich seam, Meade Peak Phosphatic Shale, Conda Mine, Idaho.
16. *Mesogondolella phosphoriensis*, from same sample as 15.
17. *Mesogondolella phosphoriensis*, holotype, upper part, Meade Peak Phosphatic Shale, Paris Canyon, Idaho.
18. *Mesogondolella prolongata*, from near base, Retort Phosphatic Shale, Teton Pass, Wyoming.
19. *Mesogondolella retortensis* (n. sp.) from lower part, Retort Phosphatic Shale, Dalys Spur, Montana.

carina and blade, a rounded posterior platform, and a cusp of circular outline.

*Mesogondolella glenisteri* (fig. 1.3) occurs in the middle part of the Skinner Ranch Formation and is characterized by discrete denticles of relatively equal size, no noticeable gap between cusp and first posterior denticle, a terminal cusp of circular outline and a low fused blade.

*Mesogondolella asiatica* (fig. 1.4) also occurs in the middle part of the Skinner Ranch Formation, has a short range, and is very variable in platform outline, almost always wide, but the widest point is very variable. It is also characterized by a few widely spaced, discrete posterior denticles, a fused blade, and a terminal cusp of circular outline. *M. asiatica* appears to be derived from *M. gujioensis* by a widening of the platform and a reduction in the fusion of the posterior most denticles.

*Mesogondolella zszusanna* (figs 1.5-7) occurs in the upper part of the Skinner Ranch Formation and the lower part of the overlying Cathedral Mountain Formation. It is characterized by a high carina and blade. The cusp is generally terminal, but large specimens may have a small brim. The cusp is relatively small in that the middle denticles of the carina are nearly of equal size. The first few posterior denticles in front of the cusp are slightly reduced and more closely spaced than most of the carinal denticles, large specimens display a partially to mostly fused carina and a fused blade, the posterior platform is generally rounded. I have illustrated the one specimen from a large sample population that exhibits a square posterior platform and overall triangular shape.

Again, this is the one specimen that exhibits this shape from several hundred!

*Mesogondolella idahoensis* (figs 1.8-11) occurs in the middle of the Cathedral Mountain Formation and extends into the base of the Road Canyon Formation. It is common in the lower part of the Meade Peak Phosphatic Shale and rare in the underlying *Neostreptognathodus*-dominated Grandeur Formation in Idaho. Smooth gondolellids end in West Texas with *M. idahoensis*, so we move to the Phosphoria basin and the Meade Peak Phosphatic Shale to continue our examination of the succession of these forms. *M. idahoensis* is characterized by low carina with 3-4 diminutive denticles in front of the large cusp of circular outline that is terminal in all but the largest specimens, which have a small brim, a low blade that is fused anteriorly, and a blunt to slightly rounded posterior platform. Very blunt or squared posterior platforms are common. Figures 1.8 and 1.9 are from near the base of the range of *M. idahoensis*. Here, the apparatus of *M. idahoensis* is clearly distinguishable from that of *M. zszusanna* from beds immediately below. Also, my abundant specimens come from the Split Tank section of the Cathedral Mountain, where the formation is domi-

nated by shelfal carbonates (as opposed to slope and basinal siltstones and mudstones). Both the high-bladed *M. zsuksannae* and low-bladed *M. idahoensis* are from the same facies and do not indicate a difference in water mass (temperature) or province. Figure 1.10 is from the upper part of the range in species from West Texas, as is Figure 1.11, the holotype from the Meade Peak Phosphatic Shale.

*Mesogondolella gracilis* (figs. 1.12-13) is from lower part of the Meade Peak Phosphatic Shale, being most abundant in the false cap (for details of the local mining terms of the Phosphoria refer to Behnken *et al.*, 1986). *M. gracilis* is characterized by a dominating high, large terminal cusp of circular outline and conical shape, the posterior most denticles are miniscule, and in large specimens only faintly recognizable, the platform is narrow and laterally upturned, the blade is only partially fused, and the denticles are commonly mostly discrete. The serrated gondolellid that co-occurs with *M. gracilis* is commonly identified as *Jinogondolella nankingensis* which has a much broader platform, a completely different denticulation pattern of a lower cusp and prominent posterior denticles and clearly represents the marker species of the Roadian at the northern end of its geographic cline. Therefore, *M. gracilis* is Roadian. Its first appearance coincides with that of *J. nankingensis*.

*Mesogondolella gracilis* (transitional to *M. phosphoriensis*) (fig. 1.14) occurs in the middle silt of the Meade Peak Phosphatic Shale and is characterized by a large cusp that is longitudinally elongate, small, but clearly developed posterior denticles that are fused in large specimens, and a blunt posterior platform margin termination.

*Mesogondolella phosphoriensis* (figs. 1.15-17) occurs in the upper part of the Meade Peak Phosphatic shale, with its first appearance in the buckshot phosphorite, and it is very abundant in the rich seam. It co-occurs with *J. nankingensis* and a form I believe to be the predecessor to "*M.*" *bitteri* that appears to be derived from *J. nankingensis* as it has the same denticulation pattern. I illustrate a representative specimen (fig. 1.16), a gerontic, pathologic specimen (fig. 1.15) from the rich seam and the holotype (fig. 1.17) from the upper part of the Meade Peak in Paris Canyon, just a few miles southwest of Montpelier on the northwest side of Bear Lake. *M. phosphoriensis* is characterized by a bluntly rounded to square posterior margin, a generally triangular shape, a prominent longitudinally elongate cusp, prominent carinal denticles that increase in size anteriorly and are discrete to partially fused with low short partially fused denticles on the blade, and indistinct furrows. *M. gracilis*, the transitional morphotype, and *M. phosphoriensis* all have indistinct furrows; whereas, *M. prolongata* and *M. retortensis* (n. sp.) have narrow, but distinct furrows.

*Mesogondolella prolongata* (fig. 1.18) occurs in the lower part of the Retort Phosphatic Shale where it co-occurs with *M. retortensis*. It is characterized by a large, slightly longitudinally elongate cusp, delicate discrete denticles that steadily increase in size anteriorly, short only partially fused denticles on the blade, and a narrow platform. It is most like *M. gracilis* but differs in discrete, closely spaced posterior denticles, a less prominent cusp and a platform that is posteriorly rounded and extends further posteriorly around the cusp so that in large specimens a thin brim is developed and in lateral profile there is commonly a bulge where the brim will develop that is not present in *M. gracilis*. Intermedi-

ate specimens between the stratigraphic interval where *M. gracilis* is common and *M. prolongata* is present are not known at the present time.

*Mesogondolella retortensis* (n.sp., fig. 1.19) occurs in the Retort Phosphatic Shale in Montana and Wyoming and the upper part of the Gerster Limestone in the Leach Mountains, Nevada. At Dalys Spur, Montana, where it occurs in great abundance, it co-occurs with rare specimens of "*M.*" *bitteri* and *Jinogondolella aserrata*. "*M.*" *bitteri* is abundant in more shelfal deposits of the Retort in Wyoming and is common in the upper part of the Gerster Limestone through most of its extent in Nevada and Utah. *M. retortensis* is Wordian. It is characterized by a broad platform that is widest near the posterior and gently narrows anteriorly, a square to bluntly rounded posterior platform and the platform is triangular in overall outline, a prominent longitudinally elongate cusp, a brim in moderate to large specimens, the first four denticles in front of the cusp are small, of variable spacing and size distribution, the remaining carinal denticles increase in size anteriorly, the blade is low, generally short and fused, and the fusion of carinal denticles is variable, commonly more fused on larger specimens. This form differs from *M. rosenkrantzi* from Greenland in having a fused blade (where the Greenland forms have much more discrete anterior denticles) and more consistent bluntly rounded posterior margin.

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## A Global Hiatus in the Middle Permian Tetrapod Fossil Record

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Fossils of tetrapods (amphibians and reptiles) have long been used to correlate regionally Permian nonmarine strata (Lucas, 1998). However, the development of a global Permian tetrapod biostratigraphy and biochronology has been hampered by several problems. The most serious may be the presence of a global gap (hiatus) in part of the Middle Permian record of tetrapods.

It has long been known that the global fossil record of Permian tetrapods has a great geographic discontinuity. Early Permian tetrapod body fossils are known primarily from western North America (Texas, Oklahoma and New Mexico, USA) and Western Europe (principally Germany and the Czech Republic), whereas Middle-Late Permian tetrapods are known primarily from South Africa and Russia. Thus, there is a pronounced geographic shift in the record

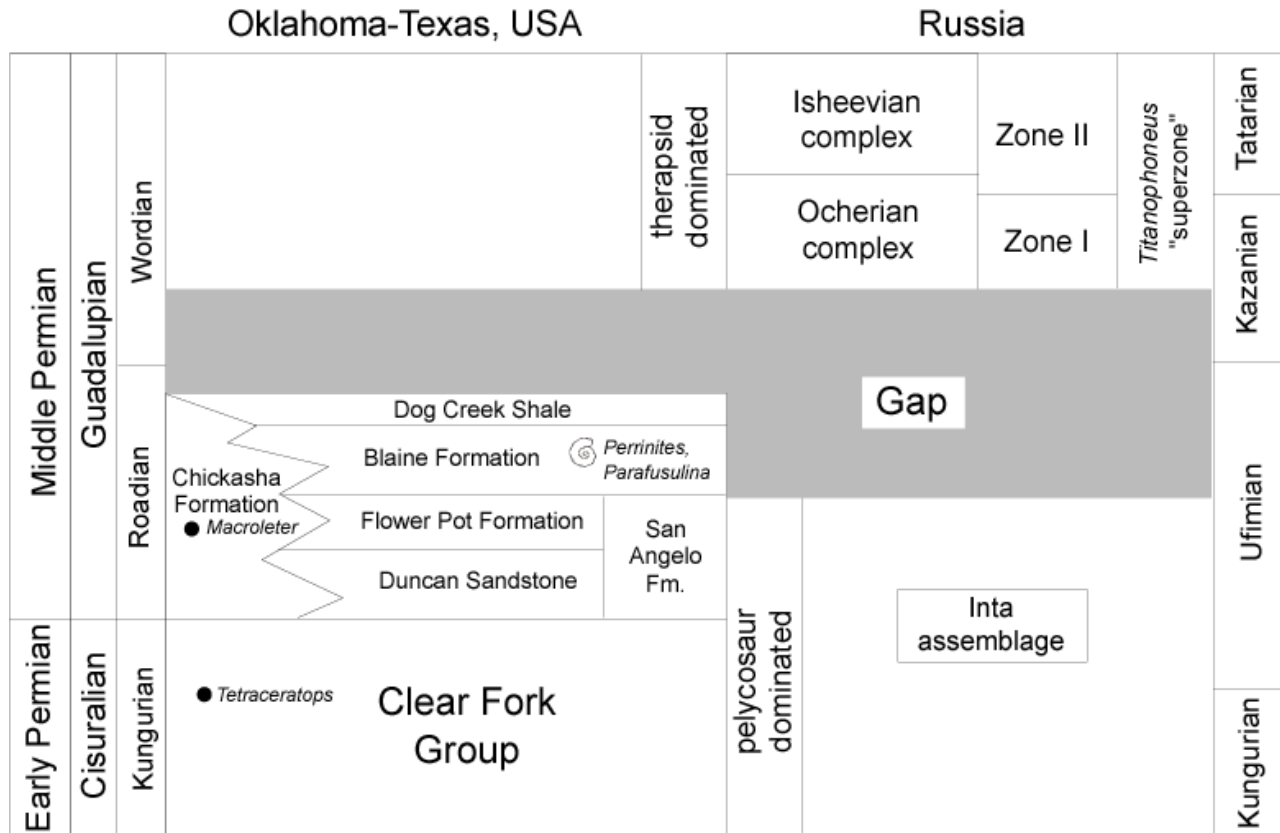


FIGURE 1. Correlation of youngest North American and oldest Russian Permian tetrapod assemblages.

from the youngest Early Permian and earliest Middle Permian tetrapod assemblages in Texas-Oklahoma, USA to the oldest Middle Permian tetrapod assemblages in Russia and South Africa. This shift is accentuated by the fact that the oldest Permian tetrapod assemblages in South Africa and Russia are dominated by therapsids, so they differ significantly from the older, pelycosaur-dominated assemblages of the American Permian. Note also that the oldest South African Permian tetrapods (*Eodicynodon* Assemblage Zone of Rubidge, 1995) are nearly impossible to correlate to the Permian marine timescale. They are about the same age as the oldest Russian therapsid-dominated assemblages, or perhaps slightly older (Rubidge and Hopson, 1990, 1996). Also, the youngest non-Russian European Permian tetrapods are from the upper Rotliegend and thus much older in the Early Permian than the youngest American Permian tetrapods (Lucas, 1998). Therefore, from a practical point of view, a complete record of Permian tetrapods is one that bridges the North American Early-Middle Permian and the Russian Middle-Late Permian records (Fig. 1).

The stratigraphically highest (and youngest) tetrapod assemblages in the American Permian are from the San Angelo, Flowerpot and Chickasha formations of Texas-Oklahoma. Olson and Beerbower (1953) identified therapsids in the San Angelo Formation, so Olson (e.g., 1962; also see Yefremov, 1956 and Olson and Chudinov, 1992) consistently correlated the tetrapod assemblage of the San Angelo and (equivalent) Flowerpot formations with the oldest Russian therapsid-dominated assemblages (Zones I and II of Yefremov, 1937, or *Titanophoneus* "Superzone" of Ivakhnenko et al., 1997). This correlation was not based on shared low-level taxa (genera and species), but on the supposed presence of therapsids in the Texas assemblage and the presence of "counterparts"

(equivalent evolutionary grade) among the Texan and Russian amphibians and caseid pelycosaurs. Recognition that the San Angelo "therapsid" fossils are actually pelycosaurs (e.g., Sidor and Hopson, 1995) undermines this correlation, and suggests that the therapsid-dominated faunas, that are the oldest Permian assemblages in Russia (and South Africa), postdate the youngest North American Permian faunas.

Recent work on the Chickasha Formation assemblage in Oklahoma has identified the "parareptile" *Macroleter*, a characteristic member of the Russian Zone I assemblage (Reisz and Laurin, 2001). Olson (1980) originally published this specimen as *Seymouria agilis* and it is from Blaine County, Oklahoma in strata of the Chickasha Formation laterally equivalent to the Flowerpot Formation. Lozovsky (2001) has recently concluded that the presence of *Macroleter* in the Chickasha Formation, and some evolutionary-grade similarities of Russian and Chickasha caseids, support correlation of the Chickasha to the oldest Russian therapsid-dominated assemblages (also see Reisz and Laurin, 2001).

However, the minimum age of the tetrapod assemblages of the San Angelo, Flowerpot and Chickasha formations is constrained by the age of the overlying Blaine Formation, which has yielded species of ammonoids (*Perrinites*) and fusulinids (*Parafusulina*) that, at their youngest, are Roadian in age (Plummer and Scott, 1937; Dunbar et al., 1960; Jones, 1971; Tharalson, 1984; DiMichele et al., 2001). Some even consider these fossils from the Blaine Formation to be late Leonardian (Kungurian) in age, though the San Angelo Formation has an unconformable base generally correlated to the sequence boundary at the base of the marine Guadalupian (e.g., Ross, 1987). The Blaine Formation overlies the San Angelo and Flowerpot formations and either overlies or is

laterally equivalent to the majority of the Chickasha Formation (e.g., Fay, 1964; Jones, 1971). Indeed, that part of the Chickasha Formation that is above and therefore post-dates the Blaine, lacks identifiable tetrapods (Olson, 1965). Therefore, the Roadian (or late Kungurian) Blaine Formation sets a minimum age on the underlying San Angelo, Flowerpot and Chickasha vertebrates (Fig. 1). These youngest North American Permian tetrapods thus are earliest Guadalupian (Roadian) in age or possibly older (late Kungurian).

The oldest Russian therapsid-dominated assemblage, variously called Zone I (Yefremov, 1937), the Belebey horizon (Lozovsky, 1992), the Ocherian complex (Olson, 1957, 1962) or the Mezen complex (Ivakhnenko *et al.*, 1997), is of late Kazanian age (e.g., Lozovsky, 1992). The beginning of Roadian time is generally correlated to a horizon within the Russian Ufimian (between the Solikamsk and Sheshma horizons); and, the Kazanian is correlated to at least part of the Wordian (e.g., Ross and Ross, 1988; Kotlyar, 1999, 2000). This means that the upper Kazanian Zone I assemblage is much younger than the youngest North American Permian tetrapods (Fig. 1). The hiatus between them is equivalent to at least part of Roadian-Wordian (Ufimian-Kazanian) time. It is difficult to calibrate this gap numerically, but most numerical timescales suggest it is a few million years.

In Russia, there is a tetrapod assemblage older than Zone I. This is the Inta River assemblage, dominated by endemic archegosaurs, originally described by Konzhuskova (1953) and assigned by her to the Early Permian. Later workers (Gubin, 1984, 1986; Lozovsky, 1992; Olson and Chudinov, 1992; Ivakhnenko *et al.*, 1997) assigned it to an Ufimian age. Nevertheless, there is no evidence that the Inta assemblage fills part of the gap. Indeed, all data suggest it is no younger than the San Angelo-Flowerpot-Chickasha assemblages and, indeed, the Inta assemblage may even be older (Fig. 1).

As noted above, this global gap in the Permian tetrapod record is marked by a dramatic turnover in the Permian tetrapod fauna, from pelycosaur dominated to therapsid dominated. A few antecedents of the therapsid-dominated assemblages of the Middle-Late Permian are known from the Texas Permian. They include the Chickasha record of *Macroleter* already discussed, and the Leonardian (Kungurian) record of *Tetraceratops*, possibly the oldest therapsid (Laurin and Reisz, 1996). Nevertheless, there remains a crucial hiatus in the Middle Permian tetrapod record during which a major evolutionary turnover took place, one for which a fossil record remains to be discovered.

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- abrupt change from *J. granti* to *C. postbitteri* is indicative of an unconformity and that the breccia could support this.”
- Mei *et al.* (1998) also described: “... debris flow deposits occur less frequently in the Penglitan section. The Maokou Formation comprises mainly thin-bedded cherty wackestone, diagenetic chert, carbonate turbidite and debris flow deposits”. Mei *et al.* (1998) also show in Text-figure 3 that cross bedding and crinoid debris are present in the uppermost Maokou Formation. It is thus noteworthy that there is breccia, debris, and cross bedding in the uppermost part of the Maokou Formation.
- Henderson stated (Jin, 2000b) “I agree with you (=Jin) 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.”
- It is thus clear that:
- Both Jin and Henderson are convinced that there is a diastem between lower and upper 6i. What is a diastem? A diastem is a gap at a bedding plane or in other words, a bedding plane caused by a small gap. Only some marine bedding planes are connected with a gap, mostly the bedding planes simply indicate changes in physical condition as supply of finer or coarser material. Not every bedding plane is a diastem.
  - This boundary is a sequence boundary, and could be viewed as the beginning of a new sequence (Text-fig.1).
  - Henderson does not believe that there is any one correlative conformable surface, but rather an interval.
- Mei, Jin and Henderson have supported the boundary between lower and upper 6i as a GSSP for the base of the Lopingian. The definition of such a GSSP boundary at a small gap or diastem is at variance with the International Stratigraphic Guide “The boundary-stratotype of a stage should be within a sequence of continuous deposition” (Hedberg,1976) and also with the International Commission on Stratigraphy’s guidelines for the establishment of GSSPs (Remane *et al.*, 1996).

## Re-discussion of the Base of the Lopingian Series

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This paper presents a discussion on proposals for definition of the base Lopingian GSSP which also has implications relating to the main principles for the establishment of GSSPs in general. The following two points are noteworthy.

#### 1. A gap and/or diastem (small gap at a bending plane) is present between beds 6i lower and upper.

I may conclude from the following descriptions made by previous authors that there is a small gap or diastem (small gap at the bedding plane) between beds 6i lower and upper, even if this is not regarded as an unconformity.

Henderson (Jin, 2000b) wrote “It could be argued that the

#### 2. What is necessary for the establishment of a GSSP: supposed punctuated evolution or concrete evolutionary lineage?

Henderson (2000) pointed out “there are many philosophical and taxonomic issues that need to be considered before a final consensus on the Guadalupian-Lopingian boundary can be reached. One of these issues involves how the nature of evolutionary mode and tempo affect our taxonomic concepts. If one argues that conodont species only arise by phyletic gradualism, then it is clear it would be difficult to imagine *Jinogondolella granti* as the ancestor to *C. postbitteri* as Wang and Kozur suggest. However, if punctuated evolutionary events are considered, then the ancestor relationship of these two taxa become more probable since very different morphologies would be expected. The clarity of such a rapid event would make an ideal boundary position for a GSSP. This point occurs at the boundary between lower bed 6i and upper bed 6i.”

With regard to these points of view I wish to point out the

following.

1. It is not clear what morphological changes in a single form element (Pa) of a conodont has to do with the evolution of the conodont animal; these changes could reflect different species, genera or suprageneric taxa.
2. Kozur has investigated numerous phylomorphogenetic lineages, mostly among ostracodes (real phylomorphogenetic lineages). However, Kozur accepted punctuated evolution, but only if proven by overlapping ranges of the forerunner and successor. He also argued for phyletic gradualism and pointed out that phylomorphogenetic gradualism with minor evolutionary steps occurred in most lineages, in which one species evolved from an ancestral species. He also recognized "punctuated events", when in a geologically short time taxonomically high rank changes occurred. In these cases several taxa are often derived from one taxon. However, in all cases of such "punctuated evolution" in continuous sequences, the newly evolved taxon does not begin after the ancestor disappeared, but occurs in a certain interval together with its forerunner.
3. Unproven assumptions about a punctuated evolutionary event have not been used for the establishment of a GSSP before. What is reiterated in the International Stratigraphic Guide is that the boundary stratotype should be within a continuous depositional sequence and within a clear phylogenetic lineage. Unproven assumptions about a possible punctuated evolutionary event means that there is no morphological evidence for the relationship of the species discussed.
4. As mentioned above, there is a diastem or small gap between lower and upper 6i. It is not a punctuated evolutionary event, but a faunal break.
5. A GSSP cannot be established at a point based on supposed punctuated evolution without any evolutionary evidence.
6. Stratigraphically, "*Jinogondolella*" *granti* and *Clarkina postbitteri* are very close, but morphologically they are very different, and no evidence has been presented which could verify that "*Jinogondolella*" *granti* is the forerunner of *C. postbitteri* or that this is a punctuated evolutionary event. These are two stratigraphic species.
7. This boundary is not an ideal boundary position for a GSSP. The level chosen by Henderson is a sequence boundary and a very good reference criterion for the base of the Lopingian.

### Summary of Agreements and Disagreements

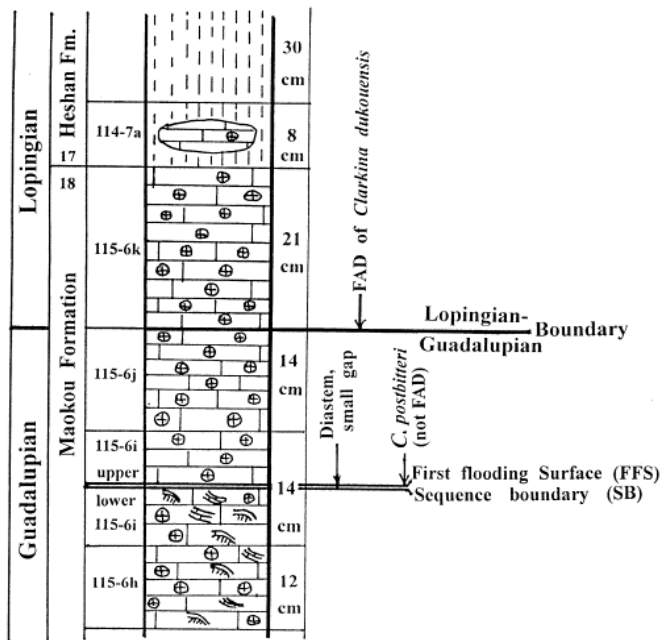
#### Agreements

- 1) Individuals involved with this boundary study agree that the GSSP for the Guadalupian-Lopingian boundary should be at the Penglaitan section in South China. Only Kozur (pers.comm., 2000) has the opinion that Penglaitan section should be replaced by another candidate section for GSSP, if in another section a phylomorphogenetic cline can be found which includes the forerunner of *C. postbitteri* until advanced *C. postbitteri*.
- 2) Individuals involved with this boundary study agree that *C. postbitteri* is the ancestor of *C. dukouensis*. The ancestor of *C. postbitteri* is still not agreed upon, and even where somebody strongly supports *C. postbitteri* as a definer, consensus has not been reached regarding concrete evidence for its ancestor. *Clarkina postbitteri* was not derived from "*Jinogondolella*" (= *Mesogondolella*) *granti*

- or "*Jinogondolella*" *xuanhanensis*. The so-called evolutionary lineage from "*Jinogondolella*" *xuanhanensis* to *Clarkina postbitteri* proposed by Jin (2000a) cannot be demonstrated at the Penglaitan section.
- 3) Individuals involved with this boundary study agree that there is a diastem between lower and upper 6i (Jin, 2000b, Henderson, 2000), that it is a sequence boundary (Henderson, 2000; Wang, 2000), that it is also a first flooding surface (FFS, Wang, 2000b), and an important reference criterion for the base of the Lopingian.
- 4) The Base of 115-6j that Jin proposed as the point of GSSP of the Lopingian is not the FAD of *C. postbitteri*. This point should be abandoned.
- 5) The morphologic differences between "*Jinogondolella*" *granti* and *Clarkina postbitteri* are clear, but there is no consensus regarding morphological evidence to verify that the latter is derived from the former.
- 6) The FAD of *C. dukouensis* appears in a continuous section. It is the first widespread biozone just above the first flooding surface of the sequence (Text-fig.1).
- 7) *C. dukouensis* is more widespread than *C. postbitteri*.

#### Disagreements

- 1) The differences between "*Jinogondolella*" *granti* and *Clarkina postbitteri* are due to punctuated evolution or they morphologically have no evolutionary relationships, only two stratigraphic species named by related authors. What caused the differences for these two species: assumed unproven punctuated evolution or diastem or faunal break?
- 2) As a definition species, it must have a clear origin and ancestor, which can be verified by morphological variation, or only a hypothesis of punctuated evolution without concrete morphological evidence.
- 3) Can a GSSP be defined at a diastem (a small gap) or not.
- 4) Individuals involved with this boundary do not agree whether the first occurrence of *C. postbitteri* at Penglaitan is a true FAD or not. The supporters for the true FAD cannot propose concrete evidence except the hypothesis of the punctuated evolution (Henderson, 2000, Jin, 2000b), but supporters for the immigration of *C. postbitteri* to the Penglaitan section with deepening of the sea have proposed concrete evidence (Wang, 2000a, Kozur, 1998, 2000). According to Kozur (pers.comm., 2000) the Guadalupian gondolellid fauna of the intraplatform basin in China and in USA (Delaware Basin) totally disappeared during the short but big regression at the end of the Guadalupian. The Lopingian fauna evolved from open-sea faunas, which are represented by smooth *Mesogondolella* faunas from the Roadian up to the top of the Capitanian. The youngest representative of the open sea smooth *Mesogondolella* (*Mesogondolella* n.sp. Kozur) from the uppermost Capitanian of Sicily is morphologically very similar to *C. postbitteri*.
- 5) Individuals involved with this boundary do not agree as to the exact point for the base of Lopingian GSSP at the Penglaitan section, which is caused by the different definitions, taxonomy, and principles for defining a GSSP.
- 6) According to Kozur (pers. comm., 2000) the FAD of *C. postbitteri* would be a very good base of the Lopingian, if



Text-fig. 1. Sequence boundary and biostratigraphic boundary at the Penglaitan section. The present author prefers to draw the Guadalupian—Lopingian boundary at the base of Bed 115-6k, 21 cm higher than the sequence boundary (SB) or first flooding surface (FFS).

a phylomorphogenetic lineage from its ancestor to the advanced forms of South China could be proven in one continuous section. In agreement with the present author, according to Kozur the base of the Lopingian cannot be defined by the first occurrence of *C. postbitteri* in the Penglaitan section because this first occurrence cannot be proven as FAD of *C. postbitteri*. The immediately underlying beds are shallow-water limestones without or only with few broken, probably reworked gondolellid pieces. The conodont fauna below this shallow-water limestone contains the *Mesogondolella* (= "*Jinogondolella*") *granti* fauna of a restricted intraplatform basin which is morphologically unrelated to the *C. postbitteri* fauna. As the *C. postbitteri* lineage is an open sea lineage, a derivation of the restricted basin serrated *Mesogondolella* is not probable. Therefore a continuous open-sea Guadalupian-Lopingian boundary section with smooth *Mesogondolella* in the upper Guadalupian (e.g., in Oman) should be investigated. The Tethyan open sea smooth *Mesogondolella* n. sp. from the uppermost Capitanian of Sicily is morphologically much closer to *C. postbitteri* than any of the restricted basin serrated "*Mesogondolella*" of the uppermost Capitanian in Penglaitan. If *Mesogondolella* n. sp. or *C. crofti* can be proven as the forerunner of the advanced South China type, *C. postbitteri* in an open-sea continuous Guadalupian-Lopingian boundary section of Tethys without pronounced facies change then the FAD of *C. postbitteri* can be used for definition of the base of the Lopingian, but not in the Penglaitan section.

## Conclusions

A GSSP cannot be defined at a diastem or a small gap, it must be within continuous deposits without very pronounced facies changes. The boundary between lower and upper 6i is a diastem and may indicate a short gap. It is a good sequence boundary, but it is not a true biostratigraphic boundary proper at which a phylomorphogenetic cline can be observed. Defining species should have a clear origin or ancestor. As *C. postbitteri* starts with advanced forms without a recognizable ancestor in this section, the ancestor of *Clarkina postbitteri* is not clear, and therefore, this species is not suitable to be a definer. *Clarkina dukouensis* is clearly derived from *Clarkina postbitteri*, its FAD being within continuous deposits. *Clarkina dukouensis* is completely suitable to be a definer for the base of the Lopingian, 21cm higher than the sequence boundary or the first flooding surface within continuous deposits (Text-fig.1). Wang & Su (2000) have pointed out that the first flooding surface (FFS) or sequence boundary (SB) in shallow marine facies should be regarded as an important reference criterion for the selection of a GSSP, and the GSSP should be taken at a point coincident with the base of the first widespread biozone just above the first flooding surface (FFS) of the sequence.

We have to consider the population characters of the definer at its FAD timespan. Wang (2000b, in Permophiles 37) has listed four characters for the earliest population of the definer.

The establishment of the GSSP should be based on detailed taxonomic work with a reliable evolutionary lineage, but not on the supposed unproven punctuated events without concrete morphological evidence.

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Permian Subcommittee in 1999. However, a vote for this boundary was withheld because dissension arose at the last minute. The primary disagreement centred on whether *Clarkina postbitteri* originated from *Jinogondolella granti* in a continual depositional succession in South China or from *Jinogondolella crofti* in Texas and then migrated to South China after the marine basin of SW USA dried up. In addition, Wang CY (1999) indicated that he found *Clarkina postbitteri* in a bed about 3m below Bed 6j at the Penglaitan Section and suggested the FAD of *Clarkina dukouensis*, at the base of Bed 6k, as a potential stratotype point. This dissension pushed the conodont experts away from a compromise solution back to a dispute as to whether to accept the base of the *Clarkina postbitteri* Zone or the base of the *C. dukouensis* Zone as the Guadalupian-Lopingian boundary (GLB); a dilemma we have intensively discussed previously (Jin *et al.*, 1993, 1994, 1996, 1998).

Prior to the ICCP meeting in Calgary in August 1999, a general agreement on the GSSP for the basal boundary of the Lopingian Series had been reached at the origination of *Clarkina postbitteri* and appeared finally in publication (Wang *et al.*, 1998, Mei *et al.*, 1998). Relevant experts were quite aware that most evolutionary appearances are a matter of conceptual interpretation that need constant reevaluation. The hypothesis that *C. postbitteri* originated in the USA, migrated to the Paleotethys and became a dominant group is interesting, but an alternative interpretation has also been advanced, namely that *C. postbitteri* evolved from *Jinogondolella granti* in the South China part of the Paleotethys. Moreover, most colleagues share the opinion of Glenister (2000): that “Irrespective of where the GSSP is placed within this interval, it (the Penglaitan Section) will be fully functional, and this will remain one of the most intensely studied sections in the world”. Two years of lengthy discussion (Wang CY, 1999, 2000; Jin, 2000a) and particularly an independent test of the samples with disputed conodonts (Henderson in Jin, 2000b, 2001) brought out a consensus that “the GSSP for the G/L boundary should be defined by either the FAD of *Clarkina postbitteri* at the upper part of Bed 6i, or at an arbitrary point within the lineage from *Clarkina postbitteri* to undisputed *C. dukouensis* at the Penglaitan Section”. The FAD of *Clarkina postbitteri* reported by Wang CY (1999) from Bed 4f could not be replicated. In addition, the specimens reported by Wang CY (1999) as *Clarkina dukouensis* from Bed 6k are now recognized as a subspecies of *Clarkina postbitteri*. As a consequence, the focus was narrowed down to the documentation of the ancestry of *Clarkina postbitteri* and of the lineage from *Clarkina postbitteri* to undisputed *C. dukouensis* (Henderson *et al.*, 2000). Based on new samples collected by Dr. Jin and a cooperative effort by Drs. Henderson, Mei and Wardlaw, a report on this subject is now presented in this issue, which enables us to put forward the proposal that follows. We trust that most members of the Permian Subcommittee are rather open to accommodate a final decision. Let’s reach an early agreement on the GSSP for the Guadalupian-Lopingian boundary so that we can then progress to a more collaborative scientific focus!

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## A Commentary on the proposal for the GSSP for the Guadalupian/Lopingian Boundary

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A proposal to establish the GSSP for the basal boundary of the Lopingian Series at the first occurrence of *Clarkina postbitteri* in Bed 6j at the Penglaitan Section (Bed 6j and 6i upper of present usage) was described by the Chairman in the annual report of the



**PROPOSAL FOR THE GLOBAL STRATOTYPE SECTION AND POINT (GSSP) FOR THE GUADALUPIAN-LOPINGIAN BOUNDARY**

**1. Introduction**

In the new edition of the International Stratigraphic Chart recommended by the International Commission on Stratigraphy (Remane, 2000) the Lopingian Series is referred as a semiformal global standard chronostratigraphic unit for the youngest series of the Permian System. This series and its component stages, the Wuchiapingian and Changhsingian stages can be precisely defined by biostratigraphic, sequence stratigraphic, and magnetostratigraphic subdivisions as well as isotopic age. As a decision of the Subcommittee, the Guadalupian - Lopingian boundary or Capitanian - Wuchiapingian boundary has been informally defined at the base of the *Clarkina postbitteri* Zone and that of the Changhsingian Stage, at the base of the *Clarkina subcarinata* Zone.

The boundary between the Guadalupian and Lopingian Series was historically designed to coincide with a global regression, that is, the boundary surface between the Middle and the Upper Absaroka Megasequences. It has been documented as a level coincident with an important mass extinction event. Consequently, this boundary should be precisely delineated within a conformable sequence and it also offers advantages for international correlation and in practical field geology.

Extensive surveys on marine sections over the past few decades prove that only a few sections can be considered to be continuous across the Guadalupian - Lopingian boundary. Those with complete succession of pelagic faunas are particularly rare. Guadalupian - Lopingian boundary successions were reported from Abadeh and Jolfa in Central Iran, S.W. USA, and the Salt Range. The section of the Laibin Syncline in Guangxi Province, China is unique among these sections in that it contains a complete and inter-regionally correlatable succession of pelagic conodont zones and other diverse, and inter-regionally correlatable Permian fossils. Here we formally propose to establish the Global Stratotype Section and Point (GSSP) for the basal boundary of the Lopingian Series at the first occurrence of *Clarkina postbitteri postbitteri* Mei and Wardlaw in Bed 6k of the Penglaitan Section, and to refer the Tieqiao (Rail-Bridge) Section on the western slope of the syncline as a secondary reference section.

**2. Location of type section**

The county town of Laibin is midway between Guilin, one of the major tourist cities in China, and Nanning, the provincial capital of Guangxi Province, and takes about two hours to reach it from these two major cities. The completeness of the sequence, excellent exposure, and easy accessibility of the Laibin sections have attracted many visitors from foreign countries since Dr. Richard Grant visited the Permian sections in 1980.

This county has been officially approved by state government as an "OPEN AREA", which is legally free for foreign visitors to access. However, visitors who wish to collect samples from the proposed stratotype are required to obtain permission and assistance from the Bureau of Nature Resources in this county's government, since the GSSP would be under the permanent protection of this bureau as soon as it is ratified.

Structurally, these sections are located on the eastern slope of the Laibin Syncline. Penglaitan is the name of a rocky islet of the Hongshui River, some 20km east to Laibin. The Penglaitan Section of the Maokouan-Lopingian strata was measured along the southern bank of the Hongshui River nearby this rocky islet. The Tieqiao (Rail Bridge) Section on the western slope of the syncline is situated on the northern bank of the Hongshui River, 2 km south of the county town of Laibin.

**Description of type section**

Permian rocks are extensively exposed along the banks of the Hongshui (Red-water) River, and have not suffered any substantial structural disturbance. The Chihhsia Formation contains ikaite, which may indicate the invasion of cold currents or it may result from low salinity. The Maokou Formation of the Guadalupian reaches 302m in thickness. Member IV (Beds 115-118) consists of interbedded radiolarian chert and cherty lime mudstone and sandstone, 133m thick; Member V or the Laibin Limestone (Bed 118), 10m in thickness, is composed of massive limey sandstone and siltstone of distal tempestite facies. The Heshan Formation, 150m in thickness, is composed of black cherty limestone of basinal facies in its basal part. Abundant conodont samples were made along three parallel sections (Section A, B and C) of the Guadalupian-Lopingian boundary interval at the Tieqiao Section. This is the Penglaitan Section, Member V or the Laibin Limestone. The Heshan Formation, 70m in thickness, is mostly composed of chert and lenticular limestone of basinal facies.

**Depositional sequence**

"If major natural changes in the historical development of the Earth can be identified at specific points in sequences of continuous deposition, these may constitute desirable points for the boundary-stratotypes of stages." (Hedberg, 1977). The Guadalupian-Lopingian boundary coincides with the boundary surface between the Middle and the Upper Absaroka Megasequences that is caused by an important event of global sea-level change. The Penglaitan Section is just the right place in identifying the position of the sequence boundary.

From Member IV of the Maokou Formation to the Laibin Limestone, chert and the cherty lime mudstone of the shelf basin facies change into the grainstones and packstones of distal tempestite facies. This marks a rapid shallowing as several transitional facies units are missing in between.

The Lower part of the Laibin Ls. (Bed 2-5 in Tieqiao; Bed 2-3 in Penglaitan) characterized by packstone of tempestite facies and wackestone with rich algal lamellae shows continual shallowing. Well-developed stylolites in Bed 5 of the Tieqiao Section may have formed at an interval indicating submarine erosion or non-deposition. Faunal changes further prove that Bed 3 to Bed 5 (except the upper part) in Tieqiao and Bed 3 (except the topmost part) in Penglaitan represent the deposits of the maximum regression in the Laibin area. The Guadalupian-Lopingian succession of conodont faunas was dominated by the gondolellid conodonts that inhabited deeper environments as a whole, but was interrupted by dominance of a shallow water conodont fauna, the *Hindeodus excavatus* Zone, in Beds 3, 4 and most 5 of the Tieqiao Section and Bed 3 (except the topmost part) of the Penglaitan Section. The brachiopods, corals and other shallow-water benthic

fossils are frequently present in these beds. Accordingly, the sequence boundary or the maximum regression lies on the top of Bed 5 at Tieqiao, and the top of Bed 3 at Penglaitan.

The top of the uppermost shallowing-upward cycle of the "lowstand" unit is the transgressive surface (Van Wagnor *et al.*, 1988, 1990). The early transgressive systems tract (Bed 5f to Bed 6h in Tieqiao, Bed 3c6 to Bed 6k in Penglaitan) with thick-bedded crinoid grainstone and lenticular packstone, reflects an overall deepening. These rocks consist of high frequency cycles of fining upward deposition. Each cycle is dominated by the hummocky, cross-stratified crinoid grainstone in the lower portion, lenticular packstone in the upper, and often with vertical burrows or infilling structures at the top. The facies change is interpreted to range from proximal slope deposition with platform-derived sediments to fine-grained deposits of relative deeper below-wave-base facies to the intertidal environment. The conodonts of the *Jinogondolella granti* and *Clarkina postbitteri* zones are associated with deposition of the earliest TST, and occur mostly in the lenticular packstone. It is obvious that there were depositional hiatuses between all cycles, however, none of them are significant in term of the resolution of conodont chronostratigraphy because most of them occur within the same conodont zone.

The last two cycles in the Penglaitan Section are respectively composed of Bed 6h - 6i lower and Bed 6i upper-6k. The lower beds contain abundant mud-rich intraclasts (Bed 6i upper), numerous small solitary corals (Bed 6j), or other platform-derived sediments. Wavy bedding between the neighbouring couplets is distinct, but well developed burrows are only seen from the upper part of Bed 6k. The cycle of Bed 6h - 6i lower indicates a much faster and widespread transgression starting in the top part of the Laibin Limestone. The flooding event is delineated by the occurrence of the *C. postbitteri* conodont Zone extending northward to the Chengzhou Basin of southern Hunan, far beyond the distribution of the underlying conodonts of the *J. granti* Zone.

The subsequent transgressive unit (Bed 7) in Penglaitan is composed of deepening-upward cycles from lenticular mud limestone deposited below storm-wave-base to chert of the shelf-basin facies, with or without clay bed at the base. This transgressive unit is a response to the most rapid sea-level rise at the time of the *C. dukouensis* Zone.

#### Fossil successions

Conodonts from the Laibin Limestone in both Tieqiao and Penglaitan sections are exclusively dominated by *Jinogondolella* species in the basal part (Bed 2 at Tieqiao and Bed 2 at Penglaitan) and *Clarkina* species in the upper part (the upper part of Bed 5 to Bed 8 at Tieqiao; the uppermost Bed 3 to Bed 6). The lower part of the Laibin Limestone (Bed 3 to the middle of Bed 5 at Tieqiao; Bed 3 (except the uppermost part) at Penglaitan) is dominated by *Hindeodus*. Rare specimens of shallow water elements like *Sweetognathus fenshanensis* and *Iranognathus erwini* were also recovered respectively within the lower Bed 3 and 6k at Penglaitan. *Jinogondolella* and *Clarkina*

species also dominate conodonts from equivalent beds at the Fengshan Section, but contain more common to abundant nearshore shallow water elements *Hindeodus*, *Sweetognathus fenshanensis*, *Iranognathus erwini*, and *Sweetina* (in order of decreasing abundance). Based on the stratigraphic range and evolution of species of *Jinogondolella* and *Clarkina*, three phylogenetic conodont zones are recognized around the Guadalupian and Wuchiapingian boundary in Tieqiao and Penglaitan sections: the *Jinogondolella granti* Zone ranges from upper part of Bed 5 through Bed 6h in the Tieqiao Section, and from the uppermost Bed 3 through 6i (4.8m thick) in the Penglaitan Section; the *Clarkina postbitteri* Zone ranges from Bed 6i through lower Bed 9 in the Tieqiao Section, and from 6j through 7d in the Penglaitan Section; the *Clarkina postbitteri* Zone is overlain by the *Clarkina dukouensis* Zone that starts at Bed 7e in the Penglaitan Section. Recently, the *Clarkina postbitteri* Zone in the Penglaitan section has been subdivided into two subzones: the lower *Clarkina postbitteri hongshuiensis* subsp. nov. Subzone ranges through 6j, and the upper *Clarkina postbitteri postbitteri* Subzone ranges from 6k through 7d. *Clarkina postbitteri hongshuiensis* subsp. nov. is transitional between *Jinogondolella granti* or *Jinogondolella crofti* and *Clarkina postbitteri postbitteri*. It is close to *Jinogondolella granti* in its denticulation with closely spaced denticles and less reduced anterior platform and it is close to *Clarkina postbitteri postbitteri* with a high anterior blade, a usually much more reduced anterior platform and lack of anterior platform serration.

Fusulinaceans are rich in the Maokouan-Lopingian boundary succession of the Laibin section. The lower part of the Laibin Limestone comprises the fusulinaceans of the *Metadolliolina* Zone. The upper part of this Member is referred to an acme zone, the *Lantschichites minima* Zone. This zone is very thin, only 2 metres in thickness. The *Codonofusiella kueichowensis* Zone is recognized in the beds with the conodont *Clarkina postbitteri* in the Tieqiao Section, which contains monotonous *Codonofusiella* and *Reichelina*. The newly established *Palaeofusulina jiangxiana* Zone occurs in the lower part of the Heshan Formation, which also contain the *Clarkina asymmetrica* conodont Zone and range upward to the *C. guangyuanensis* conodont Zone.

Ammonoids referred to *Waagenoceras* have been found in the topmost part of the Maokou Formation (Bed 6k) at the Penglaitan Section. This fact implies that Maokouan ammonoids extend upward into the *C. postbitteri* Zone as do the ammonoids from the same zone in southern Hunan.

#### Magnetostratigraphic investigation and isotopic dating

For magnetostratigraphic investigation, Menning collected 640 oriented cylinders from the Chihsia, Maokou and basal part of the Heshan formations at the Tieqiao Section and the Guadalupian-Lopingian boundary sequence at the Penglaitan Section (Menning *et al.*, 1996). Partial or total remagnetization complicates the magnetostratigraphic research. Isotopic age of the tuff beds at the Penglaitan Section has been studied since 1995, and the tuff bed of the late Changhsingian was dated as  $252.4 \pm 0.2$  Ma by Bowring *et al.* (1998). Samples from Bed 6a and 7c near the boundary in the Penglaitan Section are under analysis.

## Chemostratigraphy

Values for  $\delta^{13}\text{C}$  drop from +2.0 per mil in the Laibin Limestone to -0.7 per mil at the base of the Heshan Formation (Bed 8a to Bed 8c, the upper part of the *C. postbitteri* Zone), return to an average value in Bed 9, and jump to the highest value 5%  $\delta^{13}\text{C}$  in the reef carbonate of the Heshan Formation. Change of isotope strontium value is consistent with isotope carbon with a dramatic drop in Bed 8a to Bed 8c. (Wang *et al.*, in press).

In summary, the Penglaitan and the Tieqiao sections are excellent sections in which to establish a finely resolved chronology and meet with the requirements for serving as GSSP. However, the Penglaitan Section is preferred as the GSSP for the Guadalupian-Lopingian boundary because of excellent outcrops of both Wuchiapingian and Changhsingian beds.

## Potential stratotype points

Two levels are presented here for selection. The proposal for the FAD of *Clarkina dukouensis* at bed 6k is not regarded as an acceptable choice for selection because the basal boundary of the *C. dukouensis* Zone, after further study by conodont experts, is at bed 114-7d of the Penglaitan Section, which is just above a clay bed (114-7c) that may indicate considerable environmental change (Jin, 2000). A detailed study proved that specimens of *Clarkina* from bed 6k belong to *Clarkina postbitteri* rather than to early forms of *Clarkina dukouensis* (Henderson *et al.*, 2000; Henderson, 2001) and herein, bed 6k (Figure 1) is reported to contain the first appearance of *Clarkina postbitteri postbitteri* (Henderson *et al.*, this issue).

### Option A:

This option is a point defined by the FAD of *Clarkina postbitteri hongshuiensis* subsp. nov. (Henderson and Mei, in press) that occurs within an evolutionary lineage from *Jinogondolella granti* to *Clarkina postbitteri postbitteri*. Henderson *et al.* provide the informal descriptions of these taxa elsewhere in this issue of Permophiles.

The FAD of *C. postbitteri hongshuiensis* is close to the boundary surface between the Middle and the Upper Absaroka Megasequences. This horizon can be traced in different lithofacies by the recognition of either the major sequence boundary or a remarkable changeover from conodont faunas dominated by *Jinogondolella* below in the Maokouan to those dominated by *Clarkina* above with total absence of *Jinogondolella* in the Wuchiapingian. The conodont succession around the Guadalupian – Lopingian boundary is marked by a rapid change from *Jinogondolella* into *Clarkina*. Consequently, it would be easy to locate the Guadalupian-Lopingian boundary close to the sequence boundary by the level of lowest occurrence of *Clarkina* and other corresponding stratigraphic markers.

Two questions are raised by this option. The first is that the occurrence of *Clarkina postbitteri* in Texas is in dispute. Henderson and Mei are convinced that the illustrated highest conodonts in West Texas are *Jinogondolella xuanhanensis crofti*, which appeared prior the global maximum regression. Wardlaw suggests that *Clarkina postbitteri* is present in West Texas. A model of convergent evolution may accommodate a new subspecies of *Clarkina postbitteri* evolving from *Jinogondolella crofti* in Texas, which subsequently became extinct as the S.W. USA Delaware

Basin was drained. A second lineage developed within a continuous marine environment from *Jinogondolella granti* or from another subspecies derived from a Panthalassan refuge to *Clarkina postbitteri hongshuiensis*.

The second question is that a depositional hiatus was suggested below Bed 6i upper. As described in the paragraph on depositional succession, the upper part of the Laibin Limestone consists of high frequency cycles. Both Bed 6i lower and Bed 6k form the upper parts of the uppermost two cycles and are fairly continuous with the lower parts. Though depositional gaps might occur between cycles, they seem no more than those at normal bedding planes; that is, they are insignificant in terms of the resolution of conodont chronostratigraphy. A conodont zone usually comprises many cycles.

Some colleagues consider that only such rapid change of fossils and rocks permits worldwide correlation and recognition of beds of a defined age. Regarding the rapid faunal and sedimentological changes as reflecting an incomplete geological record, would lead to a boundary definition based on subtle stratigraphic changes that are not useful for subsequent correlation.

### Option B.

A point defined by the FAD at the base of Bed 6k of *Clarkina postbitteri postbitteri* within an evolutionary lineage from *C. postbitteri hongshuiensis* subsp. nov. to *C. dukouensis*. The FAD of *C. postbitteri sensu lato* could also be used to approximate this boundary as it is only 20 cm below the defining point at the base of Bed 6i upper at the Penglaitan Section. The reason for taking the name *Clarkina postbitteri postbitteri* is that the holotype of *C. postbitteri postbitteri* is from Bed 6k, of which the main part was originally marked as Bed 115 and the topmost part, as Bed 114.6.

*Clarkina postbitteri postbitteri* is a transitional form between *C. postbitteri hongshuiensis* and *C. dukouensis*. Therefore, the FAD of *C. postbitteri postbitteri* is defined within a gradational lineage in which deposition is continuous.

The main questions regarding this option are as follows. First, it is hardly possible to consistently demonstrate the exact point at which *Clarkina postbitteri hongshuiensis* becomes *C. postbitteri postbitteri*. An arbitrary point in a morphologic transition is exactly that, arbitrary, and almost certainly inconsistent.

Second, alternative GSSP positions at the base of the *Jinogondolella altudaensis* and *C. dukouensis* zones are at least two zones away from the geologically important boundary defined by sequence stratigraphy and extinction. It has been realized that these two levels do not correspond to any major event in global biological or environmental change, and thus, these fossil zones alone are not sufficient for inter-regional correlation of the Guadalupian-Lopingian boundary sequences.

## Lopingian Boundary Working Group Preference

There is general agreement that the boundary-stratotype of a stage should be located within a sequence of continuous marine deposition and should be associated with distinct marker horizons that can be readily recognized and widely traced as an isochronous horizon and therefore, it should be selected at or near the marker horizons. Unfortunately, there is rarely an ideal point that can

satisfy both of the requirements of depositional completeness and correlation potential. With that in mind, "priority can be given to the level with the best correlation potential" (Guideline of the ICS, 1996) and a compromise solution between these two requirements for the candidate section must be found. Our members need reliable information from various sources, including especially from the conodont workers, in order to make the right decision. In addition, a flexible mind and some concessions in selection of the GSSP are necessary in order that this arbitrary reference point can gain a majority of votes.

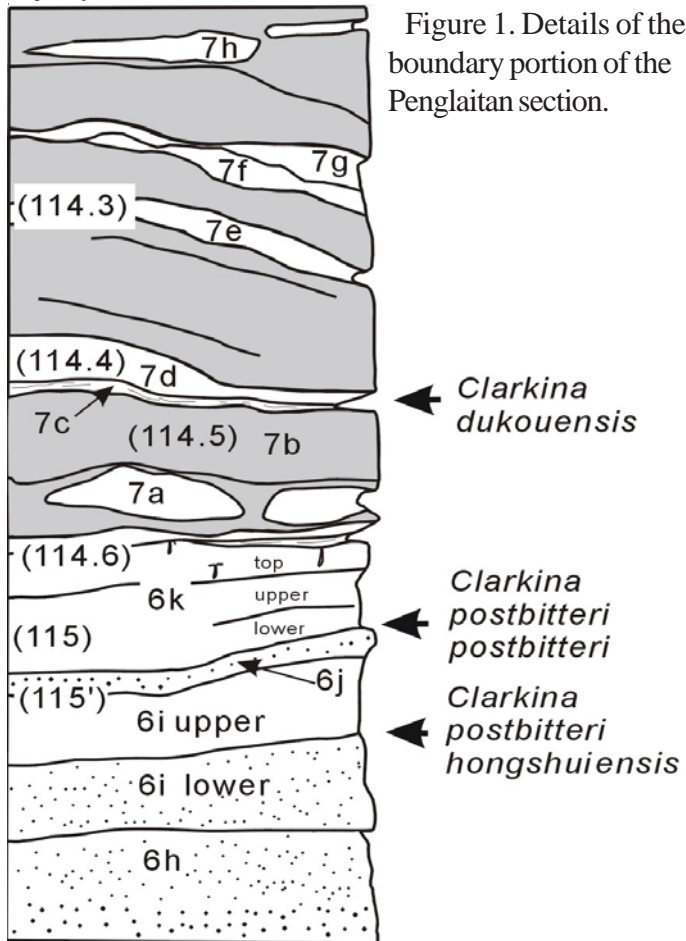


Figure 1. Details of the boundary portion of the Penglaitan section.

The Lopingian Boundary Working Group consists of Yugan Jin, Bruce Wardlaw, Shilong Mei, Cheng-yuan Wang, Charles Henderson, Brian Glenister, Heinz Kozur, Liao Zhuoting, Galina Kotlyar, Ernst Leven, Claude Spinosa, Douglas Erwin, V. Davydov, Shuzhong Shen, Jinzhang Sheng, Xiangdong Wang, and Yukio Isozaki. The authors of this paper have agreed that the preferred level is Option B, at the FAD of *Clarkina postbitteri postbitteri* at bed 6k at the Penglaitan section, Laibin area, Guangxi Province, South China. A formal proposal with additional figures will be submitted to the next issue of Permophiles, and SPS voting members will be asked to vote on the boundary.

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## New Conodont Definitions at the Guadalupian-Lopingian Boundary

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### Introduction

There has been considerable debate regarding the definition for the Guadalupian-Lopingian boundary GSSP. In this issue of *Permophiles* Jin *et al.* propose that two possible positions for the GSSP should be considered. The first of these is the FAD of *Clarkina postbitteri* in bed 6i upper at Penglaitan. This position is excellent as it represents the first appearance of *Clarkina* anywhere in China, although there is a possibility that it is not the true FAD of *Clarkina*. This position potentially represents a major evolutionary change within the conodont succession. The problems of this point relate to the lack of consensus regarding the origin of *Clarkina postbitteri* and the fact that this introduction is associated with a sequence boundary. However, at this location this po-

sition represents the conformable interval for the sequence boundary and therefore any gap is very minor in duration and of little chronostratigraphic significance. The second position is at a point within the lineage of *Clarkina postbitteri* to *C. dukouensis*. This position necessitates the identification and description of two subspecies of *C. postbitteri*. The Lopingian Boundary Working Group prefers the second position. Although *Permophiles* does not normally accept descriptions of new species/subspecies, we are making an exception by adding these informal descriptions so that *Permophiles* readers can see that there is a consensus. These taxa have been formally described and will appear in the proceedings volume of the International Congress on the Carboniferous and Permian (Henderson and Mei, 2001).

The taxonomy of these neogondolellids is revised to reflect the importance of morphologic characters like the carina in contrast to previous descriptions that emphasized the platform outline. The diagnoses presented here revise and improve upon previous descriptions. The evolution of *Clarkina* throughout the Lopingian is generally quite gradual. As a result, the descriptions must consider the population as a whole and not isolated specimens or morphotypes. Wardlaw and Collinson (1979; p. 156) first recognized this problem when they stated “that neogondolellid species 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.”

### Informal Taxonomic Notes

*Clarkina dukouensis* Mei and Wardlaw 1994a

**Original Diagnosis:** A species of *Clarkina* characterized by a Pa element with a blunt, but rounded posterior platform termination; width of platform increasing gradually until the middle; cusp terminally located, erect and larger than the denticles on the posterior half of the element; posteriormost denticle generally small; denticles increasing in size anteriorly (except the distal two smaller denticles) and discrete posteriorly; furrows moderately developed and smooth; lateral margins slightly upturned at the widest point; platform narrowing sharply on the anterior half and continuing near the anterior end.

### Emended Comparison:

The changes between *C. dukouensis* and *C. postbitteri* are minor and gradual over a short interval, but the changes can be recognized consistently within the typical parts of their range. In particular, the denticles of *C. dukouensis* are more closely spaced compared to those of typical *C. postbitteri*. *Clarkina dukouensis* first appears at the Penglaitan section in bed 114-7e.

*Clarkina postbitteri* Mei and Wardlaw 1994b

**Original Diagnosis:** A species of *Clarkina* characterized by a Pa element that has a rounded posterior termination, a small brim, a relatively long and narrow platform that is widest in the anterior half just posterior to the anterior narrowing where the platform is mildly upturned (except for some large forms which may be widest near the posterior termination), posterior sides of platform are roughly parallel with a slight indentation on the posterior inner side, a moderate cusp of circular to elongate oval cross section, space between cusp and first posterior denticle is larger than any other on the carina, first 3-4 denticles more widely spaced and less

fused than anterior denticles, furrows narrow and well developed, platform margin mildly upturned, anterior narrowing of platform in anterior third to fourth of specimen.

**Emended Diagnosis:** Mei *et al.* (1998) added that the Pa elements mostly have a rounded posterior termination.

**Original Comparison:** *C. postbitteri* differs from *C. dukouensis*, which evolved from it, by having a rounded rather than bluntly rounded posterior termination to the platform, distinct posterior brim, and a gap between the posteriormost denticle and the cusp which is filled by a small denticle in *C. dukouensis* (Mei and Wardlaw in Mei *et al.*, 1994). The platform of *C. dukouensis* is broader and does not have slight indentation on the inner side well developed. Transitional specimens between *C. postbitteri* and *C. dukouensis* show a blunting of the posterior end of the platform and the development of denticles in the posterior gap(s), though most remain slender like *C. postbitteri*.

**Emended Comparison:** Most workers currently consider the shape and outline of the platform as not particularly diagnostic because many morphotypes are generally recognized within a population, although one morphotype may dominate. The population approach is necessary to properly assess taxonomic differences; in some cases variability within population samples is significant whereas in other population samples the morphotype is homogeneous. The most significant differences on the platform between these two taxa are that a brim is often present and that the posterior end is mostly rounded in *C. postbitteri*. The form of the carina in lateral view has proven to be the most valuable character for comparison. The carina in *C. postbitteri* shows a significant gap between the cusp and posterior denticle and smaller, but still significant gaps between the posterior 3 to 4 denticles. In *C. dukouensis*, the large gap is commonly filled with a variably sized, but generally small denticle. Otherwise the denticles increase in height anteriorly, become fused, and particularly become very high and fused in the anterior-most part (the latter is a *Clarkina* character) in both taxa. Henderson (2001) pointed out that specimens illustrated by Wang (2000) can be used to discriminate the two taxa. Denticles on the specimens of Wang's plate I and plate II, figures 1-8 are more discrete compared to those illustrated on plate 2, figures 9-15. The former should be referred to *C. postbitteri* and the latter to *C. dukouensis*.

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

**Diagnosis:** A subspecies of *C. postbitteri* in which the primary characteristics become stable and morphologic variability reduced. Most Pa elements exhibit a narrow brim and usually a rounded posterior termination and abrupt narrowing of the platform in the anterior quarter of the element. All of these elements show upturned platform margins and distinct adcarinal furrows. A large gap usually occurs between the cusp and posteriormost denticle. The next three to four denticles in mature specimens are nearly equal in height and are discrete; the gaps between these denticles are not as large as between the posteriormost denticle and cusp. The middle to anterior denticles become increasingly fused and the anteriormost denticles are high and fused.

**Occurrence at Penglaitan:** Bed 6k to bed 7b. The holotype for *C. postbitteri* is from bed 6k.

*Clarkina postbitteri hongshuiensis* n.subsp. Henderson and Mei, 2001

**Diagnosis:** A subspecies of *C. postbitteri* that exhibits a wide range of morphotypes, but always has smooth anterior margins. Almost all mature specimens have a narrow brim and high, fused anterior denticles forming a blade. The diagnostic aspects of these taxa appear in larger adult forms; small juvenile specimens cannot be used for species discrimination. Some show rounded posterior terminations whereas others are more blunt or square-rounded. In some specimens the platform narrows abruptly anteriorly, but in many the platform narrows somewhat more gradually. The platform margins tend to be flat and the adcarinal furrows indistinct. The number of posterior and middle denticles is rather variable and in some they are mostly discrete, but in others most of the denticles become closely spaced to fused. In most specimens there is a gap between the posterior denticle and the cusp. Some specimens show gaps between the posterior denticles, but in others the posterior denticles are very tightly spaced or fused.

**Occurrence at Penglaitan:** Bed 6i upper to bed 6j.

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## Progress on the definition for the base of the Changhsingian

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We would like to report that significant progress has been made regarding a potential GSSP for the base of the Changhsingian. This progress is based on the analysis of new conodont collections from near the base of the Changxing Formation. The evolution of the denticulation around the boundary between the Longtan Formation and the Changxing Formation in the D section can be characterized within populations of adult specimens. Small, juvenile forms generally show more discrete denticles than large, adult forms, and are similar throughout the Changxing Limestone. Very large, gerontic forms display excessive fusion and commonly pathologic, bizarre characters. In the basal part of the Changxing Limestone, a distinctive change in denticulation configuration of *Clarkina* Pa elements has been observed in or near bed 4 (sensu Yin *et al.*, 1996).

#### Bed 2:

The denticulation in adult Pa elements of *Clarkina* from Bed 2 and below show a cusp that is largely reclined and thus low, or as high as or a little bit higher than the posteriormost denticle. The anterior slope of the cusp is gentle and usually 1.5 to 2 times as long as the height of the cusp. The posteriormost denticle is usually considerably reduced and fused with the anterior portion of the cusp to form the lowest and narrowest part of a posteriorly declining carina, forming a wide concave arc in lateral view. This denticulation cannot be substantially differentiated from that of *Clarkina longicuspidata*. As a result, *Clarkina longicuspidata* is tentatively used herein as a species in terms of population concept to include morphotypes with various platform outlines, but the same denticulation as mentioned above. The specimens in bed 2 may differ slightly from somewhat lower specimens of *Clarkina longicuspidata*.

#### Beds 3 to Lower 4:

We do not have specimens from bed 3 at present. This will need to be documented before a formal definition can be put forward. Specimens in the lower part of bed 4 are not common and appear transitional in that the middle denticles are higher and more wall-like, but a gap sometimes exists between the cusp and posteriormost denticle.

#### Beds Upper 4 to 9:

The denticulation in adult Pa elements of *Clarkina* from Upper Bed 4 to Bed 9 (sensu Yin *et al.*, 1996) has posterior denticles that are not reduced and a cusp that is not clearly separated from the

carina that bears largely fused denticles. As a result, the carina in lateral view keeps the same height towards the end of the platform and looks like a high "wall". Specimens with this type of denticulation, but with different shapes of platform outline were tentatively named as *Clarkina prechangxingensis* (round-morphotype), *C. wangi* (narrow-morphotype), *C. predeflecta* (square-morphotype) and *C. subcarinata* (transitional morphotype) by Mei *et al.* (1998) in an attempt to consolidate the disparate morphologic form taxa identified previously. Based on the holotypes of morphospecies we apply the names *Clarkina wangi* to the forms with the high, wall-like carina, and *Clarkina subcarinata* (sensu strictu) to the forms with a similar denticulation to *C. wangi*, but the posterior denticles are usually moderately reduced in height and partially discrete. This new phylogenetic species concept completely encompasses the holotype and topotypes of *Clarkina subcarinata* (Sweet, 1973). *Clarkina orientalis*, the most easily identifiable *Clarkina* species for the Lopingian, ranges through Bed 2 to Bed 4; it is particularly common in bed 4, but it is not present above. Its distinct denticulation may suggest that it probably belongs to a different lineage.

#### Metreage in section:

Base of bed 2 = 0 m	Top of bed 2 = 0.7 m
Base of bed 4 = 1.48 m	Top of bed 4 = 2.1 m

#### Conclusion:

The transition from the denticulation of *Clarkina longicuspidata* to that of *C. wangi* occurs in a very short interval either within bed 3 or more likely within bed 4 (about 60 cm) and thus allows us to be able to distinguish these two species fairly consistently. The sample from the upper part of Bed 4 (sensu Yin *et al.*, 1996) yielded abundant adult forms with a high, wall-like carina, and the sample from the top of Bed 2 (sensu Yin *et al.*, 1996) yielded abundant adult specimens with a denticulation more typical of *Clarkina longicuspidata*. Rare specimens from the top of Bed 2 have a posteriormost denticle that is not so much reduced, and thus similar to that of *Clarkina wangi*. Samples from Bed 3 are still in process. The first occurrence of *Clarkina wangi* should be somewhere within Bed 3 or Bed 4. We suggest that the base of the Changhsingian be defined by the FAD of *Clarkina wangi* in Section D at Meishan, Changxing County, China at a point to be determined very soon.

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# ANNOUNCEMENTS

**The Proceedings of the Brescia International Congress, on “Permian continental deposits of Europe and other areas, Regional reports and correlations”, were recently published. The 375 page volume includes 38 papers by 86 authors. A list of contributions is given below:**

## EUROPE

ZIEGLER P. A. & STAMPFLI G. M. - Late Palaeozoic - Early Mesozoic plate boundary reorganization: collapse of the Variscan orogen and opening of Neotethys.

## - ITALY

SCIUNNACH D. - Early Permian palaeofaults at the western boundary of the Collio Basin (Valsassina, Lombardy).

NICOSIA N., RONCHI A. & SANTI G. - Tetrapod footprints from the Lower Permian of western Orobic Basin (N. Italy).

FORCELLA F., SCIUNNACH D. & SILETTO G. B. - The Lower Permian in the Orobic anticlines (Lombardy Southern Alps): criteria for field mapping towards a stratigraphic revision of the Collio Formation.

FORCELLA F. & SILETTO G. B. - Structure and stratigraphy of the Permo-Carboniferous cover and Variscan metamorphic basement in the northern Serio Valley (Orobic Alps, Southern Alps, Italy): recognition of Permian faults.

SCHIROLLI P. - Geological setting of the Brescian Alps, with particular reference to the Permian outcrops: an overview.

BREITKREUZ C., CASSINIS G., CHECCHIA C., CORTESOGNO L. & GAGGERO L. - Volcanism and associated sub-lacustrine crystal-rich mass-flow deposits in the Early Permian Collio Basin (Italian Alps).

NICOSIA U., SACCHI E. & SPEZZAMONTE M. - New palaeontological data for the Val Gardena Sandstone.

AVANZINI M., CEOLONI P., CONTI M.A., LEONARDI G., MANNI R., MARIOTTI N., MIETTO P., MURARO C., NICOSIA U., SACCHI E., SANTI G. & SPEZZAMONTE M. - Permian and Triassic tetrapod ichnofaunal units of Northern Italy: their potential contribution to continental biochronology.

VISSCHER H., KERP H., CLEMENT-WESTERHOF J.A. & LOOY C.V. - Permian floras of the Southern Alps.

BERETTA C. & RADRIZZANI S. - The Bellerophon-Werfen boundary in the western Dolomites (Italy). Petrographical studies and a new interpretation.

BENCIOLINI L., POLI M.E., VISONA' D. & ZANFERRARI A. - The Funes/Villnöss basin: an example of Early Permian tectonics, magmatism and sedimentation in the eastern Southern Alps (NE Italy).

RONCHI A. - Upper Paleozoic and Triassic continental deposits of Sardinia: a stratigraphic synthesis.

FONTANA D., NERI C., RONCHI A. & STEFANI C. - Stratigraphic architecture and composition of the Permian and Triassic siliciclastic

succession of Nurra (northwestern Sardinia).

ALDINUCCI M., SANDRELLI F., PANDELI E. & GANDIN A. - A Permian marine sedimentary record in the Farma Valley (Monticiano-Roccastrada ridge, southern Tuscany).

## - OTHER REGIONS

LASHERAS ADOT E., LAGO SAN JOSÉ M., GALÉ BORNAO C., ARRANZ YAGÜE E. & GIL IMAZ A. - The Upper Permian alkaline magmatism of the Cinco Villas massif (Spain): a record of the late-Variscan evolution of the western Pyrenees.

Lago San José M., Gil Imaz A., POCOVÍ JUAN A., ARRANZ YAGÜE E. & GALÉ BORNAO C. - The Permian calc-alkaline magmatism of the Iberian Belt (Spain): an updated synthesis.

DEROIN J.P. (coordinator), BONIN B., BROUTIN J., CABANIS B., CHÂTEAUNEUF J.J., DAMOTTE R., DURAND M. & GAND G. - The Permian of Southern France: an overview.

CAPUZZO N. & BUSSY F. - Synsedimentary volcanism in the Late Carboniferous Salvan-Dorénaz Basin (Western Alps).

SCHÄFER A. - Stratigraphical constraints on molasse depositional systems in the Permo Carboniferous Saar-Nahe Basin, Germany.

VOIGT S. - Variation and preservation of *Ichniotherium* in the Tambach Sandstone (Rotliegend, Thuringia).

VOZÁROVÁ A. - Permian evolution of the western Carpathians, based on the analysis of sedimentary sequences.

YANEV S., MASLAREVIC LJ. & KRSTIC B. - Paleogeography of the Balkan Peninsula during the Late Paleozoic.

MASLAREVIC LJ. & KRSTIC B. - Continental Permian and Lower Triassic red beds of the Serbian Carpatho-Balkanides.

CASSINIS G. & YANEV S. - Upper Carboniferous and Permian continental deposits of Bulgaria and Italy: a review.

YANEV S., POPA M., SEGHEDI A. & OAIE G. - Overview of the continental Permian deposits of Bulgaria and Romania.

SEGHEDI A., POPA M., OAIE G. & NICOLAE I. - The Permian System in Romania.

ESAULOVA N.K., BUROV B.V. & GUBAREVA V.I. - Upper Permian type sections of the East European Platform and their correlation.

LOZOVSKY V.R., KRASSILOV V.A., AFONIN S.A., BUROV B.V. & YAROSHENKO O.P. - Transitional Permian-Triassic deposits in European Russia, and non-marine correlations.

MALYSHEVA E.O. - The continental Permian of northeast Europe.

## NON-EUROPEAN TERRITORIES AND GLOBAL MATTERS

DUNN M. T., SPINOSA C. & WARDLAW B. R. - Invertebrate faunas and preliminary palynology, Carboniferous-Permian boundary stratotype, Aidaralash creek, Kazakhstan.

UTTING J. - Permian and Early Triassic palynomorph assemblages from Canadian Arctic Archipelago, Alaska, Greenland, and Arctic Europe.



LIAO ZHUOTING & LIU LUJUN - Formation and evolution of the Permian strata of the eastern Tianshan mountain in Xinjiang, China.

HAUBOLD H. & LUCAS S. G. - Early Permian tetrapod tracks – preservation, taxonomy, and Euramerican distribution.

MENNING M. - A Permian Time Scale 2000 and correlation of marine and continental sequences using the Illawarra Reversal (265 Ma).

WARDLAW B. R. & SCHIAPPA T. A. - Toward a refined Permian chronostratigraphy.

**Those who wish to acquire a copy should contact the “Segreteria del Museo Civico di Scienze Naturali, Via Ozanam 4, 25128 Brescia, Italy (Fax +39.030.3701048; E-mail: <[pschirolli@comune.brescia.it](mailto:pschirolli@comune.brescia.it)>).**

**The field trip guidebooks for Sardinia (116pp.) and the Southern Alps (157 pp.), which were distributed during the meeting, are also available. These can be obtained directly from the “Casa editrice GRAFO, Via Maiera 27, 25123 Brescia, Italy (Fax +39.030.3701411; E-mail: <[grafobs@tin.it](mailto:grafobs@tin.it)>).**

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## FIRST INTERNATIONAL PALAEOONTOLOGICAL CONGRESS

**6-10 July 2002 Sydney, Australia**

The International Palaeontological Association, the Australasian Association of Palaeontologists, Macquarie University Centre for costratigraphy and Palaeobiology, and the Australian Museum extend a warm invitation to you to attend the First International Palaeontological Congress (IPC-2002) to take place in Sydney on 6-10 July 2002. Formal sessions of IPC-2002 will take place principally at Macquarie University.

Palaeontologists throughout the world have suggested themes for symposia at the Congress; we hope we have included most topics of current interest. We have endeavoured to cover topics that will showcase our science as a vital one, contributing to solving problems for biologists, geologists, isotope geochemists and climatologists alike. If anyone feels they have not been catered for, please contribute to Symposium 21: Aspects of other organisms.

Associated with the Congress will be two symposia: a Symposium in honour of Prof. Geoffrey Playford's sustained contribution to micropalaeontology, especially palynology, and the Jane Gray Memorial Symposium celebrating Jane's lifetime commitment to innovative research.

Coupled with the Congress will be meetings of IGCP 410 The Great Ordovician Biodiversity Event: implications for global correlation and resources, and IGCP 421 North Gondwana mid-Palaeozoic bioevent/biogeography patterns in relation to crustal dynamics, as well as meetings of the Association of Australasian Palaeontologists and the Pander Society. The Congress will be an appropriate venue for showcasing other activities of IUGS

subcommissions on stratigraphy, and IGCP projects with a significant biochronologic focus. Please contact the Organising Committee in order to book a time-slot.

The Committee received excellent feedback from the [First Circular](#); as a consequence, titles of some of the symposia have been altered slightly and excursions modified. The excursions, as well as visiting regions noted for their outstanding palaeontological interest, will provide opportunities to see some of the unique landscapes of Australia. Despite problems with airlines, both international and domestic, the Committee is determined to push forward with the program as set out herein. Any changes will be communicated directly to individuals who may be affected and as general announcements on Paleonet and on the Congress web page.

Sydney is built around one of the most scenic harbours in the world. Its comparatively mild winters, and high diversity of food, wine and coffee houses offers an ideal location to interact with colleagues and make new friends. Technical aspects of the Congress will be intercalated with a diverse spectrum of social activities including a day for local excursions to enable visitors to sample the many attractions, scientific and cultural, of Sydney and its surroundings. The venue for the Congress is Macquarie University, 17 km northwest of the Harbour Bridge and the Central Business District (CBD).

The Committee looks forward to meeting you in July 2002 at Macquarie University in what we believe will be a series of educationally stimulating and culturally enjoyable events.

John A. Talent  
Chair of the Organising Committee  
President of the International Palaeontological Association

### *Important Dates*

Submission of Abstracts: March 30, 2002

Registration and deposit: March 30, 2002

Final Payments and Accommodation booking: March 30, 2002

Technical Sessions: Sat. July 6 to Wed. July 10, 2002

Pre-congress excursions: Commence from June 23; most from June 30, 2002

Post-congress excursions: Commence July 11; last one concluding on July 29, 2002

For more information go to the website at <http://ipa.geo.ukans.edu/convention.html>

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Coming Soon! – Canadian Society of Petroleum Geologists MEMOIR 19

**CARBONIFEROUS AND PERMIAN OF THE WORLD, XIV INTERNATIONAL CONGRESS ON THE CARBONIFEROUS AND PERMIAN (M19)**

This memoir highlights a 100 million year interval during which the supercontinent Pangea was assembled, addressing issues of sedimentology, stratigraphy, resources, and paleontology. Memoir 19 contains 60 refereed papers representing the selected proceedings of the XIV International Congress on the Carboniferous and Permian held at the University of Calgary in August 1999. This publication will be valuable to geoscientists interested in Carboniferous and Permian geology, not only in Western Canada, but also around the world. Topics covered include:

- Belloy Formation sequences and paleogeography in the Peace River Basin
- Seven papers on Cyclothems from Western Canada, USA, and Spain
- Coal Resources and a North Sea gas play
- U-Pb geochronology, sedimentology and stratigraphy of tuff in the Exshaw Formation
- Carboniferous palynology and megaf flora
- Carboniferous sedimentology and stratigraphy of eastern North America
- Paleontological correlations of the Carboniferous and Permian
- Discussions on Global Stratotype Sections and Points for Carboniferous and Permian stages.

The International Congress on the Carboniferous and Permian (ICCP) was first held in June 1927 in Heerlen, The Netherlands. The meetings have been held mostly in Europe (Heerlen, Paris, Sheffield, Krefeld, Moscow, Madrid, Krakow), but also in South America (Buenos Aires), Asia (Beijing), and North America (Urbana, Illinois and for the first time in Canada at Calgary, Alberta in August 1999). The meeting began by looking only at the Carboniferous from the perspective of understanding the geology of this resource-rich, coal-bearing system. At Beijing in 1987 the Permian System was added to the congress, which was a natural extension to many Carboniferous geological problems. The ICCP is one of the oldest and most prestigious of the stratigraphic congresses associated with the International Commission on Stratigraphy and the International Union of Geological Sciences. Almost three hundred people attended the Calgary meeting and presented over 300 talks, posters, and core displays. The meeting was in part sponsored by the Canadian Society of Petroleum Geologists.

**Edited by Len V. Hills, Charles M. Henderson, and E. Wayne Bamber, 2001 (December), hard cover, approx. 800 pages, ISBN 0-920230-008**

To order your copy go to: [www.cspg.org/Publications/publications/.html](http://www.cspg.org/Publications/publications/.html)

Available in February, 2002

List Price: \$136.00 Canadian (about \$87.00 US); CSPG Member Price: \$102.00 Shipping in Canada: \$10.00; Shipping in the USA: \$15.00

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**Deadline of Feb. 18th for #39 is a firm deadline so we can get back on track.**

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