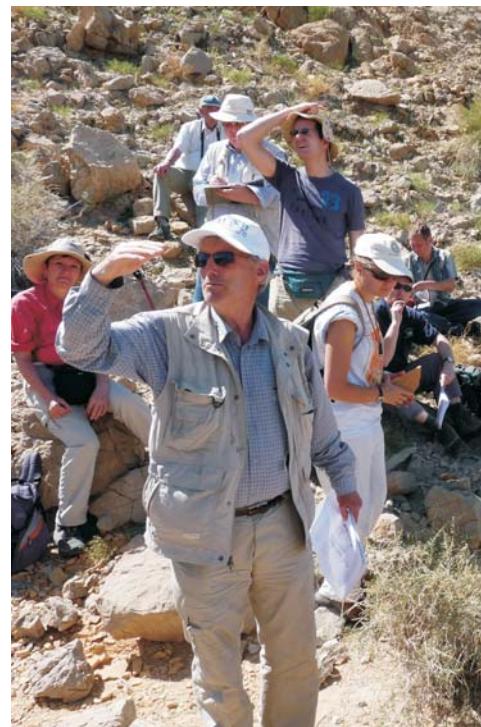




# Permophiles

International Commission on Stratigraphy  
International Union of Geological Sciences



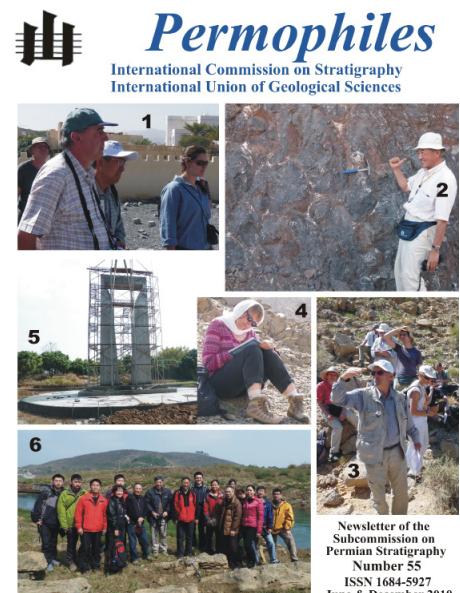
Newsletter of the  
Subcommission on  
Permian Stratigraphy  
**Number 55**  
**ISSN 1684-5927**  
**June & December 2010**

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## Explanation of Cover

1. Tadeusz Peryt (Chair of XIII ICCP) in foreground with Leo Krystyn, Shuzhong Shen, and Kate Zubin-Stathopoulos listening to fieldtrip instructions in Oman.
2. Yukio Isozaki showing “way-up” in this deposit of pillow basalts.
3. Co-leaders Aymon Baud (foreground) and Sylvain Richoz wondering where co-leader Michaela Bernecker is in Oman.
4. She is taking notes.
5. Monument nearly complete for the Guadalupian -Lopingian GSSP near Laibin, Guangxi, on the Hongshui River.
6. Chinese group visiting GSSP sites including the GLB with Shuzhong Shen (red coat in middle) and to his right (left in picture) are Shanchi Peng (ICS Vice Chair) and Xu Chen (former Ordovician Chair).



# EXECUTIVE NOTES

## Notes from the SPS Secretary

**Shuzhong Shen**

### Introduction and thanks

I am sorry that this issue of *Permophiles* has been long delayed and we have only one issue for the year 2010. This issue was edited by Charles and I in Nanjing and I thank Charles for his visit to Nanjing to complete this issue. Thanks to Charles, Spencer Lucas, Aymon Baud and Michaela Bernecker for their contributions to this issue.

### Previous and forthcoming SPS Meetings

There was no official SPS business meeting held during the last year. However, the SPS executive committee including SPS chair Charles Henderson, vice-chair Vladimir Davydov and myself met together during the ICS Workshop “The GSSP Concept” held between May 30 and June 3, 2010 in Prague, Czech Republic. About 50 colleagues from different committees of the subcommissions of stratigraphic systems attended this workshop. ICS celebrated the success of the GSSP process. ICS members and participants extensively discussed not only examples of successes and broader implications of GSSPs, but also problems that have arisen. Resolving differences in usage of stratigraphic nomenclature and classifications, revising ICS statutes, setting ICS standards were also topics discussed during this workshop. The SPS executive committee also discussed the plan and possible topics for potential sessions of the 17th ICCP, which will be held between July 3 and 8, in Perth Australia (see circular in this issue) with the executive committee members of the International Subcommission on Carboniferous Stratigraphy. SPS has a plan to hold a business meeting during the ICCP2011. We hope we will meet together in Perth, Australia.

### Permophiles 55

This issue contains the report of the progress of the potential Artinskian-base GSSP prepared by Charles Henderson. Charles reported the biostratigraphic, geochronologic and geochemical progress on the Dal'ny Tulkas section as the GSSP section studied by different research groups. We would welcome any comments and suggestions on this section for future detailed proposal. Charles also provided a detailed annual report of SPS. As the Permian GSSPs, established and in progress, are based on marine sequences, the correlation between marine and terrestrial sequences is becoming one of the most perspective future subjects for the Permian community. Spencer Lucas provides a report on the perspectives and problems of the Permian timescale based on tetrapod evolution. In his report, he mentioned that the endemism, incomplete successions and other geochronologic tools to calibrate the tetrapod zones are the most difficult problems for the terrestrial. We hope to discuss the ter-

restrial timescale and correlation problem during ICCP2011.

Aymon Baud and Michaela Bernecker provide a report on the field excursion in Oman (see cover and reports in this issue), which was held between February 21-26, 2010. We thank them for organizing a wonderful trip and all the participants are very happy to some excellent Permian-Triassic sections including the Wadi Wasit limestone block.

The XVI International Congress on the Carboniferous and Permian (ICCP2007) was successfully held in Nanjing, China, from June 21st to June 24th, 2007. During the past two years, two new special issues of ICCP 2007 were published. One is edited by Xiangdong Wang et al. (2009, Palaeoworld, 18:77-212, <http://www.sciencedirect.com/science/journal/1871174X>) and has the theme “Carboniferous and Permian Biota, Integrative Stratigraphy, Sedimentology, Palaeogeography, and Palaeoclimatology”. The other is edited by Shuzhong Shen et al. (2010, Geological Journal, 45:119-349, <http://www3.interscience.wiley.com/journal/123391514/issue>) (see an introduction in this issue).

In addition, the chair of the organizing committee of ICCP2011, Dr. Chen Z.Q. provides a circular of ICCP2011 in this issue. Detailed information is provided at the website <http://www.iccp2011.org/index.html>.

### Future issues of *Permophiles*

The next issue of *Permophiles* is the 56th issue of *Permophiles*. Charles and I plan to edit *Permophiles* #56 in Perth during ICCP2011. We are getting fewer reports from our colleagues during the past year. We hope our colleagues in the Permian community can contribute papers, reports, comments and communications. The deadline for submission to Issue 56 is July 1, 2011. Manuscripts and figures can be submitted via my email address ([szshen@nigpas.ac.cn](mailto:szshen@nigpas.ac.cn) or [shen\\_shuzhong@yahoo.com](mailto:shen_shuzhong@yahoo.com)) as attachments. Please follow the format on page 3 of Issue 44 of *Permophiles*.

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### Notes from the SPS Chair

**Charles M. Henderson**

This issue began during the summer of 2010 and was finally finished in February on a trip to Nanjing. I apologize to *Permophiles* readers regarding this delay – it is entirely my responsibility. I had hoped to produce a GSSP proposal for the base-Artinskian and circulate this to the Permian community for their comments. This has not proven possible, at least in part because research on

some of the correlation tools has been ongoing, but I do include a summary of the current status for this proposal on page 15 and I ask *Permophiles* readers to send comments to Shuzhong Shen and myself by April 15, 2011. Work is also progressing on the other remaining GSSP proposals (base-Sakmarian and base-Kungurian) and my goal is to be able to announce at the IGC meeting in Brisbane that “the Permian GSSP process is complete”. You can expect two issues of *Permophiles* in 2011.

My annual report to ICS was submitted December 4, 2010 and is included in this issue. The time scale at the back of this issue on page 33 is modified from the previous issue and this is the current version planned for the next Global Time Scale book, but there may be a few revisions yet.

Our most important meeting this year will be the International Congress on the Carboniferous and Permian, Chaired by Zhong Chen and held at Perth, Australia this July. Information about the meeting can be found in this issue or by visiting the website at [www.iccp2011.org/](http://www.iccp2011.org/). Abstract deadline is April 1, 2011. There are some excellent sessions and fieldtrips planned! We will have a business meeting at ICCP and one item will be information about the nomination procedure for the next executive. I will be retiring from the Chair position at the Brisbane IGC meeting in 2012.

## REPORTS

### SUBCOMMISSION ON PERMIAN STRATIGRAPHY ANNUAL REPORT 2010

#### 1. TITLE OF CONSTITUENT BODY and NAME OF REPORTER

International Subcommission on Permian Stratigraphy (SPS)

#### SUBMITTED BY:

Charles M. Henderson, Chairman SPS

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#### 2. OVERALL OBJECTIVES, AND FIT WITHIN IUGS SCIENCE POLICY

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

**Fit within IUGS Science Policy:** The objectives of the Subcommission involve two main aspects of IUGS policy:

1. The development of an internationally agreed chronostratigraphic scale with units defined by GSSP’s where appropriate and related to a hierarchy of units to maximize relative time resolution within the Permian System; and

2. Establishment of framework and systems to encourage international collaboration in understanding the evolution of the Earth during the Permian Period.

#### 3. ORGANIZATION

The Subcommission has an Executive consisting of a Chairman, a Vice-Chairman, and a Secretary; all three are Voting Members of the Subcommission. There are sixteen total Voting Members representing most regions of the world where Permian rocks are exposed. The objectives of the Subcommission are pursued by both stratigraphic and thematic Working Groups that are retired upon completion of their directed task. For example, the Working Groups on the Carboniferous-Permian Boundary, on the Guadalupian stages (Middle Permian), on the base-Lopingian boundary (base-Wuchiapingian Stage), and on base-Changhsingian have been retired upon the successful establishment of their defining GSSP’s and ratification by IUGS. The current working groups include the following: 1. Cisuralian stages, 2. Continental Permian, 3. Transitional biotas as gateways for global correlation, 4. Neotethys, Paleotethys, and S. China Correlations, and 5. International Lopingian Working Group.

#### 3a. OFFICERS FOR 2008-2012:

Chair: Professor Charles M. Henderson, University of Calgary

Vice-Chair: Dr. Vladimir Davydov, Boise State University

Secretary: Dr. Shuzhong Shen, Nanjing Institute of Geology and Palaeontology

SPS website is located at [www.nigpas.ac.cn/permian/web/index.asp](http://www.nigpas.ac.cn/permian/web/index.asp). This site includes all back issues of *Permophiles* in downloadable PDF format (#1 in 1978 to #54 December 2009). A link

to *Permophiles*/Permian research has also been established at [www.ucalgary.ca/conodont/sp/](http://www.ucalgary.ca/conodont/sp/).

#### 4. INTERFACES WITH OTHER INTERNATIONAL PROJECTS

SPS interacts with many international projects on formal and informal levels. SPS has taken an active role on the development of integrated chronostratigraphic databases by participating with CHRONOS and PALEOSTRAT (now GeoStratSys), which are NSF funded initiatives. Vladimir Davydov and Walter Snyder are concentrating on developing their system to include improved taxonomic dictionaries, database sharing and manipulation with GeoStratSys. SPS is also involved in a NSFC supported study comparing the Proterozoic-Cambrian transition with the Permian-Triassic transition.

#### 5. CHIEF ACCOMPLISHMENTS AND PRODUCTS IN 2010

**GSSPs:** Progress was made on the three remaining Lower Permian (Cisuralian) stage GSSPs including base-Sakmarian, base-Artinskian, and base-Kungurian. We have decided to change the section and point for the base-Sakmarian to the Usolka section and a proposal will be voted on in 2011. The Kondurovsky section failed to reproduce the requisite conodont results and problems about the evolution of *Sweetognathus merrilli* were

discussed during ICOS2009. Fortunately, the Usolka section had been fully worked up as a potential parastratotype and we have excellent carbon isotope, U-Pb isotopic ages and abundant conodonts to define the boundary. A penultimate proposal for the base-Artinskian is appearing in *Permophiles* 55. At both of these sections the Sr isotopes of conodonts have also been shown to be an accurate correlation tool. The SPS community will be invited to give input on the Artinskian proposal and based on that input a revised proposal will be submitted to SPS voting members in April 2011 for voting. Finally, it was decided that the Mechetlino section in Russia is not satisfactory for a GSSP – samples did not yield conodonts, zircons are all reworked, and the rocks are too deeply weathered to produce meaningful carbon isotopic values. Two sections in the United States, which have already been extensively studied are now being considered as potential GSSPs using the same point (FAD of *N. pnevi*); these include the Cassia Mts in southern Idaho and Rockland sections in northern Nevada. Detailed samples were collected in early July 2010 by Bruce Wardlaw, Charles Henderson, Vladimir Davydov and Mark Schmitz at the Rockland section. Conodonts, fusulinids and Sr isotopes for these samples will form the basis to make a GSSP preliminary proposal during the winter 2011 and a workshop is planned in early June (see budget request).

**Publications:** The December 2010 issue of *Permophiles* (#55) was produced online during the Fall of 2010 and will be distributed as a pdf document to a mailing list of 280. Owing to reduced submissions SPS is producing only one issue in 2010 (#55), which will go online in late December 2010. We have a complete series of *Permophiles* on our website (1978 to 2009).

**Meetings:** The SPS conducted a business meeting in association with the ICS business meeting in Prague, Czech Republic during late May 2010.

**Membership:** There were no changes to the membership in 2010. We have 17 voting members representing Argentina (1), Australia (2), Canada (1), China (3), France (1), Germany (1), Italy (1), Japan (1), Russia (3), and United States (3). We also have five honourary Members.

## 6. CHIEF PROBLEMS ENCOUNTERED IN 2010

There were no major problems in 2010, but progress is slow owing to the voluntary nature of most of this work and minimal financial support.

## 7. SUMMARY OF EXPENDITURES IN 2010:

### INCOME

University of Calgary (1): \$2084.00

NIGPAS (2): \$2,000.00

ICS (3): \$ 2,700.00

**TOTAL: \$6784.00** (quoted in US\$ using 0.99 as the conversion from Canadian\$. (1) University of Calgary support from NSERC grant to Charles Henderson for travel to ICS workshop and Wells Nevada for fieldwork. (2) NIGPAS (Nanjing Institute of Geology and Palaeontology) support from NSF-C grant to Shuzhong Shen for travel to ICS workshop. (3) ICS allocation to SPS \$1500 and \$1200 for travel to ICS workshop..

### EXPENDITURES

Printing, Mailing, and Web support *Permophiles*: \$250.00  
Travel costs to Prague \$4603.50.00 (Henderson and Shen)  
Travel costs for *Permophiles* Production: \$0  
Travel costs for Wells Nevada fieldwork \$1930.50  
**TOTAL: \$6784.00** (quoted in US\$)  
**BALANCE: \$0.00**

## 8. WORK PLAN, CRITICAL MILESTONES, ANTICIPATED RESULTS AND COMMUNICATIONS TO BE ACHIEVED NEXT YEAR (2011):

1. Production of *Permophiles* #56 in Calgary during summer 2011.
2. Vote on base-Artinskian in April 2011.
3. Vote on base-Sakmarian in 2011.
4. Workshop for base-Kungurian in Boise Idaho and Wells Nevada.
4. SPS business meeting during ICCP meeting in Perth Australia during July 2011.
5. Production of *Permophiles* #57 in China late 2011 or early 2012.
6. Completion of new GSSP proposal for base-Kungurian by September 2011.

My major goal is to complete the GSSP process for the Permian stages prior to the IGC in Brisbane in August 2012.

## 9. BUDGET AND ICS COMPONENT FOR 2010

### EXPENDITURES

We have sufficient leftover funds for the minor cost of website and printing. The primary budget request for 2011 is for a workshop at Boise Idaho with field excursion to the Rockland Section near Wells Nevada. This workshop is essential if we are to convince the international Permian community that the Rockland section is appropriate for the base-Kungurian GSSP. This is the biggest hurdle confronting SPS because we have rejected a long viewed potential section in Russia. This workshop is essential for SPS to complete the GSSP process before IGC in 2012. Financial support is necessary to bring at least 3 foreign researchers (at least one from Russia) to Boise Idaho by paying for airfare and subsidizing accommodation (\$5000). Other SPS members will be invited, but subsidies will be limited (\$1000). Workshop will be conducted over two days at Boise State University in early June 2011 with fieldtrip to the potential GSSP field site. Fieldtrip costs will include vehicle rentals and 2 night's accommodation in Wells Nevada (\$2000) for the group. Samples can be collected by participants. Workshop at Boise State will include presentations and viewing of conodonts and fusulinids as well as the isotope labs of Mark Schmitz. SPS Executive will attend using their research funding. They will also attend the ICCP meeting in Perth in July 2011 using their own funds.

### **TOTAL 2009 BUDGET \$8,000.00**

#### Income

Support for trip to Boise from University of Calgary (Henderson; NSERC) \$750.00

Support for trip to Boise from NIGPAS (Shen; NSF-C) \$2,000.00

Support from Boise State (Davydov; NSF) \$250.00  
Requested ICS contribution (1) \$5,000.00

**TOTAL BUDGET REQUEST (ICS) \$5,000.00**

**10. REVIEW CHIEF ACCOMPLISHMENTS OVER PAST FIVE YEARS (2006-2010)**

The SPS has approved the general divisions of the Permian and has now had 6 GSSP's ratified by ICS and IUGS (Asselian, Roadian, Wordian, Capitanian, Wuchiapingian, Changhsingian).

Proposals for the latter two stages were published in Episodes in 2006. Support for documentation (fieldwork and publications) of the various chronostratigraphic methods for the establishment of the GSSP's has been the most outstanding and differentiating character of this Subcommission. Substantial work has been conducted toward producing excellent proposals for the remaining stages. *Permophiles* has become an internationally respected newsletter and bears an ISSN designation (1684-5927) and is deposited in the National Library of Canada; nine issues were published during the five year period.

**11. OBJECTIVES AND WORK PLAN FOR NEXT 2 YEARS (2010-2012)**

The primary objectives are to complete the GSSP's for the last three GSSP's (Sakmarian, Artinskian, and Kungurian). We will produce one or two issues of *Permophiles* each year depending on input. We anticipate the following schedule:

1. Vote on base-Artinskian in April 2011.
2. Vote on base-Sakmarian in 2011.
3. **Workshop** to decide feasibility of base-Kungurian. Boise State University in June 2011.
4. Business meeting at International Congress on Carb and Permian July 2011; Perth Australia.
5. Production of *Permophiles* 56 and 57.
5. Election process for new executive including SPS Chair to take effect at IGC, Brisbane 2012.

Once the GSSP process is completed SPS will shift focus toward three directions beginning in 2012:

1. correlations into continental deposits,
2. correlations across provincial boundaries and within the Tethys region,
3. detailed documentation of the geologic evolution of the Earth during the Permian with respect to the established chronostratigraphic framework.

**12. WEBSITE STATUS AND ACTIVITIES:**

SPS website is located at [www.nigpas.ac.cn/permian/web/index.asp](http://www.nigpas.ac.cn/permian/web/index.asp). This site is updated regularly and includes all back issues of *Permophiles* in downloadable PDF format (#1 in 1978 to #54 December 2009) as well as other information about SPS activities including annual reports, membership.... Shuzhong Shen at Nanjing China maintains the site and Henderson and Shen both have administrator rights.

**13. FOUR YEAR SUMMARY OF ACTIVIES:**

**GSSP's:** The base-Wuchiapingian and base-Changhsingian

(Upper Permian or Lopingian Series) GSSPs were published in Episodes (volume 29, No. 3&4) in 2006. Progress was made on the three remaining Lower Permian (Cisuralian) stage GSSPs including base-Sakmarian, base-Artinskian, and base-Kungurian. An international field excursion was conducted in early July 2007 (reported in *Permophiles* #49; p. 4-6) and samples for carbon isotopes, geochronology and biostratigraphy were collected and have now been processed. The geochemical samples will provide further correlation potential for the proposed GSSPs; these materials are being analyzed at Boise State University and the Nanjing Institute of Geology and Palaeontology. The biostratigraphy samples will determine reproducibility of GSSP definitions. Decisions have been made on the basis of this new work and this is described above in section 5. The most significant decision was to reject the base-Kungurian section at Mechetlino. Detailed samples were collected at the Rockland section in Nevada and a workshop is proposed to consider the feasibility of this section.

**Publications:** The June 2006 issue of *Permophiles* (#47) was produced at Nanjing China during June 2006 and distributed as a pdf document to a mailing list of 280. The December 2006 issue of *Permophiles* (#48) was produced at the University of Calgary during November 2006 and distributed as a pdf on our website. We now have a complete series of *Permophiles* on our website (1978 to 2006). The June 2007 issue of *Permophiles* (#49) was produced at Nanjing China during June 2007 and distributed as a pdf document to a mailing list of 280. The December 2007 issue (#50) was produced in January 2008 after a field excursion to Australia. June 2008 issue (#51) was produced in Calgary in July 2008. December 2008 (#52) was produced online in January 2009 and #53 was produced in July 2009 in Calgary and #54 was produced online. We now have a complete series of *Permophiles* on our website (1978 to 2009).

**Meetings:** The SPS conducted one business meeting at the 2nd International Palaeontology Congress in Beijing, China in June 2006. The SPS conducted one business meeting at the XVI International Congress on the Carboniferous and Permian in Nanjing, China in June 2007 and is reported in *Permophiles* #49. Business meetings were held in Sydney Australia (January 2008; *Permophiles* #50) and IGC in Oslo (August 2008). In 2009 business meetings were held in Trelew Argentina and at ICOS2009 in Calgary. A business meeting was held at Prague, Czech Republic in late May 2010 during the ICS workshop.

**Membership:** Two changes were made to voting membership in 2006. Dr. John Utting retired as a voting member and was named by the SPS Executive as a Honorary Member given his long service to SPS (past Secretary) and distinguished research record in Late Paleozoic palynology. Dr. Lucia Angiolini was nominated by the executive to fill this vacancy. This increased the membership from Europe bringing it more in line with other major regions. Secondly, we sadly lost our distinguished colleague and friend Professor Jin Yugan who died in June 2006 (see *Permophiles* 48 for a tribute). His was a very distinguished career in Late Paleozoic paleontology and service including as a past-Secretary and past-Chairman of SPS. He has been replaced as a voting member by Professor Yue Wang. There were no changes to the membership in 2007, but as noted in the 4 year summary we have made several changes over the past four years. In addition,

the current executive will continue for a second term. We currently have 16 voting members representing Australia (2), Canada (1), China (3), France (1), Germany (1), Italy (1), Japan (1), Russia (3), and United States (3). We also have five honorary Members. No changes in 2008. In 2009 we added one new voting member, Dr. Nestor R. Cuneo from Argentina to add to our complement noted above. There were no changes to the membership in 2010.

**Summary (2006-2010):** Two GSSP proposals for the base-Wuchiapingian (also base-Lopingian Series) and base-Changhsingian were prepared, voted, ratified and published in Episodes during the past four years. Significant progress has been made on the last three Cisuralian GSSP proposals for the base-Sakmarian, base-Artinskian, and base-Kungurian stages. An international workshop was conducted in July 2007 to determine reproducibility and accessibility as well as collect new geochemical data. During the reporting period, *Permophiles* #47 to #54 have been produced with #55 to come later this year. In addition, a website was constructed and hosted by the Nanjing Institute of Geology and Palaeontology during the reporting period. Among other items, this website has pdf versions of all issues of *Permophiles* dating back to #1 in 1978.

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## APPENDIX

### Officers and Voting Members as of November 2010

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**Permian timescale based on tetrapod evolution: perspectives and problems**

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The completion of a GSSP-defined Permian timescale based on marine biostratigraphy is at hand. Nonmarine Permian biostratigraphy and biochronology, and the correlation of nonmarine and marine chronologies, thus should become a major focus of Permian timescale research. Permian tetrapod (amphibian and reptile) fossils have long provided a basis for nonmarine biostratigraphy and biochronology (see reviews by Lucas, 1998, 2002, 2004, 2006). Lucas (2005c, 2006) proposed a formal global Permian tetrapod biochronology that recognizes 10 time intervals (land-vertebrate faunachrons) (Fig. 1). This biochronology is based on the body-fossil record of tetrapods and provides a tetrapod-based timescale that can be used to determine and discuss the temporal relationships of Permian tetrapod assemblages. Parts of it can also be correlated with reasonable precision to the standard global chronostratigraphic scale (SGCS) for the Permian, which is based on marine biostratigraphy (Fig. 1). Here, I discuss some of the challenges faced by the Permian timescale based on tetrapod evolution.

**Permian tetrapod record and timescale**

Substantial fossil records of Permian tetrapods come from the western United States, western Europe, the Russian Urals, northern China and South Africa. The most extensive Lower Permian tetrapod record is from the western United States, especially from Texas, Oklahoma and New Mexico. Fossil vertebrates have been collected from the nonmarine Permian redbeds in north-central Texas since the 1870s, and in northern New Mexico since the 1880s, and were published on extensively by E. D. Cope, E. C. Case, S. W. Williston, A. S. Romer, E. C. Olson and D. S Berman, among others, and they provide the basis for most of what is known about the Early Permian evolution of tetrapods. The New Mexican and Texas records were thus used to construct the Early Permian tetrapod biochronology of five LVFs (Fig. 1).

The Lower Permian red-bed section in Texas represents fluvial deposition on a broad coastal plain between a Permian seaway to the west and a series of ancestral Rocky Mountain uplifts (Ouachita, Arbuckle and Wichita) to the east and northeast. The nonmarine red beds intertongue with, and are laterally equivalent to, marine strata, allowing cross-correlation of nonmarine and marine biostratigraphies. This means it is possible to correlate directly a tetrapod biostratigraphy developed in the

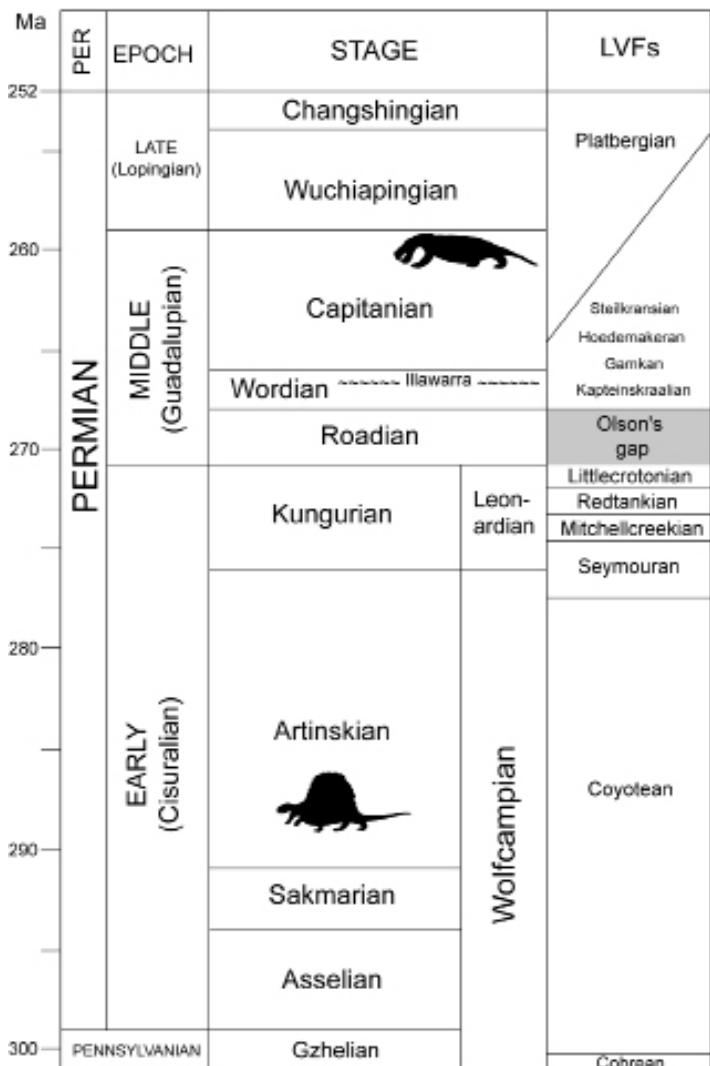


Fig. 1. Global Permian tetrapod biochronology and its correlation to the SGCS of Wardlaw *et al.* (2004, with numerical ages updated according to Permophiles, 54:40). LVF = land-vertebrate faunachron.

Texas red beds with a marine biostratigraphy based largely on fusulinids and ammonoids and for which some conodont data are becoming available (Lucas, 2006). The Texas section thus provides an excellent basis for Early Permian tetrapod biostratigraphy, and this biostratigraphy can be readily correlated to marine biostratigraphy.

Nevertheless, this section has a glaring weakness in lacking an extensive record of tetrapods across the Pennsylvanian-Permian boundary. To remedy this, Lucas (2005c, 2006) included the Pennsylvanian-Permian boundary record of tetrapods in northern New Mexico (Rio Arriba County: Berman, 1993; Lucas *et al.*, 2005a, b, 2010) to form a composite standard of New Mexico-Texas for the oldest Permian tetrapod faunachrons. Thus, the New Mexican record superposes tetrapod assemblages that are entirely latest Pennsylvanian, cross the Pennsylvanian-Permian boundary and are of Early Permian age. When combined with the Texas record, the tetrapod succession encompasses the entire Early Permian.

The Middle-Upper Permian tetrapod fossil record and its bio-

stratigraphy in the Karoo basin of South Africa has long provided the classic succession of Middle to Late Permian tetrapod assemblages. Discovered in 1838, Karoo tetrapod fossils have been extensively studied and published on since the 1850s. Articles in Rubidge (1995) recognize six successive assemblage zones of Permian tetrapods in the Karoo basin. Lucas (2005c, 2006) recast five of the assemblage zones as biochronological units (LVFs) to encompass most of Middle and Late Permian time (Fig. 1). However, few reliable data correlate the South African Middle-Late Permian tetrapod to the SGCS.

In the Ural foreland basin the Russian succession of Middle-Upper Permian tetrapod assemblages broadly correlates to the Karoo succession and has the advantage that the lowermost (Kazanian) Russian tetrapods can be directly tied to marine biostratigraphy. Furthermore, the Illawara magnetostratigraphic event has been identified in the Russian Tatarian, which provides another way to correlate the Russian section to the SGCS (Menning, 2001). Unfortunately, prior to the LO of *Dicynodon* in the Russian section (just above the Illawara event), virtually all of its genus-level taxa are endemic, and thus of limited biostratigraphic value. Rare exceptions include the parareptiles *Belebey* (also known in China) and *Macroleter* (reported from Oklahoma), but they provide only a limited basis for correlation. For this reason, correlation of the Russian tetrapod assemblages to coeval assemblages in Gondwana (especially in the South African Karoo) have mostly been based on assessments of stage of evolution usually expressed as family-level correlations (e.g., Rubidge, 2005), not on low-level (genus or species) taxonomic identity, so they are inherently imprecise. Thus, the Russian record provides the primary basis for correlating the Middle-Late Permian tetrapod biochronology to the SGCS, but this is a much less precise correlation than is possible for the Early Permian.

### Problems and Challenges

1. Incompleteness of the Permian tetrapod fossil record: As extensive and long studied as the Permian record of tetrapods is, it is not without significant biases and imperfections, including the virtual geographic restriction of Early Permian tetrapods to the United States and western Europe, and the global gap in part of the Middle Permian tetrapod fossil record (Lucas, 2004). This global gap approximates the duration of the Roadian Stage, though its presence/absence and duration are wrapped up in debate over the global correlation of the Russian Ufimian Stage to the SGCS as well as disagreements over the correlation of the Roadian (e.g., Lozovsky, 2005; Lucas, 2005a; Leven and Bogolovskaya, 2006; Lozovsky *et al.*, 2009). Recent discoveries and analyses of primitive therapsids are bridging the evolutionary break posed by Olson's gap (e.g., Kemp, 2006; Liu *et al.*, 2009, 2010), but they are not closing the temporal hiatus.

Early Permian tetrapod fossils are restricted to the Pangean equatorial zone in North America and western Europe. During the Middle and Late Permian, the tetrapod record becomes more global in extent, with substantial records in both Laurussia and Gondwana. Nevertheless, Permian tetrapod fossils (as is the case with most vertebrate fossils) are often found as isolated records or in bone beds (mass death assemblages) that lack stratigraphic

range. The Middle-Upper Permian record of tetrapod fossils in the Karoo basin is a striking exception to this, but even in the Karoo most of the collected record lacks detailed stratigraphic provenance within a given assemblage zone, so that there is still a significant amount of stratigraphic imprecision. Both the geographic and stratigraphic inadequacies of the Permian tetrapod fossil record will always limit its utility in biostratigraphy and biochronology. New discoveries with precise stratigraphic data continue to be needed.

2. Endemism and index fossils: Most of the problems with developing a Permian tetrapod biostratigraphy and biochronology reduce to one problem--the rarity or lack of good Permian tetrapod index fossils. Good index fossils are easily identified, abundant and have a broad geographic (facies) range but a short stratigraphic (temporal) range. Few, if any, Permian tetrapod genera or species meet these criteria. Most Permian tetrapod taxa (genera and species) are endemic to a single locality or to a geographically restricted region. In part this is an artifact of taxonomy, which requires much of a skull or skeleton to make many genus-level and all species-level identifications. Indeed, as Williston (1915) and Romer (1928) noted long ago, most Permian tetrapod species are specimen-specific: they are based on and known from one (or at most a few) exceptionally well-preserved fossils. This is why we are far from a species-level taxonomy of Permian tetrapods that is useful for biostratigraphy. Instead, the genus is the operational taxonomic unit of Permian tetrapod biostratigraphy.

A priori, most vertebrate paleontologists have viewed Permian genera or higher level taxa as relatively cosmopolitan across Permian Pangea. A good demonstration of this was provided by the discovery of the Bromacker quarry, a Lower Permian bonebed in Germany. For more than a century, North American red-bed tetrapod assemblages differed strikingly from age-equivalent upper Rotliegend assemblages in Europe, which are mostly brachiosaur-dominated and from carbonaceous, lacustrine facies. The Bromacker quarry tetrapod assemblage is in fluvial red beds similar to the North American red bed facies and yields some of the same genera (e.g., *Seymouria*, *Diadectes*, *Dimetrodon*), indicative of the relative cosmopolitanism of some Early Permian tetrapod genera.

However, there still appears to be some real endemism in the Permian tetrapod record. For example, Sidor *et al.* (2005) report a Middle-Late Permian tetrapod assemblage from Niger composed of endemic genera that is not readily correlated to other Permian tetrapod assemblages (though note this is a small [low diversity] assemblage that might, if better known, include index taxa for correlation). On a larger scale, as mentioned above, Middle-Late Permian tetrapod assemblages in the South African Karoo basin and the Russian Ural foreland overlap temporally, but they share few (if any) genera, thus, tetrapod-based correlations between South Africa and Russia rely on family-level taxa (e.g., Rubidge, 2005), so they lack precision. This classic endemism in two well known but nearly bi-Polar tetrapod assemblages may in part reflect provincial taxonomy.

3. Taxonomy and lineages: As was just noted, the genus is the operational taxonomic unit for Permian tetrapod biostratigraphy and biochronology. This is because most species-level taxa of Permian tetrapods are meaningless for correlation, as they are

usually based on a single specimen or a local assemblage of well-preserved material and cannot be recognized at multiple localities. However, some species of Early Permian tetrapod genera (such as species of *Seymouria* and *Bolosaurus*) are of use in correlation, and taxonomic revisions of some other genera (such as *Eryops* and *Dimetrodon*) should produce species-level taxa of value to biostratigraphy. Werneburg (e.g., 1989; Werneburg and Schneider, 2006) has also argued that species lineages (chronoclines) provide a more precise biostratigraphy than do genus-based correlations. I agree with him in principle, but am unable to construct meaningful species lineages for most of the Permian tetrapod genera that are of value to a global biochronology.

What Feduccia (1999) aptly called the “jihad of cladism” has given rise to a type of alpha taxonomy based on cladistics (cladotaxonomy) that is undermining many widespread and long recognized Permian tetrapod taxa useful to biostratigraphy. *Dicynodon* is the poster child of this problem (Lucas, 1997, 2005b, 2006; Angielczyk and Kurkin, 2003). Thus, what was long recognized as a single genus *Dicynodon* (e.g., Cluver and Hotton, 1981) becomes multiple genera upon cladistic analysis, so that the one taxon can no longer be used to correlate. This is a large problem for vertebrate paleontology, which I will discuss at length elsewhere, but I note here that the a posteriori reasoning inherent to cladistics renders it a questionable tool for alpha taxonomy (Lucas, 2005c), and what I call “cladotaxa” have proven to be of little biostratigraphic utility.

4. General lack of non-biostratigraphic chronology: “Integrated timescales,” in which biostratigraphy, magnetostratigraphy, radio-isotopic ages and chemostratigraphy provide calibration, are the most precise timescales, because they use independent methods to evaluate correlations and datum points. However, there is a general lack of radioisotopic ages, magnetostratigraphy, isotopic data and other non-biostratigraphic means of correlating nonmarine Permian strata.

No significant and consistent behavior of the magnetic field has been documented for the Early Permian, nor is a succession of isotopic events clearly established. A surfeit of Early Permian radioisotopic ages is known from the nonmarine Lower Permian of Western Europe, but these dates are of low precision and not readily correlated to tetrapod biostratigraphy. Instead, they are well correlated to plant biostratigraphy, but this European plant biostratigraphy is of limited applicability across Permian Pangea. Thus, the Early Permian tetrapod biostratigraphy/biochronology is difficult to test against other correlation tools. These tools—especially magnetostratigraphy and radioisotopic ages---are needed in much of the nonmarine Permian section to work towards an integrated scheme of correlation.

## Prospectus

Beyond those issues just discussed, three problems are evident in looking at the scheme of Permian land-vertebrate faunachrons (Fig. 1):

1. The long duration of the Coyotean LVF, which is truly a “chronofauna” sensu Olson. This LVF needs to be subdivided, if possible.
2. The Mitchellcreekian, Redtankian and Littlecrotonian

LVFs can only be correlated over a limited geographic area (essentially Texas-Oklahoma), and tetrapod assemblages of these ages need to be discovered elsewhere.

3. The age and correlation of the Platbergian LVF with regard to the SGCS still remains a problem, because of the apparent(?) diachroneity of the lowest occurrence of Dicynodon in the South African and Russian sections.

These are three obvious places to start working to test and improve the Permian timescale based on tetrapod evolution.

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## New special issues of ICCP2007 published

The XVI International Congress on the Carboniferous and Permian (ICCP2007) was successfully held in Nanjing, China, from June 21st to June 24th, 2007. Two more special issues planned during the ICCP2007 were recently published. The first special issue has a theme “Carboniferous and Permian Biota, Integrative Stratigraphy, Sedimentology, Palaeogeography, and Palaeoclimatology”. It was edited by Xiangdong Wang, Shuzhong Shen and Ian Somerville (Wang *et al.*, eds. 2009) and published as a special issue of *Palaeoworld*.

This *Palaeoworld* special issue includes 11 papers and covers broad research aspects of the Carboniferous and Permian geology including the stratotypes, boundaries and global correlations of the Carboniferous and Permian, palaeobiological case studies, Permian palaeobiogeographical pattern and evidence of the pre-Lopingian (end-Guadalupian) biotic crisis based on rugose corals and brachiopods, and the long-term palaeoclimatic and tectonic changes of various regions during the Carboniferous and Permian. The collection of articles provides a significant and original contribution to the understanding of the amazing geological record of Carboniferous and Permian biotic and physical processes. It provided an excellent method for demonstrating the latest research achievements in the field of Carboniferous and Permian sedimentology, and promoted international exchange and cooperation in geological sciences. All papers are available online at <http://www.sciencedirect.com/science/journal/1871174X>.

The second special issue is edited by Shuzhong Shen, Charles M. Henderson and Ian Somerville and published on “Geological Journal”. It has a theme “Lopingian (Late Permian) stratigraphy of the world, major events and environmental change” and focuses on the high-resolution timescale of the Lopingian Series, Lopingian biostratigraphy and global correlation, marine and terrestrial lithofacies and biota in different regions, major biological events immediately before the Lopingian and at the end of the Changhsingian, isotopic geochemistry and Lopingian palaeobiogeography and palaeogeography. 13 papers are included in this issue, and all are available online at <http://www3.interscience.wiley.com/journal/123391514/issue>.

Thus, four special issues in total were published for the ICCP2007. Our special issues bring together a wide range of scientific work in Carboniferous and Permian aspects. They are listed below:

1. Shen Shu-zhong, Wang Xiang-dong & Erwin, D.H. (eds).

2007. Contributions to brachiopod paleontology, Permian and Carboniferous stratigraphy and end-Permian mass extinctions-in memory of Prof. Jin Yugan. *Palaeoworld* 16 (1-3):1-263.
2. Wang Yue, Zhang Hua & Wang Xiao-juan (eds). 2007. XVI International Congress on the Carboniferous and Permian, abstracts. *Journal of Stratigraphy*, vol. 31, supp. 1, p. 1-242.
  3. Wang Xiang-dong, Shen Shu-zhong & Somerville, I.D. (eds). 2009. Carboniferous and Permian biota, integrative stratigraphy, sedimentology, palaeogeography, and palaeoclimatology. *Palaeoworld*, 18(2-3):77-212.
  4. Shen Shu-zhong, Henderson, C.M. & Somerville, I.D. 2010. (eds). Lopingian (Late Permian) stratigraphy of the world, major events and environmental change. *Geological Journal*, 45(2-3):119-349.

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## Report on the second IGCP 572 field workshop, Feb. 20-26, 2010, in the Sultanate of Oman

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The IGC Program 572 aims to investigate the recovery of ecosystems following the end-Permian mass extinction through analyses of the rock and fossil records via studies of biostratigraphy, paleontology, paleoecology, sedimentology, geochemistry and biogeochemistry. A one-day meeting, February 21, 2010, was organized at the GUtech campus (Muscat area) by Michaela Bernecker. The participants and invited scientists (about 50) were welcomed by the Rector of GUtech, Prof. Dr. Burkhard Rauhut

Following a short presentation of the IGCP 572 Program by its leader Zhong Qiang Chen, the opening of the session was dedicated to the Memory of Jean Marcoux with a reminder of his scientific career and his works on the Permian and Triassic of Oman. Aymon Baud presented an introduction to the field trip, with the main topics to be discussed on the Permian-Triassic transition outcrops.

Thomas Aigner gave the Keynote lecture: Outcrop Characterization of the Khuff Formation from Production- to Exploration-scale. Zhong Qiang Chen gave a talk on “Permian-Triassic mass extinction and subsequent recovery: an ecosystem’s perspective” and Oliver Weidlich with co-authors presented a review of the Permian-Triassic Boundary in the Middle East. After coffee break following talks were held:

- End of gigantism in tropical seas by cooling: End-Guadalupian (Permian) extinction of the photosymbiotic tropical trio by Yukio Isozaki and Dunja Aljinovic.
- An unusually well preserved mollusk fauna from the earliest Triassic of South China: A unique window into the early survival phase after the end-Permian mass extinction event by Michael Hautmann et al.



Welcome to the participants at the GUtech meeting room

- Ostracods (Crustacea) and Permian -Triassic boundary events by Sylvie Crasquin.

After lunch, the afternoon session was comprised of seven talks:

- A Permian-Triassic carbonate sequence in southwestern Tibet, China and implications of dramatic environmental changes across the Permian-Triassic boundary in the oceanic setting in Neotethys by Shuzhong Shen, Yichun Zhang, Changqun Cao and Charles Henderson.



Explanations on the Wadi Aday outcrop by Oliver Weidlich (red backpack).

Group photo in front of the Saiq village





Introduction to the field trip by Aymon Baud

- End-Permian mass extinction and boundary microbialite in Upper Yangtze Region by Xinchun Liu, Xiaozheng Chen, Wei Wang, Zhuoting Liao, Yue Wang and Yuping Qi.

- Early and Middle Triassic recovery of the carbonate biofactory in the Western Tethys domain by Joachim Szulc.

- Deep water records of the Latest Permian Extinction from NW Pangea and the Tethys: Buchanan Lake versus Buday'ah by Stephen Grasby, Benoit Beauchamp and Aymon Baud

- The Middle Permian succession at Wadi Wasit Section, Oman by Charles Henderson, Alda Nicora and Aymon Baud.

- Deep water Permian-Triassic successions from Tethys: Oman Buday'ah revisited by Aymon Baud, Benoit Beauchamp, Fabrice Cordey, Stephen Grasby, Charles Henderson, Leopold Krystyn, Jean Marcoux, Alda Nicora and Sylvain Richoz.

- Upper Permian to Lower Triassic carbon isotope record in the Oman Mountains: An overview from the shallow platform to the basin by Sylvain Richoz, Aymon Baud, Leopold Krystyn, Jean Marcoux and Micha Horacek.

The talks were concluded by a round table discussion followed by a session with five posters:

- The Permian-Triassic sedimentary sequences in the External Dinarides (Croatia) by Dunja Aljinovic and Yukio Isozaki

- Carbon isotopic composition of the basinal carbonates of the Upper Permian Zechstein Limestone (Ca1) in West Poland by Tadeusz Marek Peryt and Stanislaw Halas

- Carbon and oxygen stable isotope composition of fish teeth from Lower Triassic of Spitsbergen as an environmental proxy by Blazej Blazejowski, Andrzej Gaździcki and Krzysztof Malkowski.

- Complex colonisation patterns of benthic communities in the immediate aftermath of the end-Permian mass extinction: New data from the Dolomites by Richard Hofmann, Michael Hautmann, Nicolas Gouemand, Martin Wasmer, and Hugo Bucher.

- Lower Triassic of the Julian Alps: first record of a fossil amphibian in Slovenia by Tea Kolar-Jurkovšek, Spencer G. Lucas & Bogdan Jurkovšek.

A great official dinner closed a successful first day.

A four and a half day field workshop excursion offered participants the opportunity to visit the magnificent outcrops of the Oman Mountains that provide unparalleled access to the Permian-Triassic transition units along the Gondwana margin of the Tethys. The units vary from shallow carbonate platform through tilted block margin, continental slope and abyssal plain deposits. It started on February 22 with a half day trip led by Oliver Weidlich and Michaela Bernecker to the Permian Triassic boundary of the metamorphic autochthonous unit at Wadi Aday, close to Muscat. This very interesting outcrop shows that this part of the Oman margin acts as a high where basal Triassic dolomites have been removed by erosion (basal Mahil unconformity).

The second day, February 22, was led by Aymon Baud and Sylvain Richoz. The participants moved to the Saiq Plateau locality, situated on the southern flank of the Djebel Akhdar antiform the mountain village of Saiq (about 100 km SW of Muscat, 2000 m altitude). It is one of the best exposures of the Permian-Triassic transition of the Oman Autochthonous and the type area of the Permian Saiq Formation.

The day's three stops were situated below and at an abandoned quarry (coordinates: N23°10'00" E 57° 39' 50"). The first one was situated at the top of Member B (=B4) of the Saiq Formation where Permian-Triassic transition light dolomitic mudstone is overlying dark bioclastic dolostone with rugose corals colony of Wentzelella-type. Climbing along the Induan Member C of the Saiq Formation, the participants had an opportunity to discuss new data revealed by a Late Griesbachian conodont recovered by Charles Henderson and Alda Nicora at the top of C1 Member and the implications for the overlying unconformity – erosional surface at the base of the 14m thick lithoclastic dolorudstone (C2). Lithoclast accumulation is due to rapid lithification and tectonic instability with block tilting. At the last stop in the abandoned quarry we examined an oolitic dolograinstone with hardground at the top of the Saiq Formation and a green, brown and red clay mudstone with desiccation cracks at the base of the Mahil Formation (Olenekian). On the way back, the opportunity to look at the Middle Permian spectacular giant bivalve Alatoconchida sp. level were given to interested participants.

For the third day, February 23, led by L. Krystyn, S. Richoz, A. Baud and C. Henderson, the participants went to the locality of Wadi Wasit, about 80 km south of Muscat. Wadi Wasit provides one of the best and the most extensive exposures of Permian and Triassic deep-water sediments in the allochthon of the Hawasina window. Here, the Permian to Lower Triassic Al Jil Formation consists of a 250 m thick Middle Permian volcanic-sedimentary sequence of pillow basalt with 4 main intercalations, 10 to 30 m thick, of chert, volcanic breccia, calcareous gravity flow deposits with Lower and Middle Permian shallow shelf or reef boulders and of cephalopod red lime wackestone. After a stratigraphic gap of nearly 10 My, the Lower Triassic record begins with breccias of Dienerian age followed by platy limestones of Late Dienerian to Smithian age, dated at different places by conodonts. The breccia sandwiched between Permian turbiditic and Lower Triassic platy limestone are of variable thickness and are very widespread. They are channelized, clast-supported debris flows deposits, which cut

deeply into the underlying calcareous or volcanic rocks of Middle Permian age. The first stop examined the upper 40m thick limestone of the complete section that crops out on the left side of the Wadi Wasit. New data, with the recovery of Late Capitanian conodonts, were presented by Charles Henderson. A unique, entirely calcareous breccia, which occurs 1 km south of the middle part of Wadi Wasit, includes several small-sized blocks of lowermost Triassic bivalve-bearing limestone. The largest one, with a size of about 200 m<sup>3</sup>, the Wasit block, was examined in detail at the second stop of the day, with detailed explanations made by Leopold Krystyn and Sylvain Richoz. Details were given on C isotope evolution within the basal Triassic units. This block consists of three main litho-units. The basal 6 m thick Wordian unstratified grey reefal limestone is developed as rudstone, rich in various reef-building organisms (rugose corals, calcareous sponges and



Explanation of the geology of the Saiq Plateau by the leaders: Sylvain Richoz (above) with Yukio Isozaki, and Aymon Baud (centre of photo in opposite column) with part of the group



stromatoporoids). It is disconformably overlain with sharp relief by a thin, laterally discontinuous, peloidal packstone layer dated by the conodont *H. parvus* as lowermost Triassic. The documented hiatus represents a time break of more than 10 million years. The 4 m thick upper 2 litho-units consist of Coquina Limestone resp. Bioclastic Limestone units, Griesbachian (basal Triassic) in age. In terms of biofacies the Coquina Limestone is thus called the Promyalina beds. Other fossil groups are rare; small ammonoids occur in filled cavities. Toward the top of the unit shell accumulations become less dense and *Eumorphotis* more frequent. With a further decrease in bivalve shells, the lithofacies is changed to the unit. Shell concentrations are now restricted to thin layers in irregularly stratified beds within the lower metre of the unit. The bivalve composition changes remarkably owing to the disappearance of *Promyalina* and its replacement by *Eumorphotis* and *Claraia*. The upper part of the Bioclastic Limestone consists of a single 1 m thick bed with a rich and, for the time interval, astonishingly diverse invertebrate fauna. It consists predominantly of grain- and packstone with microgastropods, echinoderms (cri-noid ossicles, "Cidaris" spines), bivalve debris, ostracods and less common juvenile ammonoids, and rare bioclastic wackestone.

The Wasit block is a unique geological archive that contains evidence of an extraordinarily rapid faunal recovery after the P-T crisis with, at the same time, an increase of  $\delta^{13}\text{C}$  isotope values from +1.2‰ in the basal Triassic transgression to 3.1‰ at the end of the Griesbachian (signifying probably an increase in productivity?) as presented by Sylvain Richoz. It also contains the most diverse Griesbachian assemblage known to date, which has a community structure not normally recorded in pre-Spathian (Early Triassic) rocks and which was created under well oxygenated conditions. This shows us that where conditions of oxygenation and productivity are favourable, a diverse fauna will be recorded.



Leopold Krystyn in front of the Wasit block, between the Coquina (right) and the Bioclastic Limestone (left).

During the fourth day, February 25, led by A. Baud, with explanations by S. Richoz, B. Beauchamp, S. Grasby, C. Henderson and L. Krystyn, the participants went to the Buday'ah area, about 150 km west of Muscat. The object was to examine the Middle Permian to Lower Triassic Buday'ah section of oceanic sediments belonging to the southern margin of the Tethys. This locality (coord.: N 23° 44' 43" E 56° 54' 21") is among the very few places of real Tethyan Permian radiolarites. The first stop looked at the truncated substratum of the sedimentary succession that includes pillow basalt erupted in the Hawasina basin far away from the continent, from truly oceanic settings, but located near hot spots. In different parts of the pillow lava succession, inter-pillow cavities are filled up with red lime-mudstone yielding conodonts, particularly near the top.



Discussion between A. Baud (left), B. Beauchamp and C. Henderson (right) on the red ammonoid limestone.

The next stop examined the red limestone and the recovered ammonoids in this interval between and at the top of the lava that indicate a Late Wordian -Capitanian age for the infilling of the volcanic sequence. Near the top of the limestone, C. Henderson and A. Nicora have recovered a new conodont fauna of latest Capitanian age. The next stop was on the red radiolarian chert resting conformably on the red limestone and laterally directly on the basalt. F. Cordey recovered 9 radiolarian associations with ages ranging from latest Capitanian to Wuchiapingian. From this stop we moved over the hill to examine the Permian-Triassic boundary interval (PTBI) that consists of dark grey siliceous shale about 2 m thick overlain by light calcareous shale about 3 m thick containing conodonts at the base that spans the Permian-Triassic boundary according to C. Henderson. S. Grasby and B. Beauchamp discussed their  $\delta^{13}\text{C}_{\text{org}}$  curve with the first shift that can be correlated with the shift found at the Permian-Triassic Boundary associated with a second spike in redox sensitive elements. The overlying unit consists of alternating yellow marly shale, cm to dm thick platy limestone and marly limestone containing Griesbachian to Dienerian conodonts. At the last stop, the participants examined the papery limestones of the upper part of the Buday'ah Formation about 7 m thick in which C. Henderson and A. Nicora recovered a Lower Olenekian conodont fauna. In the discussion we compared our Tethyan oceanic section with published Panthalassa sections, showing that all localities display radiolarian chert as the dominant type strata in the lower Late Permian. Up section, successions graded into "boundary shale" and/or black shale of various thicknesses. At the end of the day, our Chinese and some of our Polish colleagues left us to go back to the airport and we continued our trip overnight in the Emirates near Hatta. We were sorry that our Slovenian and Croatian colleagues were not allowed to enter in the Emirates.

The last day, February 26, starting from the Emirates near Hatta the participants went to the entrance of Wadi Maqam belonging to the Oman territory (coord.: N 24°46'30" E 55°51'43") to look at the Permian Triassic transition in the Sumeini area with the leaders of the day: S. Richoz, A. Baud, B. Beauchamp, S. Grasby, C. Henderson and L. Krystyn. The Sumeini Group is represented by a thick sequence (about 2500 m) of slope carbonate deposits that tectonically overlies autochthonous Eocene limestone and is overlain by sediments from the Hawasina nappes. The lower part of the Sumeini Group (about 1700 m thick) is included in the Maqam Formation (Middle Permian to Lower Jurassic), further subdivided into 6 members, A, B, C, D, E and F.

The top part of the B Member and the transition to C Member records the end Permian events. Due to the instability of the slope deposits at the end of the Permian, the Permian-Triassic transition record is variable from one outcrop to the others. The model of deposition is that of a scalloped margin and two different types of Permian-Triassic transition outcrops were seen at stops 1 and 2. The first one exposed the Wuchiapingian cherty dolostone and the basal Triassic platy dolostone. At the stop 2, situated above the dolomitization front, the participants had the opportunity to sample the most complete uppermost Permian succession with late Changhsingian conodonts, followed by the thickest boundary shale (up to 3m) of the area. The conodont *H. parvus* has been recovered at the base of the overlying papery and platy limestones



Leopold Krystyn (left), Benoit Beauchamp and Charles Henderson on the PT boundary shales



On the left, the two first leaders, Sylvain Richoz (dark blue shirt) and Aymon Baud showing the basal Triassic dolostone with a stick, just above the PTB underlined by the other stick!

Stop 3 allowed the participants to become familiarized with the Induan platy limestone succession. Sylvain Richoz presented his detailed Carbon isotope curve based on the conodont biochronology of Leopold Krystyn. Based on the Richard Twitchett's previous analysis, information on the ichnotaxa during the late Induan and early Olenekian were given with picturesque examples in the outcrop. Information on the new chemostratigraphic data were given by Stephen Grasby and Benoit Beauchamp, showing a significant drop in total carbon content, suggesting disruption of carbonate sedimentation associated with the extinction event. After lunch the participants moved to the close Wadi Shuyab to look at the upper part of the very thick (up to 900 m) Smithian platy limestone and shale succession with the spectacular development of the ichnofauna. After sample collection and a lively discussion, all the participants warmly thanked the organiz-

ers, Michaela Bernecker and Aymon Baud, for their involvement in this great field workshop and conference. Some of the participants came back to Muscat, others went to Dubai Airport and some stayed for further field studies.

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The PDF file is available at: <http://www.geo.gutech.edu.om/index.php/> Click on the dropdown for IGCP 2010 and then file IGCP 572 guidebook 2.

## Update on base-Artinskian GSSP

**Charles M. Henderson**  
SPS Chair

### Introduction

Progress on producing an actual GSSP proposal for the base-Artinskian has been slow since the report provided in *Permophiles* #41 (Chuvashov et al., 2002), but considerable data have been generated and our understanding has considerably improved. Work has focused on the Dal'ny Tulkas Section in Russia. A field workshop was conducted June 25-July 4, 2007 in order to determine the reproducibility of the three potential Lower Permian GSSP sections for the base-Sakmarian, base-Artinskian and base-Kungurian. This workshop was reported in *Permophiles* #49 (Davydov and Henderson, 2007) with Boris Chuvashov, Valeri Chernykh and Viktor Puchkov as hosts and Vladimir Davydov, Emir Gareev, Charles Henderson, Elena Kulagina, Tamra Schiappa, Mark Schmitz, Shuzhong Shen and Michael Stephenson also in attendance. Since this meeting, productive conodont samples have confirmed the FAD position of the conodont *Sweetognathus "whitei"*. We also have geochronologic ages, carbon isotopes and Sr isotopic data on conodonts that provide additional data on how to correlate the GSSP into other regions. These facts were reported in a series of communications with Galina Kotlyar in *Permophiles* #54 (2009, p. 5). These data are being published by various authors in various journals and will soon be compiled into a final proposal for voting. This short progress report is provided to the Permian community for comments. Your comments will influence final production of the voting proposal.

### Previous report (quoted from *Permophiles* #41, p. 14; Chuvashov et al., 2002)

The Sakmarian-Artinskian boundary deposits are well represented in the Dal'ny Tulkus section, a counterpart of the Usolka section. The upper part of the Sakmarian Stage (Beds 28-31) at the Usolka River and Bed 18 at the Dal'ny Tulkus Section are composed of dark-coloured marl, argillite, and carbonate mudstone, or less commonly, detrital limestone with fusulinids, radiolar-

ians, rare ammonoids, and bivalves. The upper part of the stage encloses fusulinids characteristic of the Sterlitamakian Horizon including *Pseudofusulina longa* Kir., *P. fortissima* Kir., *P. pliocatissima* Raus., *P. urdalensis* Raus. and *P. urdalensis abnormis* Raus.

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

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

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

The defining chronomorphocline can be recognized also in the lower Great Bear Cape Formation on southwestern Ellesmere Island, Sverdrup Basin, Canadian Arctic (Henderson, 1988; Beauchamp and Henderson, 1994, Mei et al., 2002) and in the Schroyer to Florence limestones of the Chase Group in Kansas, USA (Wardlaw et al., 2003; this reference is now Boardman et al., 2009).

## Current Status

The FAD of *Sweetognathus "whitei"* has been confirmed within Bed 4 (new bed numbering scheme) at 2.7 metres above the base of that bed. The species is put into quotes because a taxonomic issue remains. This *S. whitei* correlates with the chronomorphocline exhibited in the Great Bear Cape Formation in the Canadian Arctic, but apparently differs from the type *S. whitei* in the Tensleep Formation and from the chronomorphocline in the Chase Group of the North American mid-continent. This taxonomic revision is in progress and will be included in the formal proposal.

Volcanic ash beds have been dated in beds 2 and 7 that provide an extrapolated geochronologic age of 290 Ma (Schmitz and Davydov, in review).

Schmitz et al. (2009) in a presentation at the International Conodont Symposium indicated a consistent secular trend of  $^{87}\text{Sr}/^{86}\text{Sr}$  isotopic values from conodont elements through the Early Permian. The  $^{87}\text{Sr}/^{86}\text{Sr}$  isotopic value for the base-Artinskian is approximately 0.70765 (Schmitz et al., 2009).

Zeng et al. (submitted) describe the carbon isotopic values obtained from the various potential Cisuralian GSSP sites. They show a marked negative excursion from Late Sakmarian  $\delta^{13}\text{C}$  carbonate values of 0 to a long-term low value of -10 to -12. These very low values would normally be attributed to diagenesis, but the authors provide an explanation and admit that they are difficult to explain.

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

## Summary

The final proposal for the base-Artinskian provisionally indicates a GSSP at the FAD of *Sweetognathus "whitei"* within the chronomorphocline of *S. binodosus-S. anceps-S. "whitei"* at the protected Dal'ny Tulkas section in Russia approximately 2.7 metres above the base of bed 4. A geochronologic age, Sr isotopic value, and carbon isotopic trends provide additional means for correlation.

Please direct any comments regarding this updated preliminary proposal to both Charles Henderson and Shuzhong Shen by **April 15, 2011**. They will be considered as the multi-author final proposal is prepared.

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## ICCP 2011 session call for papers

We would draw your attention that the International Congress on the Carboniferous and Permian will be held this year in Perth, Western Australia, July 3-8, 2011 (<http://www.iccp2011.org>). We cordially invite you to submit an abstract to the following session:

**S1: SPS session: Permian Stage Boundaries:** GSSPs and Correlation (co-chaired by: Charles Henderson, Shuzhong Shen, Vladimir Davydov)

Session description: Six of nine Permian stages have been defined by ratified GSSPs and three are in progress. This session will discuss the definitions for all ratified and proposed stage boundaries. More importantly, this session will investigate how well these stages can be correlated into various other regions distant from the stratotypes. We invite papers on any topic including paleontology, geochemistry, magnetostratigraphy, geochronology and stable isotopic stratigraphy that addresses the definition or correlation of Permian stage boundaries.

**S6: Gondwana and Peri-Gondwana:** biotas, stratigraphy, paleoclimate and paleogeography (co-chaired by Shuzhong Shen and G.R. Shi)

Session description: This session aims to provide a forum for reporting and discussion of recent progresses on the Late Paleozoic ‘deep Gondwana’ and its peripheries. In particular, we encourage any papers relevant to the following specific topical areas:

- Near-field and far-field stratigraphic records of the Late Paleozoic Ice Age.
- Biotic responses to the Late Paleozoic Ice Age and its transitions from and into a greenhouse state.
- Gondwana glaciation and its impact on global and regional climate change.
- From Oman through Tibet to New Zealand: geodynamic and tectonic processes, associated paleoenvironmental changes and biotic responses at the interface between Gondwana and Tethys.
- Gondwana and Eurasia: inter-continental correlations, biogeographic connections and implications for the reconstruction of paleogeography and paleoclimate of Pangea.
- Pan-Gondwana Late Paleozoic stratigraphic correlations and paleogeographic reconstructions.

**Abstract deadline is April 1.**

# ANNOUNCEMENTS



## Local Organising Committee

**Convenors:**  
Zheng Qiang Chen and David Haig  
**Co-ordinator of Excursions and Technical Program:**  
Arthur Mary  
**Registration Administrator:**  
UWA Extension  
**Committee:**  
John Backhouse, Matthew Dixon, Eckart Haljanson,  
Annette George, Julie Trolter, Jenny Besan

## Key Dates

Last date for submission of abstracts: 11 February 2011  
Close of Early Bird registration: 11 February 2011  
Pre-congress excursions:  
(Canning Basin): 27 June–2 July 2011  
(Timor Leste): 28 June–1 July 2011  
Ice-breaker and Registration: 3 July 2011  
Congress (including mid-congress excursions): 4–8 July 2011  
Post-congress excursion (Perth/Cameron): 9–16 July 2011

## Call for Papers

### The XVII International Congress on the Carboniferous and Permian

[www.iccp2011.org/](http://www.iccp2011.org/)

## International Advisory Committee

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or visit the website: [www.iccp2011.org](http://www.iccp2011.org)



Geological Survey of Western Australia



Perth, Western Australia,  
3–8 July 2011

## Welcome Message

Scientists interested in all aspects of the Carboniferous and Permian are invited to Perth, Western Australia, to discuss recent advances in understanding one of the most dynamic intervals in Earth history, which includes:

- the final amalgamation and initial breakup of the Pangea supercontinent
- the last major ice-ages before those of the Quaternary
- the proliferation of terrestrial vegetation as shown in the world's major coal deposits, and, at the end of the Permian,
- the greatest known global mass extinction of animals and plants.

This Congress offers delegates an opportunity to place local and regional research in a global context and to renew and initiate links with colleagues from other parts of world.

Over the course of the 5-day congress, keynote lectures, oral and poster presentations, and discussion forums will take place. The social programme will include an icebreaker cocktail reception and a gala dinner.

The extensive excursions programme has been designed to illustrate the effects of Permo-Carboniferous climate and sea-level changes along a north-south transect into the Gondwanan interior, and includes a pre-congress excursion to Timor Leste.

## The XVII International Congress on the Carboniferous and Permian, Perth 2011

### Abstracts

Authors are invited to submit abstracts of 200-300 words by post, fax or email (preferred) by April 1, 2011. The official language of the congress will be English.

As well as talks and poster presentations, we also seek expressions of interest in hosting a thematic session and in participating in field trip(s). Please see the website for the requisite forms or contact the organisers.

### Suggested Themes

- End-Permian biotic mass extinction and early Triassic recovery
- Carboniferous and Permian geochronology
- Carboniferous and Permian macro- and microfossils; integrative stratigraphy and high resolution biostratigraphy
- Late Paleozoic floras as proxies for climate change
- Stratotypes, boundaries and global correlations
- Carboniferous and Permian reefs, biofacies, and basin analysis
- Evolutionary palaeogeography and palaeoclimatology
- Pangea formation and breakup
- Isotopic geochemistry and geobiology in the Permo-Carboniferous
- Gondwana and peri-Gondwana faunas, stratigraphy, and geology
- Bio-diversity patterns and quantitative analysis of biotic databases, computerized palaeontology
- Cyclothems and sequence-stratigraphy
- Carboniferous–Permian non-marine–marine correlations

### Venue

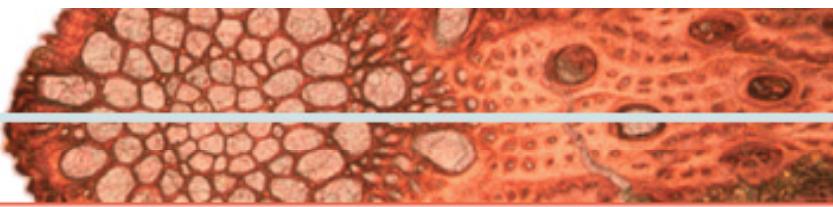
On the banks of the Swan River, within sight of Perth City and a mere six kilometres from the beautiful beaches of the Indian Ocean, lies the tranquil garden campus of The University of Western Australia. The congress will be held in the Geology and Geography building and the adjacent Undercroft of Winthrop Hall, in the heart of UWA's historic colonnaded sandstone precinct. Adjacent to the campus is Kings Park, a 400 hectare, semi-bush recreational area.

Visit [www.uwa.edu.au](http://www.uwa.edu.au) for more information on the university.

Public transport links UWA to the city, ocean beaches, and the historic port city of Fremantle, and there are shops, restaurants and accommodation near at hand.

Perth is the capital city of Australia's largest state, and enjoys a mild Mediterranean climate. July is in mid-winter when the mean daily maximum temperature is 18°C and the mean overnight minimum is 8°C. July is the wettest time of the year in Perth with an average 150 mm of rain for the month. However this is the most pleasant season to undertake field work in the warmer, semi-arid regions of the northern Perth, Carnarvon and Canning Basins and also in Timor Leste where it is the dry season. View the [www.bom.gov.au](http://www.bom.gov.au) website for more information on local climate.





## Pre-congress excursion: Northern Canning Basin Mon 27 June – Sat 2 July 2011

Guides: Arthur Mory and Roger Hocking (GSWA)

**Geology:** The excursion provides an introduction to the Lower Carboniferous and Permian exposures, and will also visit the well-exposed Upper Devonian carbonate reef complex at Windjana Gorge. Note that Artinskian and younger deposits (especially the Lower Triassic) are very poorly exposed.

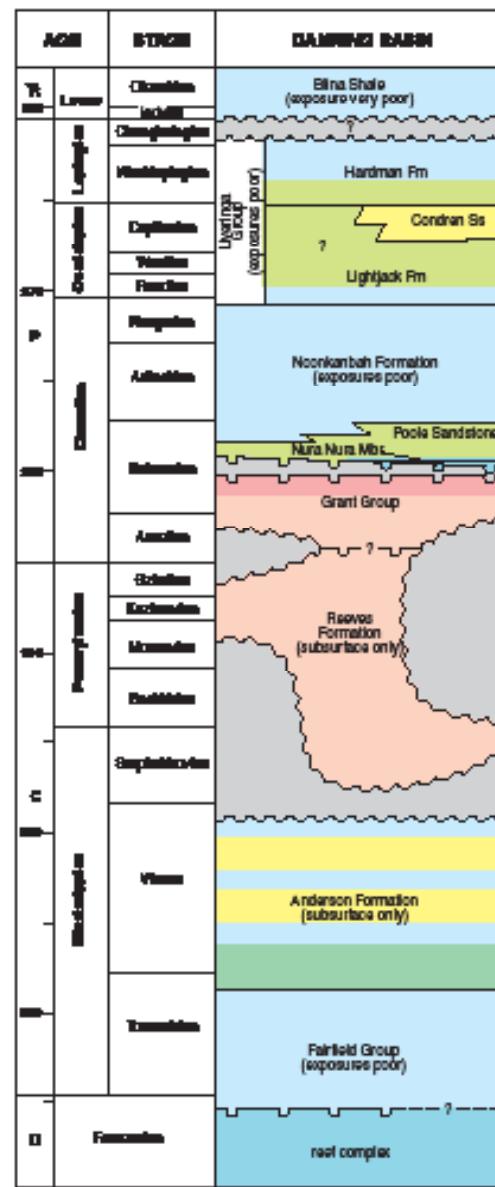
Lower Carboniferous shallow-water clastic-carbonate cycles are poorly exposed along the highway east of Fitzroy Crossing. Only the carbonate beds outcrop, and the most detailed studies are on the mostly endemic conodont, ostracod and brachiopod faunas as well as on the sedimentology.

Salmanian glacial and cyclic post-glacial siliciclastic deposits are well exposed in large anticlines in the centre of the Fitzroy Trough, but have yielded little macrofauna. The glacial deposits, along with the Upper Devonian reef complex, have been the main focus of petroleum exploration in the region, but with limited success. Fossiliferous Artinskian to Upper Permian sites will also be visited where feasible.

**Logistics:** This 6-day (5-nights) excursion starts and ends at Broome (1700 km NNE of Perth). Travel by 4WD (SUV) safari vehicles will cover about 1350 km in total. All nights will involve camping out in remote locations with no laundry facilities and limited facilities for recharging electronic items. Camping equipment will be provided as will all meals, apart from in Broome. Mobile phone coverage is limited away from Broome. Note that macrofossils have to be assessed before they can be exported under the Federal government's Protection of Movable Cultural Heritage Act 1986 ([www.deh.gov.au/heritage/movable](http://www.deh.gov.au/heritage/movable)).

**Note:** While there are at least 6 flights per day to Broome from Perth (with Qantas, Skywest and Virgin Blue, 2 hr 30 min), the only other direct connections to Broome (from Adelaide, Darwin, Sydney or Melbourne) are infrequent (2–3 flights/week).

Devonian reef complex, Windjana Gorge.



from each). It is advisable to book flights well in advance (possible to book up to 14 months in advance from Perth) as Broome is a popular tourist destination at this time of year. Similarly, unless you fly from Perth early in the morning it will be necessary to stay overnight in Broome at your own expense (<http://www.broomevisitorscentre.com.au>), and that accommodation also should be booked early (try the Broome Motel, Kimberley Klub Backpackers, the Mangrove or Oaks Resort, in order of increasing tariffs).

**Numbers:**

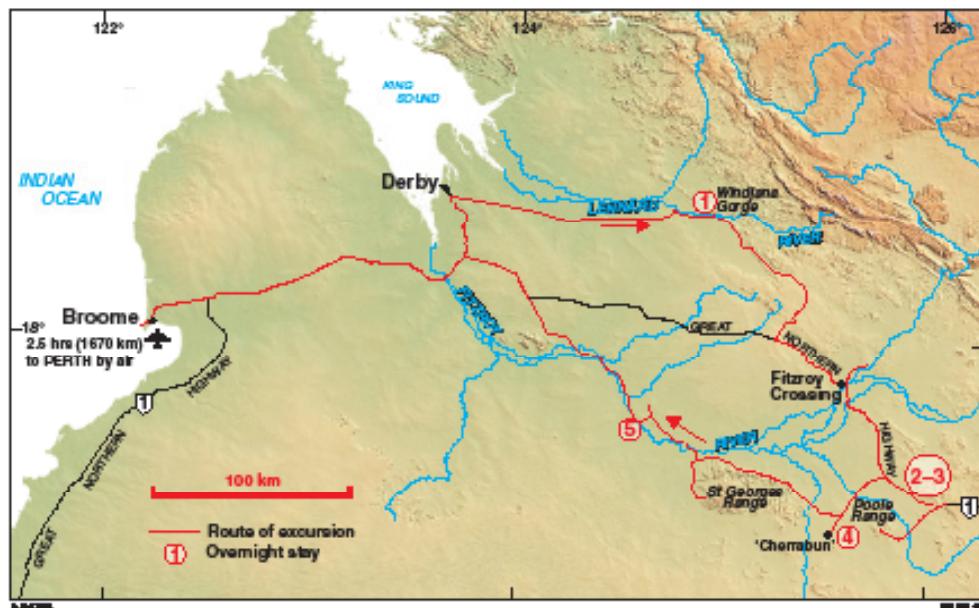
Minimum 8,  
maximum 20  
participants.

**Cost:** In the vicinity of Aus\$1750 per participant.

**Book by:** to be determined.

**Bring along:**

Boots that provide ankle protection, broad-brimmed hat, 30+ sun screen, clothes for 6 moderately warm days, pullover for evenings, towel and toiletries, camera, day pack, water bottle.



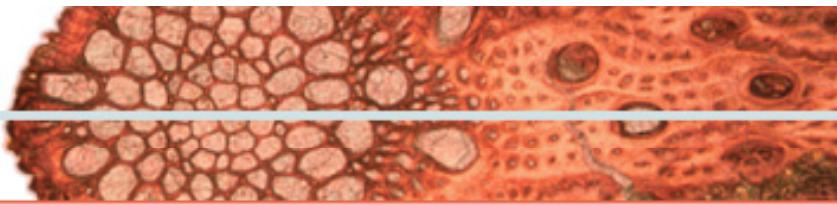
**Note:** Whilst on the excursion the opportunity to replenish personal items is limited. Similarly, mobile phone coverage is poor away from Broome and Fitzroy Crossing (Telsira's 850 MHz NextG is the only network, albeit with limited coverage, away from Broome). Facilities to recharge personal electronic items will be limited. Chargers will be provided for international participants if required.

**Recommended reading:** GSWA Records 2008/9 and 2009/5, Report 68 (can be downloaded free of charge from [http://www.iccp2011.org/GSWA\\_publications](http://www.iccp2011.org/GSWA_publications)).

**Details of Itinerary:**

Day	Date	Travel	Accommodation	Geology/Stratigraphy	Age	Localities	Total
1	Mon 27 June	Broome–Windjana Gorge	camp	travel			300
2	Tue 28 June	Windjana–Prices Creek	camp Prices Creek	reef complex, Fairfield Group	Franian–Touronian	Gorge, along highway	250
3	Wed 29 June	Mimbi–Poole Ra area	camp Prices Creek	Grant Group – Poole Ss	Salmonian	Poole Range, Desadesia	120
4	Thu 30 June	Mimbi–Cherabun	shearers quarters	Noontaknah Fm – Poole Ss	Artinskian	?Mimbi Caves, Brulen Yard, Mt Hutton	80
5	Fri 1 July	Cherabun–river campsite	camp	Poole Ss, Hardman Fm	Artinskian and Late Permian	St George Ra., Mt Hardman	240
6	Sat 2 July	To Broome, evening flight to Perth (option to stay on)		travel			300

total distance 1350

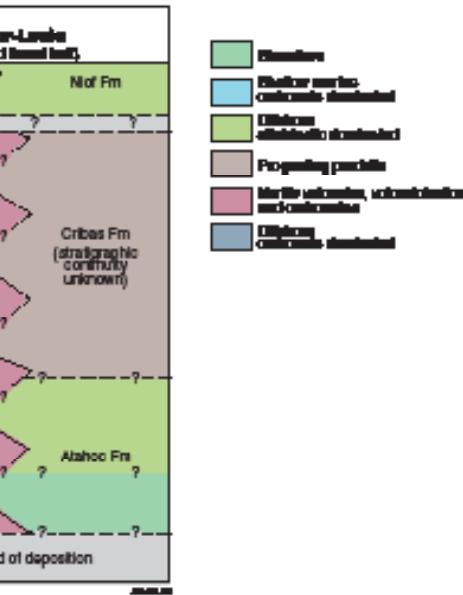


## Pre-congress excursion: Timor Leste

Sat 26 June – Fri 1 July 2011

Guides: Eujay McCourt and David Haig (UWA)

**Geology:** The excursion provides an introduction to the stratigraphy of Timor with an emphasis on the Permian. Due to structural deformation, laterally extensive and coherent sections spanning a significant time interval are rare. At this stage the stratigraphic continuity of - and the relationships between - the various facies associations are relatively poorly known. The excursion will visit Permian sections representing the major facies associations identified in East Timor including a 500 m thick Lower Permian section along the Alraun River. This largely coherent section through the core of the Crises Anticline comprises siliciclastic dominated facies associations from shoreface/lower shoreface sandstone to basinal mudstone and limestone.



- Domine
- Shallow marine
- Carbonate dominated
- Shallow
- Shallowly dolomitized
- Prograding facies
- Marine dolomitic, carbonatic and dolomitic
- Deep

In addition to Permian localities other key stratigraphic units to be visited will include: Triassic strata of the Gondwanan Megasequence; Cretaceous and Cenozoic pelagites of the post break-up Australia Margin Megasequence; Neogene strata of the Synorogenic Megasequence; and Cenozoic strata of the exotic Banda Terrane of Asian affinities.

**Logistics:** This 6-day (7-nights) excursion starts and ends at the Nova Horizonte Hotel in Dili. Accommodation (twin share) and dinner at this hotel on the 25th June and 1st July are included in the cost of the trip as is breakfast the following mornings. Travel will be by 4WD (SUV) over approximately 350 km of winding and at times rough roads. Also included are all meals, accommodation in basic hotels away from Dili, apart from two nights camping. While camping, each participant will be provided with a mosquito-proof one-man tent and mattress, as well as all non-personal camping equipment. Note that the basic hotels only have facilities for hand-washing clothes. An extensive first aid kit and qualified first aid practitioner will be on the trip.

Fossiliferous Permian limestone, Timor Leste.



Permian shales, Timor Leste.

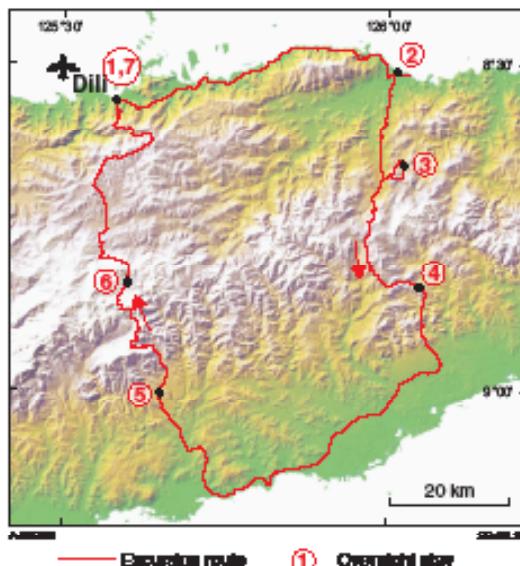


**Note:** At this stage flights to and from Dili are available every Saturday from Singapore with AustAsia Airlines, daily from Denpasar (Bali, Indonesia) with Merpati Nusantara Airlines, and daily from Darwin with Air North. There are no direct flights from Dili to Perth but daily flights via Darwin to Perth are available through Qantas, Virgin Blue and SkyWest. Another option would be via Denpasar with Merpati, and then on to Perth with another carrier (from Bali there are 3–6 flights/day to Perth). Participants require a moderate level of fitness, and comprehensive travel insurance incorporating medical evacuation provided by International SOS (<http://www.internationalsos.com/en/>).

**Numbers:** Minimum 8, maximum 10, participants.

**Cost:** In the vicinity of US\$2000 per person (does not include flights and insurance)

**Book by:** to be determined.



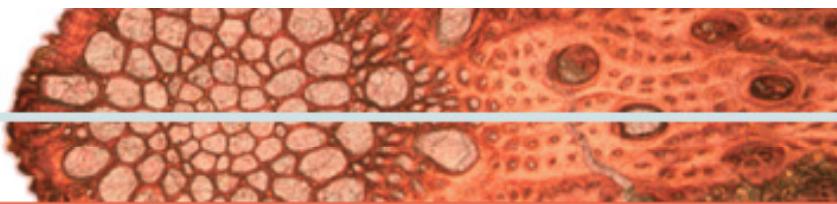
**Bring along:** Hiking footwear providing good ankle support is recommended. Access to several sections will likely require walking through knee-deep water. Temperatures will vary from moderate to hot. Laundry facilities will not be available, but washing by hand is possible on all but two nights, so light quick drying field clothes are recommended especially as no two nights are spent in the same locality. Other requirements include broad-brimmed hat, 30+ sunscreen, mosquito protection, pullover for evenings, towel and toiletries, camera, day pack, and light-weight sleeping bag. Mobile coverage during some days will be limited but there will be coverage for all but two nights. Some international mobile carriers can roam in East Timor, others cannot (check before departure), if essential, local SIM cards can be purchased by organisers prior to arrival. There should be facilities to recharge personal electronic items on all but two nights, but this cannot be guaranteed. Hammers will be provided for international participants if required.

#### Recommended reading:

- Audley-Charles, M.G., 1968. The geology of Portuguese Timor. Geological Society of London, Memoir 4.  
 Charlton, T., et al., 2002. The Permian of Timor: stratigraphy, palaeontology and palaeogeography, *Journal of Asian Earth Sciences* 20, 719–774, and literature cited in Kepp, M. and Haig D. W., 2010, Deformation and exhumation in Timor: Distinct stages of a young orogeny. *Tectonophysics*, 483, 93–111.

#### Details of itinerary:

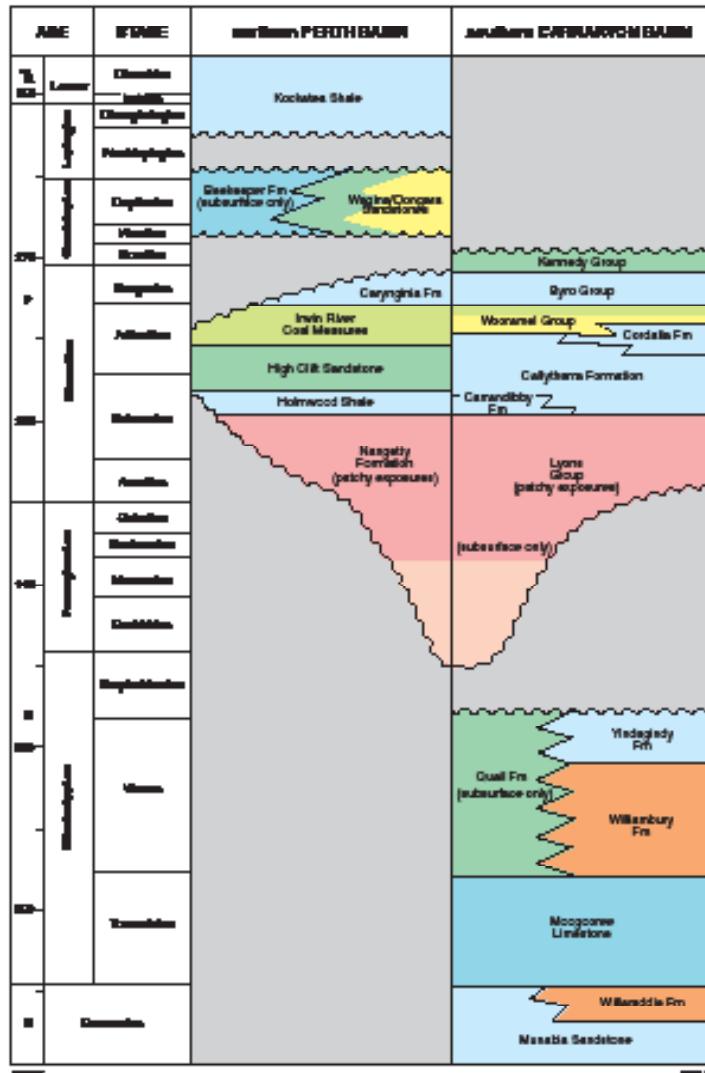
Day	Date	Travel	Accommodation	Geology/stratigraphy	Age	Localities
1	Sat 25 June	Arrive Dili	Nova Horizonte Hotel			
2	Sun 26 June	Dili-Maubisse	basic hotel	Maubisse Fm	Early Permian	Sokata River
3	Mon 27 June	Maubisse-Same	basic hotel	Maubisse & Cribas Fms	Early Permian	Maubisse Hills
4	Tue 28 June	Same-Benique	basic hotel or camp	Synorogenic & Australian Margin Megasequence, Banda Ternate	Pliocene, Cretaceous, Eocene	Same, Belano, Benique
5	Wed 29 June	Benique-Akraun River	camp riverside	Triassic Gondwana Megasequence & Cribas Fm	Late & Early Triassic, Permian	Road side, Akraun River
6	Thu 30 June	Akraun River-Manatulu	basic hotel	Cribas & Alohoc Fms	Early Permian	Akraun River
7	Fri 1 July	Manatulu-Dili	Nova Horizonte Hotel	Cribas & Maubisse Fms	Permian	Manatulu & Laleia

**Post-congress excursion: Perth-Camarvon Basins****Sat 9 - Sat 16 July 2011****Guides: David Haig (UWA) and Arthur Mory (GSWA)**

**Geology:** The excursion will visit coeval Salmanian-Arfinskian sections, 600 km apart, from both basins, as well examining cyclic clastic-carbonate shallow-water Kungurian cycles in the Camarvon Basin, and will also visit the renowned stromatolites at Shark Bay.

In this region Lower Carboniferous shallow-water clastic and carbonate facies are restricted to the Camarvon Basin but have received relatively little attention. Permian strata, by comparison, have been the focus of numerous palaeontological studies in the Camarvon Basin, and subsurface petroleum studies in the Perth Basin. Overall Permian exposures (Asselian to Roadian) of the Camarvon Basin, although dominantly siliciclastic, contain the most marine Permian facies of the Australian mainland.

**Logistics:** This 8-day (7-nights) excursion starts and ends at Perth. Travel will be by bus, with small 4WD vehicles (SUV) ferrying participants to some localities. The trip will cover about 2925 km in total. The first night and last two nights will be at hotels (twin share), but for the remainder participants will camp out in remote locations with no laundry facilities. All meals, apart from in Geraldton and Kalbarri, will be provided, as will camping equipment. Optional extras include snorkelling/glass-bottomed boat to examine modern corals at Coral Bay, fishing at Coral Bay, and a flight over Shark Bay.



Kennedy Group, eastern Kennedy Range.



Note that it is not permitted to collect any material from Shark Bay due to State government (Department of Conservation and Environment) regulations, and that macrofossils have to be assessed before they can be exported under the Federal government's Protection of Movable Cultural Heritage Act 1986 ([www.deh.gov.au/heritage/movable](http://www.deh.gov.au/heritage/movable)). Significant rainfall in the area, while uncommon in July, may make some localities too difficult to reach, especially around Kennedy Range.

**Numbers:** Minimum 14, maximum 25 participants.

**Cost:** In the vicinity of Aus\$1800 per participant.

**Book by:** March 2011

**Bring along:** Books that provide ankle protection, broad-brimmed hat, 30+ sunscreen, clothes for cool-mild days, raincoat/umbrella, pullover for evenings, towel and toiletries, camera, day pack, water bottle, and snorkelling gear for Shark Bay (water temperature ~17°C). Note that there will only be limited opportunities to replenish personal items, and mobile phone coverage is poor outside major towns north of 26°S (Telstra's 850 MHz NextG network provides the best coverage). Facilities to recharge personal electronic items and for laundry will be limited apart from the first and last two evenings. Hammers will be provided for international participants if required.

**Recommended reading:** GSWA Bulletin 133, Reports 44, 46, 51, Records 2000/10, 2005/9 (can be downloaded free of charge from [http://www.iccp2011.org/GSWA\\_publications](http://www.iccp2011.org/GSWA_publications)). Note that we will attempt to accommodate requests to visit specific localities, especially those listed in the two field guides.

#### Details of Itinerary:

Day	Date	Travel	Accommodation	Geology/Stratigraphy	Age	Localities	km
1	Sat 9 July	Perth-Mingenew	Commercial Hotel	Holmwood Sh - Carynginia Fm	Sak-Arl	Iwin River	450
2	Sun 10 July	Mingenew-Gascoyne Junction	camp	Lyons Gp, Wooramel Gp, Cundiego Fm	Sak, Arl	Coondawandy, Pells Range, Jimba Jimba	600
3	Mon 11 July	Gascoyne Junction-Moogorarie	camp at homestead	Lyons Gp, Austin Sh, Kennedy Gp	Sak, Kung-Road	Lyons River tourist area, Tokys B	170
4	Tue 12 July	Moogorarie-Middalya	camp at homestead	Lyons-Bildee, Moogorarie-Yindagindy	Sak-Arl, Tour-Vs	near Williamsbury	100
5	Wed 13 July	Middalya-Coral Bay	camp	Byro Gp	Kungurian	Wandagee, Cooloola P	200
6	Thu 14 July	Coral Bay-Carnarvon	hotel	modern coral reef	Holocene	Coral Bay	430
7	Fri 15 July	Carnarvon-Kalbarri	hotel	Modern stromatolites	Holocene	Kopje Point	280
8	Sat 16 July	Kalbarri-Perth		travel		?The Pinnacles	600
						total distance	2830





## Carboniferous-Permian Geology of the Western Australian basins

Arthur Mory

Geological Survey of Western Australia, 100 Plain Street, East Perth, WA 6004, Australia (Arthur.MORY@dmp.wa.gov.au)

Summaries of the major publications by the Geological Survey of Western Australia on the Carboniferous-Permian of Western Australian basins, of which the Perth, Carnarvon, Canning and Bonaparte Basins (Fig. 1) are the most significant, are available on the XVII ICCP website. Descriptions of major stops to be incorporated into the congress field excursions are also included in some of these publications. Although a guide book for each excursion will be published separately, these publications offer you profound background geological information for each basin. Links to these publications are also provided on the website: all can be downloaded free of charge.

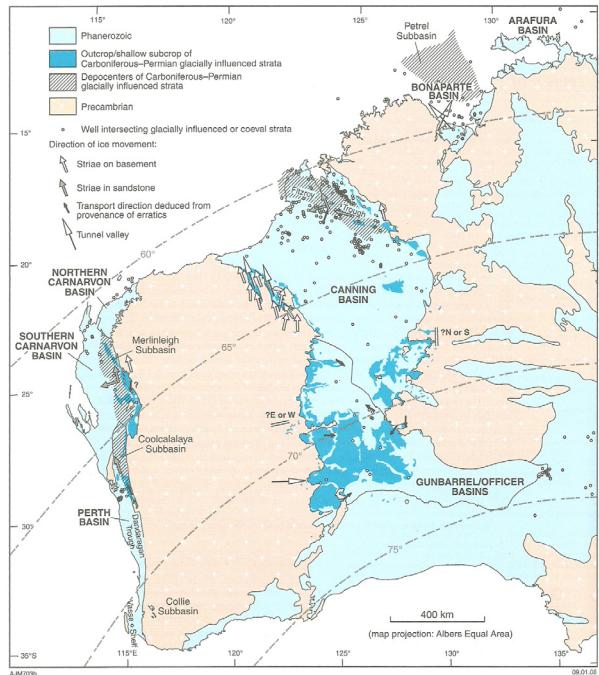
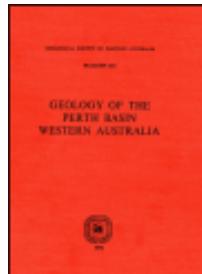


Fig. 1. Distribution of Carboniferous-Permian glacial deposits in Western Australia (after Eyles *et al.*, 2002), glacial striae directions (after Playford, 2002), 1:100,000 scale geological mapping by GSWA, and earliest Permian palaeolatitudes (after Playford, 2002).



## Geology of the Perth Basin, Western Australia

1974, Playford, PE, Cockbain, AE, and Low, GH

GSWA Bulletin 124

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=NAB124>

### Summary (part)

The Perth Basin is a deep linear trough filled with up to 15 000 m of sedimentary rocks, and extending north-south for some 1000 km along the southwest margin of Western Australia. The basin covers an area of 45 000 km<sup>2</sup> onshore and 55 000 km<sup>2</sup> offshore. Exposures are poor, and much of our knowledge of the geology is based on borehole and geophysical data from petroleum exploration. The best outcrops of older rocks are in the northern Perth Basin.

Permian and younger rocks are widespread throughout the basin. In the north, the Lower Permian succession commences with glaciogenic rocks (Nangetty Formation) followed by shale, limestone, sandstone, coal measures, and siltstone (Holmwood Shale, High Cliff Sandstone, Irwin River Coal Measures, and Carynginia Formation). The sequence, apart from the coal measures, is marine. It is overlain with slight angular unconformity by Upper Permian deposits (Wagina Sandstone). In the south the whole Permian section is continental and consists of a thick coal measures unit (Sue Coal Measures) conformably overlain by an Upper Permian to Lower Triassic sandstone (Sabina Sandstone). The total thickness of Permian rocks in the basin probably exceeds 2 600 m.

The most important elements of the economic geology of the Perth Basin are natural gas, heavy-mineral sands, and groundwater. Two gas fields, Dongara and Mondarra, [are virtually depleted, but several other smaller fields are now in production]. Dongara was the largest field, with original reserves of about 12 x 109 mJ. Production is largely from Permian sands.



## Geology of the Carnarvon Basin, Western Australia

1987, Hocking, RM, Moors, HT, Van De Graaff, WJE

GSWA Bulletin 133

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=NAB133>

### Summary (part)

The Carnarvon Basin is an epicratonic, faulted and gently folded, Phanerozoic basin which spans 1000 km along the west and northwest coast of Western Australia, and covers an area of 650 000 km<sup>2</sup>, extending to the continental/oceanic crust boundary. Onshore the basin contains up to 7 km of Palaeozoic sediments, with a Mesozoic veneer which thickens northwards and westwards, whereas the northern (largely offshore) portion contains a thick Mesozoic sequences making the succession up to 15 km thick.

In the Palaeozoic, deposition occurred in a broad, north-opening trough, the eastern half of which is preserved as the onshore portion of the Carnarvon Basin. The basin was initially an interior fracture basin in the Silurian, and developed into an interior sag basin in the Devonian. The major phases of deposition, and the sequences produced by them, are outlined below.

1. Silurian to Early Devonian — continental sandstone to shallow-marine carbonate with evaporates up to 5 km thick.

2. Middle Devonian to Early Carboniferous — shallow-marine carbonate, with fault-related continental and shallow-marine sandstone and conglomerate near the basin margin. A possible hiatus at the Devonian-Carboniferous boundary divides the sequence into a Devonian portion, about 1500 m thick, and a Lower Carboniferous portion about 600 m thick.

3. Late Carboniferous to early Late Permian — fluvial to marine-shelf sandstone, siltstone and shale with lesser carbonate. About 3 km of glacial and postglacial siliciclastics with lesser carbonate, below, are separated from about 2.5 km of deltaic to marine-shelf sandstone and shale, above, by an early Artinskian erosional hiatus. This was the last significant deposition in the onshore Carnarvon Basin.

The northern Carnarvon Basin contains the Barrow Island and Harriet oil fields, North Rankin gas field, and several other significant gas and oil accumulations, most of which are offshore. The main sources and reservoirs are Triassic or Lower Cretaceous, with Lower Cretaceous seals.

Coal exploration has centred on the Permian Woormel Group. Despite extensive exploration, only thin seams have been found, generally at depths too great for exploitation. They are not economic.



## Palaeontology of the Permian of Western Australia

1993, Skwarko, SK (ed.)

GSWA Bulletin 136

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N91A>

### Summary

This work summarizes the knowledge of Permian fossils in this State including their geographical distribution and stratigraphic range, their use in correlating and dating strata, and reconstructing paleoclimates and paleogeography.

Nine monographs, as well as numerous papers, have systematically described many species of ammonoids, bivalves, brachiopods, bryozoans, foraminifers, and gastropods. These studies were by no means exhaustive: some groups, such as the abundant trace fossils and worm trails, were completely neglected, while few crinoids and ostracods were described. On the other hand, active interest has been maintained other groups, such as brachiopods, ammonoids and palynomorphs.

In Western Australia, sedimentary rocks of Permian age occur in the Collie, Perth, Carnarvon, Canning, Browse, Bonaparte, Officer, and Eucla Basins. In most of these basins, sedimentation followed a similar pattern in which widespread accumulation of glacial deposits in Asselian-Sakmarian times was followed by the deposition of shallow-water marine sandstone and limestone alternating with terrestrial or brackish-water deposits. Sedimentation persisted possibly until the end of the Permian in the Perth Basin, into the Chhidruan (Early Tartarian) in the Canning and Bonaparte Basins, and ceased in the Kazanian or even earlier in the other basins.



## Geology of the offshore Bonaparte Basin northwestern Australia

1974, Mory, AJ

GSA Report 29

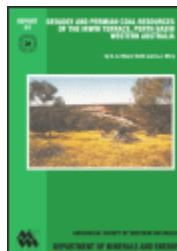
<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N91G>

### Summary (part)

The offshore part of the Bonaparte Basin extends under the Joseph Bonaparte Gulf to Ashmore Reef in the northwest, and covers an approximately triangular area of about 250 000 km<sup>2</sup>.

The oldest rocks that can be positively identified in the offshore Bonaparte Basin are Late Devonian, although Cambrian volcanic and sedimentary rocks are present in the onshore part of the basin. Devonian to Carboniferous rocks (Bonaparte Formation,

Weaber Group) in the Petrel Sub-hasin belong to a phase of mid-Phanerozoic northwest oriented rifting. The succeeding Permo-Carboniferous sequence (Kulskill and Kinmore Groups) formed during a phase of reactivated rifting and sag in which the Petrel Sub-basin continued to be the principal depocentre. In the Triassic, new depocentres developed along the northwest margin of the basin prior to northeast-oriented rifting and breakup in the Late Jurassic.



## Geology and Permian coal resources of the Irwin Terrace, Perth Basin, Western Australia

1995, Le Blanc-Smith, G, and Mory, AJ  
GSPA Report 44

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combed=N93AR>

### Summary (part)

Potentially economic coal seams of the Permian Irwin River Coalfield cover approximately 170 km<sup>2</sup> of the Irwin Terrace on the east flank of the north Perth Basin. This sub-basin contains about 1700 m of generally Permian siliciclastic rocks.

Sediment ages span Carboniferous to Early Tatarian in the Late Permian. The coals are Aktastinian. A break between the Wagina Sandstone and the underlying Carynginia Formation spans the Kungurian and Ufimian Stages.

The Irwin River Coal Measures and underlying sedimentary rocks constitute a broadly upward coarsening glaciomarine alluvial deltaic succession. The Lockier deposit in the central area of the coalfield has the best prospect for development. The coal-bearing section reaches a thickness of 76 m, and contains up to 14 m of coal in 8 seams varying between 0.1 and 8 m in width. Estimated coal resources are 1000 Mt inferred.



## Geology and Permian coal resources of the Collie Basin, Western Australia

1994, Le Blanc-Smith, G  
GSPA Report 38

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combed=N91AH>

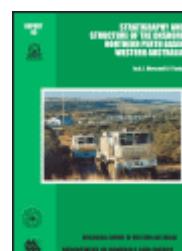
### Summary (part)

The fault-bounded Collie Basin covers 226 km<sup>2</sup> and contains about 1200 m of Permian siliciclastics. The coal-bearing section reaches a maximum thickness of 900 m, of which up to 74 m consist of coal in 60 principal seams between 0.5 and 13 m thick.

Permian stratigraphy is revised: Collie Coal Measures and Stockton Formations are raised to group status; Cardiff, Collieburn and Chicken Creek Members are discarded; new formations include Muja Coal Measures, Allanson Sandstone, Westralia Sandstone, Moorhead and Shotts Formations; the Premier and Ewington Members are raised to the rank of coal measures. Palynomorph zones indicate ages from Permo-Carboniferous to Early Kazanian.

The Ewington Coal Measures and underlying sediments constitute a broadly upwardcoarsening glaciofluvial and glaciolacustrine deltaic succession, whereas fluvial to upper delta-plain alluvial coal deposition make up the balance of the succession.

Coal is mined in four opencut and three underground mines by The Griffin Coal Mining Company Proprietary Limited and Western Collieries Limited. In the past 100 years over 100 Mt has been produced. Collie coal resources total 2400 Mt. Approximately 37% of the coal lies in the current open cut mining window.



## Stratigraphy and structure of the onshore northern Perth Basin, Western Australia

1997, Mory, AJ, and lasky, RP  
GSPA Report 46

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combed=N93AF>

### Summary (part)

The onshore northern Perth Basin is interpreted as an extensional basin on the western edge of the Australian Craton. The main sedimentary succession is Permian to Early Cretaceous in age and up to 12 000 m thick. This succession consists of:

(a) largely argillaceous Lower Permian glaciomarine to deltaic rocks,

(b) Upper Permian nonmarine and shoreline siliciclastics to shelf carbonates, and

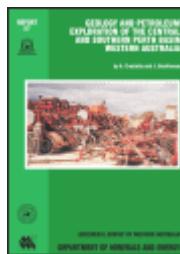
(c) Triassic to Lower Cretaceous nonmarine to shallow marine siliciclastics deposited in a predominantly regressive phase.

Analysis of structural trends indicates the basin has a complex tectonic history. Pre-existing basement fabric largely determined the pattern of faulting during the Phanerozoic phases of tectonism. Two major phases are recognized:

1. Permian extension in a southwesterly direction, and
2. Early Cretaceous transtension to the northwest during the breakup of Greater India from Australia.

The onshore northern Perth Basin contains six commercial hydrocarbon fields of which Dongara is by far the largest. Total proven reserves discovered to date are  $\sim 17 \times 10^9 \text{ m}^3$  of gas, 500 000 kL of oil and 100 000 kL of condensate.

Geohistory modelling of wells shows that the Triassic and Permian are now within the oil-maturation window. Maturation increases towards the southeast and in the southern Dandaragan Trough these units lie within the gas-maturation window. Modelling also suggests that source rocks within the northern Perth Basin reached the oil-maturation window during the period of rapid subsidence immediately before breakup in the earliest Cretaceous. All the known fields and smaller hydrocarbon accumulations are within wrench anticlines that formed in the Early Neocomian at a time that coincided with the peak period of hydrocarbon expulsion.



## Geology and petroleum exploration of the central and southern Perth Basin, Western Australia

2000, Crostella, A, and Backhouse, J

GSWA Report 57

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N97AQ>

### Summary (part)

Post-mortems of exploration wells and an overview of hydrocarbon potential are provided for the central and southern Perth Basin. No commercial fields have been discovered even though shows of gas and minor oil have been encountered in the wells drilled to date.

Although the Permian to Cretaceous stratigraphic and structural evolution of the southern Perth Basin is similar to that of the northern Perth Basin, marine intervals that break the continuity of the prevailing coarse-grained terrigenous deposits in the northern region are not present in the south, where the environment of deposition was entirely continental up until the late Neocomian. Consequently, thick regional shales are absent and the area has poor sealing potential. On the other hand, potential reservoirs, source rocks for both gas and oil, and anticlinal traps are all well documented.



## Permian stratigraphy and palynology of the Carnarvon Basin, Western Australia

1997, Mory, AJ, and Backhouse, J

GSWA Report 51

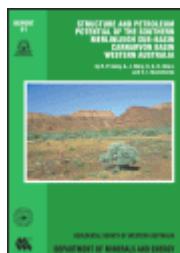
<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N95CV>

### Summary (part)

Marine to nearshore siliciclastics dominate the Permian succession of the Carnarvon Basin, and are up to 5000 m thick in the Merlinleigh Sub-basin. The basin contains a virtually uninterrupted sequence of Permian palynological zones from Stage 2 (Late Carboniferous–Asselian) to the *Dulhuntyispora parvithola* Zone (Kazanian–Tatarian), although no single well contains all zones. On the basis of these zones, the stratigraphy and age of the Carnarvon Basin Permian succession is revised from earlier work that depended on macrofossil control.

A major mid-Permian break in deposition, spanning the *Microbaculispora trisina* to *M. villosa* Zones is evident in wells on the Peedamullah Shelf. During this period over 1500 m of sediment was deposited in the Merlinleigh Sub-basin (Wooramel and Byro Groups).

The Chinty Formation, which is restricted to the Peedamullah Shelf, conformably overlies siliciclastics similar to, and coeval with, the Kennedy Group in the Merlinleigh Sub-basin and, therefore, is now included as the highest unit in the Kennedy Group. On the Peedamullah Shelf deposition of the Kennedy Group was continuous from the *Dulhuntyispora granulata* Zone into the *D. parvithola* Zone, whereas in the Merlinleigh Sub-basin there is no record of zones younger than *D. granulata*.



## Structure and petroleum potential of the southern Merlinleigh Sub-basin, Carnarvon Basin, Western Australia

1998, Iasky, RP, Mory, AJ, Ghori, KAR, Shevchenko, SI

GSWA Report 61

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N98AH>

### Summary (part)

The southern Merlinleigh Sub-basin is a northwesterly oriented ?Late Carboniferous – Permian depocentre on the eastern margin of the onshore Carnarvon Basin. Deposition began in the Silurian as part of a larger intracratonic basin and continued into the Permian. Hiatuses separate five main sedimentary cycles of ?Ordovician–Silurian, Middle Devonian to Early Carboniferous, Late Carboniferous to Permian, Cretaceous, and Tertiary age.

Three main regional tectonic events that affected most of the western margin of Western Australia are also recognized in the Merlinleigh Sub-basin:

1. west-southwesterly extension during Late Carboniferous – Early Permian rifting;

2. northwesterly extension during the breakup of Australia from Greater India in the Early Cretaceous;
  3. northerly compression during the Miocene.
- Rift faults that formed on the western margin of the southern Merlinleigh Sub-basin during Late Carboniferous – Early Permian rifting were reactivated with normal and strike-slip components during subsequent tectonic events.



## Stratigraphy and petroleum exploration objectives of the Permo-Carboniferous succession on the Barbwire Terrace and adjacent areas, northeast Canning Basin, Western Australia

1999, Apak, SN, and Backhouse, J

GSWA Report 68

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N96CQ>

### Summary (part)

The Lower Carboniferous (Upper Visean) to Lower Permian siliciclastic succession on the Barbwire Terrace of the Canning Basin and in the deeper basinal areas to the north is reinterpreted on the basis of seismic data, well logs, and palynostratigraphy. The Grant Group is restricted to the interval that can be placed in the *Pseudoreticulatispora confluens* Zone of Asselian to Tastubian (Early Permian) age. The Reeves Formation, which includes intervals previously referred as the Lower Grant Group, is the dominantly sandstone interval that underlies the Grant Group in the Fitzroy Trough, Gregory Sub-basin, and, as thin intervals, in tectonically higher areas. Four palynostratigraphic units, in ascending order, the *Grandispora maculosa*, *Spelaeotritetes ybertii*, *Diatomozonotritetes birkheadensis*, and *Deusilites tenuistriatus* Assemblages, are recognized in the Reeves Formation.

The sequence boundary at the base of the Reeves Formation or, in high areas, the Grant Group, is a regional erosional surface with large valleys, fault-controlled lows, and channels. Following the Meda Transpressional Movement, the troughs were infilled largely by a succession of debris flows, possibly derived from glacial beds, deposited in a cold water environment. The Reeves Formation infilled the troughs and extended towards the flank areas. A mild uplift took place, probably restricted to the intrabasin highs and basin flank areas, between deposition of the Reeves Formation and the Grant Group. Base-level changes, differential subsidence, and glaciation strongly influenced deposition of the Grant Group, and as the transgression progressed, broad valleys and other structural lows were infilled. Four parasequences are recognized within the Grant Group on the Barbwire Terrace. The three highest parasequences correspond to the Hoya, Calytrix, and Cianthus Formations.



## Petroleum geology of the Peedamullah Shelf and Onslow Terrace, Northern Carnarvon Basin, Western Australia

2000, Crostella, A, Iasky, RP, Blundell, KA, Yasin, AR, and Ghori, KAR

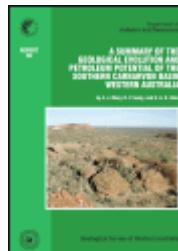
GSWA Report 73

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N96DW>

### Summary (part)

The Peedamullah Shelf and Onslow Terrace formed during Carboniferous to Jurassic rifting episodes.

Oil was sourced from the pre-Jurassic section whereas the gas, which is of biogenic origin, was from the Cretaceous section. Biogenic gas could also be present in other areas, such as the eastern part of the Exmouth Sub-basin where dry mature gas is present in basal Cretaceous reservoirs and also within Upper Cretaceous levels. Hydrocarbons on the Peedamullah Shelf and Onslow Terrace did not migrate into the area from the Barrow Sub-basin, as previously believed, because the oil from this latter area was sourced from Upper Jurassic rocks.



## A summary of the geological evolution and petroleum potential of the Southern Carnarvon Basin, Western Australia

2003, Mory, AJ, Iasky, RP, and Ghori, KAR

GSWA Report 86

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N98DQ>

### Summary (part)

The Southern Carnarvon Basin consists of two main regions: a western platform (Gascoyne Platform) with a ?Cambrian to Lower Carboniferous succession that has mostly flat-lying Cretaceous–Cainozoic cover; and an eastern set of halfgrabens (Merlinleigh and Byro Sub-basins) forming a single mid-Carboniferous – Permian depocentre, now separated by gneissic basement of the Carrandibby Inlier. The Merlinleigh Sub-basin shares a Devonian to Lower Carboniferous succession with the Gascoyne Platform, but the two regions otherwise have little in common. The low thermal maturity of the Silurian section implies little, if any, mid-Carboniferous – Permian deposition across the Gascoyne Platform, whereas up to 5000 m of strata of that age were deposited in the Merlinleigh and Byro Sub-basins. The major tectonic events in the basin, evident

from seismic and outcrop data, were in the mid-Carboniferous – Early Permian, mid- to Late Permian, Early Cretaceous, and early Neogene. These periods of faulting and folding are consistent with AFTA and vitrinite reflectance data from the Gascoyne Platform, which indicate palaeothermal-cooling episodes during the Permian, Late Jurassic, and early Neogene. No regional deformation is apparent prior to the mid-Carboniferous.

Geochemical analyses indicate that the best petroleum source beds are within the Silurian Coburn Formation, Devonian Gneudna Formation, and Lower Permian Wooramel and Byro Groups. However, Silurian and Devonian source beds are thin and probably of limited extent. By comparison, Permian source beds within the Merlinleigh and Byro Sub-basins appear to be thick and widespread. Geohistory modelling indicates that petroleum generation (and consequently migration) from Silurian and Devonian source beds peaked during the Permian, whereas generation from Permian source beds peaked during the Triassic. Therefore, on the Gascoyne Platform, mid-Carboniferous – Early Permian structures are the most prospective, even though they may have been breached by the later tectonic events, whereas hydrocarbon accumulations within the Merlinleigh and Byro Subbasins are likely only in younger structures of Early Cretaceous or Miocene age.



## Geology and Permian coal resources of the Vasse River Coalfield, Perth Basin, Western Australia

1998, Le Blanc-Smith, G, and Kristensen, S

GSWA Record 1998/7

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N95BF>

### Summary (part)

Exploration in the southern Perth Basin has located potentially economic coal seams of the Permian Vasse River Coalfield on the Treeton Terrace — an upthrown block of the Vasse Shelf, which lies west of the Bunbury Trough in the southern Perth Basin. The terrace contains over 1800 m of Permian strata, including coal measures.

In the revised Permian stratigraphy, the glacial Lower Permian Mosswood Formation (new name) underlies the Sue Coal Measures, which is here elevated to the Sue Group and contains the following newly recognized formations (in ascending order): the Lower Permian Woodynook Sandstone, Rosabrook Coal Measures, and Ashbrook Sandstone; and the Upper Permian Redgate Coal Measures and Willespie Formation. Palynological studies indicate that the succession spans almost the entire Permian from the Asselian to the Dzhulfian.

The Mosswood Formation, Woodynook Sandstone and Rosabrook Coal Measures form a glacially influenced, upward-coarsening, lacustrine, deltaic and fluvial succession. Fluvial to alluvial upper delta-plain deposits with thin coal seams make up the balance of

the succession.

There are up to sixty coal seams ranging in thickness from 0.1 to 4.5 m in a section over 1000 m thick, and these seams show significant variation in extent and quality. Coal rank increases with depth from (meta) sub-bituminous to (hypo) bituminous and the type is humic. Inferred resources of coal (Class 1) are estimated at 500 Mt, but the seams are too deep to be mined by open-cut methods.



## Geology of the Southern Carnarvon Basin, Western Australia - a field guide

2000, Hocking, RM

GSWA Record 2000/10

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N97BS>

### Summary (part)

This field guide is designed to be used in conjunction with Bulletin 133 of the Geological Survey of Western Australia and with the various maps and Explanatory Notes for the 1:250 000 Geological Series of the Carnarvon Basin.

With a few exceptions, the localities are grouped and sequenced by age, and then geographical proximity.

This guide was originally prepared in 1990 (Hocking, 1990a), and has been revised to incorporate a new cycle of work by the GSWA.



## Geology of the northern Perth Basin, Western Australia — a field guide

2005, Mory, AJ, Haig, DW, McLoughlin, S, and Hocking RM

GSWA Record 2005/9

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N05C>

### Summary (part)

The northern Perth Basin lies between about 27° and 31°30'S adjacent to the Yilgarn Craton on the western margin of Western Australia. The basin contains up to 12 km of Ordovician and mid-Carboniferous to Cretaceous, primarily nonmarine to shallow-marine strata below extensive thin, mostly non-marine, Cenozoic cover. This guide describes 37 localities in the basin, from Kalbarri to Gingin, and emphasizes stratigraphy, sedimentology, and palaeontology. These localities constitute the key exposures of the pre-Cenozoic succession in the basin and include most of the type sections defined in outcrop.



## AESC field guide: Palaeozoic geology of the Canning Basin

2008, Hocking, RM, Playford, PE, Haines, P, and Mory, AJ

GSWA Record 2008/18

<http://geodocs.doir.wa.gov.au/search.jsp?cabinetId=1101&Combined=N08AG>

### Summary

The best, and most easily accessed, exposures are in the north of the basin within the Lennard Shelf and Fitzroy Trough. These include highly fossiliferous Lower Ordovician marine strata, the extremely well exposed Middle and Upper Devonian carbonate reef complexes, and Lower Permian glacial and deltaic siliciclastic rocks.

## SUBMISSION GUIDELINES FOR ISSUE 56

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Submission Deadline for Issue 56 is  
Friday, July 1, 2011

## Permian Time Scale

AGE (Ma)	Epoch/Stage	Polarity Chron	Conodonts	Fusulinaceans	Ammonoids	Vertebrates	Main Seq. T R
250	<b>Triassic</b>		<i>Isarcicella</i>		<i>Ophiceras</i>		
252	Changhsingian	252.16 +/- .06	<i>Hindeodus parvus</i> <i>C. zhejiangensis</i> <i>C. meishanensis</i> <i>C. yihangxingensis</i> <i>C. subcarinata</i> <i>C. wangi</i> <i>C. longicuspidata</i>	<i>Palaeofusulina sinensis</i>	<i>Otoceras</i>	<i>Rotodiscoceras</i> <i>Pseudotriolites</i> <i>Pseudostephanites</i>	
254	Lopingian	254.2+/- .07	<i>C. orientalis</i> <i>C. transcaucasica</i> <i>C. guangyuanensis</i> <i>C. leveni</i> <i>C. asymmetrica</i> <i>C. dukouensis</i> <i>C. postbitteri postbitteri</i>	<i>Palaeofusulina minima</i>		<i>Paratirolites</i>	
256	Wuchiapingian		<i>C. postbitteri hongshuensis</i> <i>J. granti</i> <i>J. xuanhanensis</i> <i>J. altaudensis</i> <i>J. shannoni</i>	<i>Codonofusiella</i>		<i>Sangyangites</i> <i>Araxoceras</i> <i>Anderssonoceras</i>	
258		260.0 +/- .7	<i>J. postbitteri</i>	<i>Colaniella</i>		<i>Roadoceras</i> <i>Doulingoceras</i>	
260	<b>Capitanian</b>		<i>J. postserrata</i>	<i>Lepidolina</i>		<i>Timorites</i>	
262							
264							
266	Guadalupian	265.8 +/- .7 Illawarra	<i>Sw.=Sweetognathus N.= Neostreptognathodus M.= Mesogondolella J.= Jingondolella</i>	<i>Yabeina</i>			
268	Wordian		<i>N. neoschwagerina margaritae</i>				
270		270.0 +/- .7	<i>Afghanella schencki</i>				
272	Roadian		<i>Neoschwagerina craticulifera</i>			<i>Waagenoceras</i>	
274				<i>Neoschwagerina simplex</i>		<i>Paraceltites</i>	
276		275.0 +/- .7	<i>M. lamberti</i> <i>N. sulcoplicatus</i> <i>M. idahoensis</i>	<i>Cancellina</i>		<i>Demarezites</i>	
278	Cisuralian		<i>Sw. guizhouensis</i>	<i>Armenina</i>			
280	Kungurian		<i>N. prayi</i>	<i>Misellina</i>		<i>Pseudovidrioceras</i>	
282		282.0 +/- 1.0	<i>N. pseudoclinalis</i>			<i>Propinacoceras</i>	
284			<i>N. pnevi</i>	<i>Brevaxina</i>			
286	Artinskian		<i>N. pequopensis</i>	<i>Chalaroschwagerina Pamirina</i> <i>Parafusulina</i>		<i>Uraloceras</i>	
288			<i>Sw. clarki</i>	<i>Pseudofusulina solidissima</i>		<i>Aktubinskia Artinskia</i>	
290	Sakmarian	290.0 +/- .26	<i>Sw. whitei</i> <i>Sw. anceps</i>	<i>Pseudofusulina juresanensis</i>		<i>Popanoceras</i>	
292			<i>M. bisselli</i> <i>M. visibilis</i> <i>M. lata</i> <i>Sw. binodosus</i>	<i>Pseudofusulina pedissequa</i>		<i>Uraloceras</i> <i>Metalegoceras</i> <i>Properrinites</i>	
294		295.0 +/- .18	<i>Sw. merrilli</i> <i>M. uralensis</i> <i>S. postfusus</i> <i>M. pseudostrigata</i> <i>M. striata</i> <i>S. fusus</i> <i>M. constrictus</i> <i>M. belladontae</i> <i>S. sigmoidalis</i> <i>S. cristellaris</i> <i>S. glomerata</i> <i>I. isolitus</i>	<i>Leeina urdalensis</i>		<i>Sakmarites</i>	
296	Asselian			<i>Leeina vermuelli</i>		<i>Juresanites</i>	
298		298.7 +/- .15	<i>S. Streptognathodus</i>	<i>Sakmarella moelleri</i> <i>Sphaeroschwagerina sphaerica</i> <i>Pseudoschwagerina uddeni</i> <i>Sphaeroschwagerina moelleri</i> <i>Globifusulina nux</i> <i>Sphaeroschwagerina fusiformis</i>		<i>Svetlanoceras</i>	
300	Carboniferous		<i>S. = Streptognathodus</i>	<i>Ultradaixina bosbytauensis</i>		<i>Shumardites</i> <i>Emilites</i>	

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