Permophiles

International Commission on Stratigraphy
International Union of Geological Sciences

Newsletter of the
Subcommission on Permian Stratigraphy
Number 45
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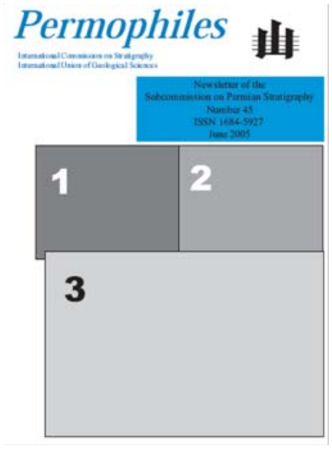
June 2005

Contents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1 and 2. Both photos were taken at the IGC meeting in Florence Italy during August 2004; 1 includes three SPS Chairmen including former Chairmen Jin Yugan and Bruce Wardlaw and current SPS Chairman Charles Henderson between; 2 includes the current SPS Executive with Vladimir Davydov, Charles Henderson and Shuzhong Shen. 3. Photo taken at Choahu, China during a mid-meeting fieldtrip associated with the “Triassic Chronostratigraphy and Biotic Recovery” meeting during May 2005. The photo depicts current SPS Chairman Charles Henderson (standing on Permian rocks) shaking hands with current STS Chairman Michael Orchard (standing on Triassic rocks) with their hands meeting at the P-T boundary. The photo shows that despite disagreements about conodont generic assignments there remains friendly communication between the two subcommissions.

EXECUTIVE NOTES

Notes from the SPS Secretary

Introduction and thanks

I want to thank those individuals who contributed articles or notes for inclusion in the 45th issue of Permophiles. Charles Henderson and I did all of the editorial work for this issue editing during 10 days from May 26th to June 4th in Nanjing. We thank Alfredo Arche, Donald Boyd and Ernest Gilmour for financial contributions to the Permophiles publication fund in support of this issue. Permophiles is recognized by the ICS as an exceptional newsletter and the continuing support of our readers is necessary to maintain that quality. ***Permophiles*** is expensive to prepare and mail; donations do not meet our current costs. We would like to reduce this cost by sending as many copies as possible via email as a PDF document so that individuals could print the issue themselves. If you are willing and able (receive a 2-4 MB file and have access to a printer) to do this then ***please send an email to me***. Send to szshen@nigpas.ac.cn or shen_shuzhong@yahoo.com and indicate your willingness. We will continue to supply printed copies to those who are unable to receive the PDF version as well as to libraries. This should reduce costs and allow for more timely distribution.

Previous SPS Meeting and Minutes

An official SPS workshop was held in conjunction with the International Symposium on Triassic Chronostratigraphy and Biotic Recovery at Chaohu, Anhui Province, China on May 24, 2005. Some abstracts related to the Permian issues are selected and published in this issue. The individuals in attendance at this meeting included the General Secretary of ICS, Jim Ogg, SPS Chair (Charles M. Henderson), Vice-Chair (Vladimir I. Davydov), Secretary (Shuzhong Shen), Aymon Baud, David Bottjer, Jun Chen, Songzhu Gu, Micha Horacek, Yukio Isozaki, Yugan Jin, Leopold Krystyn, Christopher A. McRoberts, Manfred Menning, Robert S. Nicoll, Yuanqiao Peng, Yiping Qi, Richard J. Twitchett, Jinnan Tong, Valery Ja. Vuks, Bruce R. Wardlaw, Chunjiang Wang, Yue Wang, Oliver Weidlich, Jianxin Yao, Hongfu Yin, Mike Orchard, Yuri D. Zakharov, Laishi Zhao and Jingxin Zuo. The workshop was chaired by Charles M. Henderson. He announced that the proposal of the Changhsingian-base GSSP at the Meishan Section D has been passed by the voting of ICS members and is in the process of final ratification by IUGS; this means that only three GSSPs (Sakmarian-base, Artinskian-base and Kungurian-base) in the Cisuralian remain to be defined. The current priority of SPS is to complete these three remaining GSSP's and then move our efforts to solve interregional correlations of the Permian System and other related issues. These include interregional and interprovincial correlations that are being addressed by two working groups including the "Transitional Biotas as Gateways for Global Change" working group chaired by Guang R. Shi and the "Neotethys, Palaeotethys, S. China intraplatform basin correlations" working group co-chaired by Heinz Kozur and Vladimir Davydov. In addition, an increasingly important priority of SPS will be to focus on correlations into continental successions through the efforts of the "Non-marine – Marine Correlation" working group chaired by Joerg Schneider.

Future issues of Permophiles

The next issue of ***Permophiles*** (Issue 46) is scheduled for late October 2005, which will be prepared by Charles Henderson and me in Calgary, Canada. Everyone is encouraged to submit manuscripts, announcements or communications before October 14, 2005. Manuscripts and figures can be submitted via my email address (szshen@nigpas.ac.cn; or shen_shuzhong@yahoo.com) as attachments or by our SPS website (http://www.nigpas.ac.cn/permian/web/index.asp). Hard copies by regular mail do not need to be sent unless requested. However, large electronic files such as plates in Photoshop or tif format may be sent to me on discs or hard copies of good quality under my mailing address below. Alternatively, large files can also be transferred via the submitting system on our SPS website. Please follow the format on Page 4 of this issue.

I currently use a Windows XP PC with CorelDraw 9 or 11, Adobe Page Maker 7.0, Adobe Photoshop 7 and Microsoft Office XP programs. Documents compatible with these specifications will be easier to work with.

Future SPS Meeting and IPC2006

1) The next scheduled SPS meeting will be held in conjunction with 'The Nonmarine Permian" to be held at Albuquerque, New Mexico, USA, between October 21-29, 2005. Dr. Spencer Lucas is the convener. Persons interested in this meeting please contact the following address:
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E-mail: slucas@nmmnh.state.nm.us
Web-site: www.NMnaturalhistory.org

2) The Second International Palaeontological Congress will be held at Peking University between June 17–21, 2006 (IPC2006), Beijing, China. This congress follows the first IPC2002 held in Sydney, Australia, and will focus on a series of scientific sessions and symposia devoted to new research findings in paleontology and related academic disciplines, with emphasis on the congress theme of "***Ancient Life and Modern Approaches***". A series of extremely wide-ranging sessions and an attractive fieldtrip program including to some world famous localities of extraordinarily preserved fossil organisms in China will be arranged. In addition, many tourist and social activities in Beijing will also be available to create an exciting and memorable time for your trip to China.

The First Circular of this congress is included in this issue (see p. 39). For further information of the congress including the First Circular, Pre-Registration and Reply Form, please visit our

congress website and download related files at: www.ipc2006.ac.cn. Persons interested in this meeting please contact the following address:
Secretary, Executive Committee of IPC 2006, Nanjing Institute of Geology & Palaeontology, Chinese Academy of Sciences, 39 East Beijing Road, Nanjing 210008, People's Republic of China; Phone: +86-25-83282221; Fax: +86-25-83357026; E-mail: IPC2006@nigpas.ac.cn; Website: www.ipc2006.ac.cn.

Report on the SPS vote for the Wuchiapingian-Changhsingian boundary

The Wuchiapingian-Changhsingian boundary proposal had been revised following an initial ICS Executive review (winter, 2004-05), then transmitted to ICS for final voting during February-March 2005. The voting by the Permian Subcommission was 15 "Yes" and 1 "No". The votes received from the International Commission on Stratigraphy were 12 "Yes" (80%). Three members officially "Abstained" (20%) or did not respond (two members).

The ICS submitted this GSSP for the base of the Changhsingian Stage of the Upper Permian Lopingian Series to the IUGS for ratification during late March. A modified form of this proposal will be published in ***Episodes*** following final ratification.

SPS Website is now online

Charles Henderson and I established a new website for SPS at http://www.nigpas.ac.cn/permian/web/index.asp. The SPS website provides information on activities of the SPS, events and meetings, the organization of SPS, the progress of GSSP's related to the Permian stages and various working groups as well as all issues of interest to Permophiles. It also provides links to useful partner organizations such as IUGS, ICS, the Permian Research Institute at Boise State University, and the Late Palaeozoic Research Group at Nanjing Institute of Geology and Palaeontology. We have also designed a PermoForum on the website, with the goal to stimulate on-line discussions by members of the Permian community to share ideas and thoughts. The username and password to enter this PermoForum are respectively ***SPS (username)*** and ***wangi (password)***. In addition, you can download all of the previously published Permophiles issues. The PDF versions of some previous Permophiles issues are not yet available. I will scan those issues and make the list complete as soon as possible. We have also designed an online manuscript submitting system. This is particularly useful for some large files. The maximum file that can be transferred is 50MB. The preferred method is to continue to send your files by email.

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Notes from the SPS Chair

Charles M. Henderson

This is the first issue of Permophiles to be compiled by your new executive. For the first time the Vice-Chair, Vladimir Davydov, has also provided some notes about his ideas for the subcommission and I would like to repeat his appeal for SPS members to communicate with us about your ideas for the future of SPS. I will be attending an ICS workshop at the beginning of September 2005 in Leuven, Belgium on your behalf to discuss the future of stratigraphic research, particularly by the ICS and its component subcommissions, so any comments before then would be especially timely.

The SPS Secretary, Shuzhong Shen, in his notes provided the minutes from the last SPS business meeting at Chaohu, China during late May. He reminded us of some of the priorities for the subcommission over the next few years. Our first priority is to complete the GSSP process by ratifying proposals for the base-Sakmarian, base-Artinskian, and base-Kungurian prior to the next IGC meeting in Norway in 2008. Preliminary proposals for each can be found in Permophiles 41. Progress has been made subsequently, but perhaps not rapidly enough to achieve our primary goal. To that end, I have initiated the process of setting up a Cisuralian Workshop, which is tentatively set for July 25 – August 4, 2006 in the southern Urals regions (see map provided by V. Davydov on next page). Vladimir Davydov has contacted Boris Chuvashov, Chair of Cisuralian Working Group, and he is in agreement to set up this workshop. In addition, Galina Kotlyar and Olga Kossavaya will help organize this session because of a previous research initiative between their institute at St. Petersburg and the Nanjing Institute of Geology and Palaeontology. This workshop will be limited to a maximum of twenty people, which is the normal maximum size for a Working Group and a logistical limit for the fieldtrip. Some people have already been invited, but the membership has not been finalized. I invite anyone who has worked extensively on the Cisuralian (Lower Permian) and interested to contribute to this workshop to contact me via email. The membership will be announced in the next issue of Permophiles. Those members that attend the workshop will become the voting members of the working group and will be charged with producing a formal proposal suitable to SPS voting and honourary members. The trip will probably end at Aidaralash, Kazakhstan to celebrate the production of a permanent display for the base-Permian GSSP.

Permophiles 45 will be mailed to many of you again, but this practice will not continue much longer without additional donations. We have added a new donation page to reflect this reality. Each issue, including printing and postage, costs about $1500 (Can); this does not take into account the travel costs of the Chair and/or Secretary. We received about $1000 (Can) from ICS this year. I'll let you do the math. We would like to reduce our mailings to about 50 or so institution libraries and individuals to receive the PDF version.

During production of Permophiles 45 in Nanjing we completed another important task of bringing online our new SPS website devoted exclusively to the business of the Permian. The website url is http://www.nigpas.ac.cn/permian/web/index.asp and is hosted by the Nanjing Institute of Geology and Palaeontology. This site will have all of the issues of Permophiles soon and already has many others in PDF format. It also has a PermoForum to serve as a discussion group. Shuzhong and I invite you to visit the site, add it to your favourites list, and please let us know if you encounter any problems. Finally, I would like to thank Shuzhong for his help in producing this issue and all of the logistical support that he has provided during this trip.

Our next business meeting is in association with the "Nonmarine Permian" meeting in Albuquerque during late October 2005 (see announcements this issue). This meeting, among others (see reports this issue), will contribute significantly toward one of the next major priorities for SPS, that of correlating our marine succession with the non-marine. I look forward to seeing many of you there.

Has your address changed since you last received Permophiles?

Please email or send any address changes to:

Email: szshen@nigpas.ac.cn or
shen_shuzhong@yahoo.com

Mailing address:

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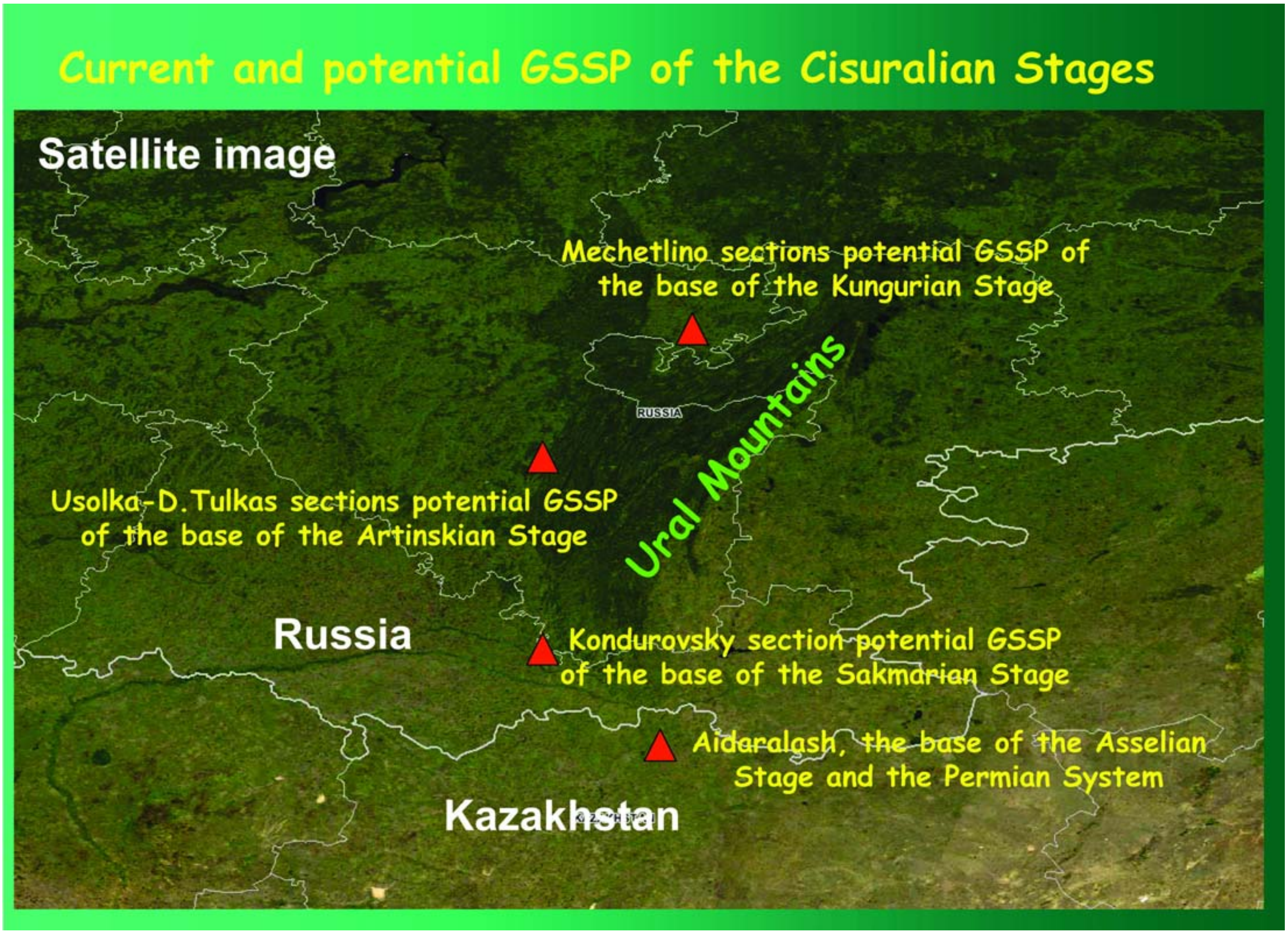
Fig. 1. Location of proposed Cisuralian Workshop fieldtrip.



Notes from the SPS Vice-Chair

Vladimir I. Davydov

The process of establishing GSSP's for the entire Permian is nearly complete and it is expected that by 2008 all GSSP's for the International Permian Time scale will be defined and officially ratified. It is therefore time to start to think about future directions for Permian stratigraphic research. The most important step for determining this direction is input from the international community of geologists and paleontologists working on the Permian. Thus, the SPS executive encourages everybody to send your notes, ideas or proposals for future steps for the Permian Subcommission. We will consider all of them, even exotic ones, and will publish a review of these proposals in a future issue of Permophiles. As a first step, we propose some new ideas about possible working groups that relate to recent challenges in Permian chronostratigraphy.

1. A Geochemistry Working Group could focus on analyzing accurate and biostratigraphically/chronostratigraphically well constrained geochemistry data, including carbon, organic

geochemical curves for the entire Permian. The existing composite geochemical curves are built on isolated samples from different localities, and are poorly constrained either biostratigraphically or radiometrically; these curves are not supported by independent studies. There are many varieties of datasets available, especially in the uppermost Permian, but sometimes it is difficult to recognize the value of these datasets in terms of biostratigraphy or chronostratigraphy and in terms of technique. The proposed group will first evaluate existing datasets and publish this review/evaluation along with a plan or recommendations for further geochemical studies. A major goal of this GWG would be to coordinate attempts to fully collaborate with paleontologists and geochronologists. Finally, this GWG would ensure that all of these valuable data be integrated into web accessible databases, such as Paleostrat or EarthRef, in order that composite sections may be built for the entire Permian based on CONOP, RASC/CASP or GraphCor quantitative correlation tools.

2. A Radioisotopic Working Group could focus on providing an accurate and biostratigraphically/chronostratigraphically well constrained radiometric calibration (U/Pb, Ar/Ar and Rn/Os) for the Permian time scale and events. This group would work in conjunction with the NSF EarthTime Initiative. Dr. Mark Schmitz, from Boise State University, is in charge of Upper Paleozoic study within EarthTime and he would be the best candidate to lead this group. This RWG will tightly integrate their work with that of paleontologists and sedimentologists and will search for volcanic ash beds within biostratigraphically well constrained marine, paralic or continental successions throughout the world. It is important to keep in mind that radiometric calibration is one of the most promising ways to provide direct correlation between marine and continental sequences as well as between different biogeographic provinces.
3. A third possible working group could be directed to recognize possible astronomical cycles in the Permian. It is hard to distinguish differences between eccentricity and tectonic signals and therefore the best places to look for an astronomical signature would be on platforms like the USA MidContinent, Moscow Basin and Timan-Pechora Basin for the Cisuralian and South China for the entire Permian. This group will work closely with the two previous groups to tie possible astronomical cycles to the chronostratigraphic scale.
4. Finally a working group could be formed to establish a set of composite sections for the main geological regions. This group may have less attraction to Permian researchers, as it would mostly deal with data compilation. However, this group may have support from the petroleum or mining industry or international projects that are eagerly looking for such data. It would be essential for all data compiled by this working group to be stored in Web accessible databases, such as Paleostrat and Stratigraphy net.

SUBMISSION GUIDELINES FOR ISSUE 46

It is best to submit manuscripts as attachments to E-mail messages. Please send messages and manuscripts to my E-mail address; hard copies by regular mail do not need to be sent unless requested. Please only send a single version by E-mail or in the mail; if you discover corrections before the deadline, then you may resubmit, but indicate the file name of the previous version that should be deleted. Manuscripts may also be sent to the address below on diskettes (zip disks, or CD) prepared with a recent version of WordPerfect or Microsoft Word; printed hard copies should accompany the diskettes. Word processing files should have no personalized fonts or other code and should be prepared in single column format. Specific and generic names should be *italicized*. Please refer to recent issues of Permophiles (*e.g*. Wang and Henderson, Permophiles #43, p. 5) for reference style, format, *etc*. Maps and other illustrations are acceptable in tiff, jpeg, eps, bitmap format or as CorelDraw or Adobe Illustrator files. The preferred formats for Adobe Pagemaker are Microsoft Word documents and bitmap images. We use Times Roman 12 pt. bold for title and author and 10 pt. for addresses and text (you should too!). Indents for paragraphs are .20"; do not use your spacebar. Word processing documents may include figures embedded at the end of the text, but these figures should also be attached as separate attachments as bitmaps or as CorelDraw or Adobe Illustrator files. Do not include figure captions as part of the image; include the captions as a separate section within the text portion of the document. If only hard copies are sent, these must be camera-ready, *i.e*., clean copies, ready for publication. Typewritten contributions may be submitted by mail as clean paper copies; these must arrive well ahead of the deadine, as they require greater processing time. Any versions that require translation must also be submitted well ahead of the deadline. All paper versions of articles for Permophiles will be destroyed after the deadline of the subsequent issue, unless a request is made for return.

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

I currently use a Windows 2000 PC with Corel Draw 12, Adobe Page Maker 7.0, Adobe Photoshop 7 and Microsoft Office programs; documents compatible with these specifications will be easiest to work with.

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Submission Deadline for Issue 46
is Friday October 14, 2005

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The following section contains selected abstracts presented at the Triassic Chronostratigraphy and Biotic Recovery at Chaohu, Anhui, China. These abstracts are published in a abstract volume of *Albertiana* and are repeated here for the convenience of the SPS members.

Late Permian and Early Triassic ichnofossil assemblages from the northwest margin of Pangea

T.W. Beatty[1], J.P. Zonneveld[2] and C.M. Henderson [1]

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Late Permian and Early Triassic ichnofossil assemblages from the northwest margin of Pangea provide a proxy record of benthic community composition across the Permian–Triassic boundary interval. These assemblages document variable recovery along the margin. To better understand the paleogeographic arrange-ment of both diverse and depauperate assemblages, Upper Permian and Lower Triassic strata repre-senting a range of depositional environments were examined in the Canadian Arctic, Canadian Rockies, the Western Canadian Sedimentary Basin subsurface, and the southwest United States. From these investigations the following conclusions can be drawn: 1) moderately diverse Early Triassic ichnofossil assemblages are not restricted to mid-high paleolatitudes; 2) instead these appear restricted to shoreface environments during the Griesbachian and Dienerian; 3) depauperate assemblages occupy shale and siltstone facies associated with the end-Permian transgression; 4) only some of the Late Permian ichnotaxa reappear in the early Griesbachian, but this may in part be due to a change in lithology across the boundary. Case studies from the Canadian Arctic, Canadian Rockies, and the southwest United States are presented below.

The Permian–Triassic boundary interval is well recorded in the Sverdrup Basin of the Canadian Arctic Islands. Here, the end-Permian transgression onlaps Late Permian strata with increasing disconformity from basin centre to basin margin. At Confederation Point ichnotaxa such as *Kouphichnium*, *Asteriacites*, *Haentzschelinia*, *Acanthoraphe*, and *Lockeia* are present within the first 20 m of strata above the boundary. The ichnofossil assemblage occurs in distal fan sandstones interbedded with distal shelf siltstones, the trace makers were likely transported although well-developed fodichnia imply somewhat suitable living conditions. Rare, diminutive (2-4mm diameter) *Planolites* characterize the first 40m of siltstone beds, but are larger and more common up-section and occur with *Helminthopsis*. At this section conodont data places the top of the Griesbachian only 2.5 m above the base of the transgression. Below, a 20m thick succession of silicified siltstone and chert of the Van Hauen Formation is devoid of trace fossils, but underlying hummocky cross-stratified spiculitic chert of the Lindstrom Formation contains *Cylindrichnus*, cf. *Schaubcylindrichnus*, *Teichichnus*, *Phycosiphon* and *Zoophycos*. At Lindstrom Creek, a more proximal section, *Skolithos*, *Spongeliomorpha*, *Cruziana*?, *Planolites*, and *Rhizocorallium* occur with *Claraia* in offshore transition sandstone 80 m above the end-Permian transgression. Here, basal shale and siltstone beds are recessive and poorly exposed, but the underlying bedded chert of the Lindstrom Formation contains *Cylindrichnus*, *Teichichnus*, *Phycosiphon* and *Zoophycos*. At Buchanan Lake, the most distal section studied in the arctic, trace fossils are not present in shales underlying or overlying the end Permian event, but rare *Bergaueria* were observed 45m above this boundary in Griesbachian siltstone.

On Williston Lake, in the Canadian Rockies, two sections that span basinal strata of the P-T boundary include chert of the Fantasque Formation overlain by silicified shale and siltstone representing the end-Permian transgression. Ichnotaxa in the chert include *Bergaueria*, *Teichichnus*, *Phycosiphon*, and *Zoophycus*. Above the boundary, shale and dolomitic siltstone beds of the Grayling Formation are devoid of trace fossils; Wignall and Newton (2003) indicate these strata were deposited under anoxic conditions. Griesbachian shoreface successions in the subsurface contain anomalously diverse ichnofossil assemblages. In the Kananaskis region of southwest Alberta, exposures of the Lower Sulphur Mountain Formation record shoaling upward offshore transition and lower shoreface successions through the Griesbachian and Dienerian. Upper Griesbachian fine-grained hummocky cross-stratified sandstone beds contain *Planolites* and rare *Diplocraterion*. In addition, Dienerian sandstone beds also contain abundant *Lockeia* on some bedding planes. Ichnotaxa present in the Lower Montney Formation in the subsurface of the northern Alberta – BC border region include *Diplocraterion*, *Halopoa*, *Helminthopis*, *Planolites*, *Skolithos*, and *Treptichnus* in heterolithic interbedded shale and silty sandstone and isolated specimens of *Cruziana*, *Diplichnites*, *Rhizocorallium*, *Rusophycus*, *Spongeliomorpha* and *Thalassinoides* (Zonneveld *et al.*, 2004). Other subcrop exposures of Lower Montney Formation shoreface successions, however, preserve only rare occurrences of trace fossils (*i.e.* Panek, 2000). The factors controlling such dissimilarities in ichnofossil assemblages occurring within comparable depositional environments are currently being studied.

Near Bear Lake, southeast Idaho, the Dinwoody Formation unconformably overlies the Permian Rex Chert. Trace fossils observed in the Rex Chert are limited to *Planolites*, *Teichichnus*, and *Conichnus*?, but the condition of the rock made identifications difficult. The duration of the sub-Triassic unconformity is uncertain, but from available conodont data it spans at least the Upper Permian. The basal Dinwoody comprises planar laminated shale and dolomitic siltstone that includes rare diminutive *Planolites* that first appear 30m from the base. Above a covered interval, lime-packstones are interbedded with fine-grained, ripple cross-laminated calcareous sandstone. The packstones contain abundant *Claraia* and disarticulated lingulid brachiopods; several specimens of *Hindeodus* sp. have been recovered from this outcrop. Sandstone beds contain diverse ichnotaxa including *Diplocraterion*, *Planolites*, *Thalassinoides*, *Bergaueria*, *Lockeia*, *Lingulichnus*?, *Phycodes*?, and *Gyrochorte*.

Evidence for complex ethologies, previously unreported from Griesbachian and Dienerian strata, has been documented in shoreface successions from higher, middle, and lower paleolatitudes along the northwest margin of Pangea. These ichnotaxa, with the exception of transported individuals, appear restricted to offshore tran-sition or shallower environments. Conditions preclusive to extended occupation of benthic environments must then have existed below these depths. If stress from anoxia played an important role during the Early Triassic as previously suggested (Twitchett and Wignall, 1996), then perhaps wave action (normal and storm) acted to mitigate this stress in shallower environments.

Panek, R., 2000. The sedimentology and stratigraphy of the Lower Triassic Montney Formation in the subsurface of the Peace River Area, Northwestern Alberta. Unpublished MSc Thesis, University of Calgary, 275p.

Twitchett, R.J. & Wignall, P.B. 1996. Trace fossils and the aftermath of the Permo–Triassic mass extinction: evidence from northern Italy. Palaeogeography, Palaeoclimatology, Palaeoecology 124:137-151.

Wignall, P.B. & Newton, R. 2003. Contrasting deep-water records from the Upper Permian and Lower Triassic of South Tibet and British Columbia: Evidence for a Diachronous Mass Extinction. Palaios 18:153-167.

Zonneveld, J.P., Henderson, C.M., Macnaughton, R. & Beatty, T.W. 2004. Diverse ichnofossil assemblages from the Lower Triassic of northeastern British Columbia, Canada: Evidence for a shallow marine refugium on the northwestern coast of Pangea. Geological Society of America Annual Meeting, Nov., 2004, Denver, Colorado.

Extinction-survival-recovery of brachiopod faunas during the Permian-Triassic transition

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The end-Permian mass extinction not only caused the largest crash in global biodiversity since the Cambrian explosion (Sepkoski, 1981), but also redirected dramatically the course of biotic evolutions and is largely responsible for much of the structure of marine ecosystems today (Bowring *et al*., 1999). Brachiopoda is the outstanding example of a clade that suffered severely the event. The fossil record of this group in the pre-Mesozoic is very abundant (Rudwick, 1970; Sepkoski, 1981), and, for the first time since their origin in the Early Cambrian, brachiopod's diversity declined rapidly in the Early Triassic oceans around the world as a consequence of the end-Permian mass extinction (Erwin, 1993). Consequently, Brachiopoda also lost their dominance in Mesozoic and later marine benthic communities and became subordinate organisms inhabiting largely in the deep oceans or marginal seas today (Rudwick, 1970).

As far as the end-Permian event is concerned, many questions remain about the magnitude and causes of this dramatic extinction. Similarly, interpretation of the delayed faunal recovery following this extinction remains highly disputed. The final recovery of marine faunas following this event is generally believed to occur in the early Middle Triassic (Anisian), about 5 million years after the extinction (Erwin, 1998). Recent several studies of this recovery based on data of other fossil groups suggest that simple, cosmopolitan, opportunistic generalists, and low-diversity paleocommunities were characteristic of the Early Triassic oceans. However, there are not yet any studies on the post-extinction recovery of the global brachiopod faunas. In particular, published data and current materials tend to indicate that the recovery pattern derived from brachiopod data will differ from that of other fossil groups (e.g., bivalves, gastropods and echinoids) because brachiopods show some clear differences to these other groups.

(1) Brachiopods are the most diverse fauna in the Permian oceans and are the second largest victims among the main marine fossil groups in the end-Permian mass extinction (Carlson, 1991). The brachiopod extinction-survival-recovery pattern should therefore have its own unique feature.

(2) Brachiopods are the most abundant representatives that survived the end-Permian event (Sheng *et al*., 1984). The relationships among the pre-extinction brachiopods, survivors and post-extinction recovery and radiating faunas are crucial to understand the process and mechanisms of brachiopod recovery after the event. As such, the brachiopod faunas are able to more precisely indicate biotic factors at extinction, survival and recovery intervals summarized by Kauffman and Erwin (1995).

(3) There are rare Lazarus genera (Jablonski, 1986) in marked contrast to a few Lazarus genera in other groups (e.g. gastropods), which commonly reappear near the close of the recovery interval (Erwin, 1998). Consequently, the recovery model of brachiopods is much less influenced by Lazarus effect at generic level, although the Lazarus effect affected this fossil group at familial level to some extent.

(4) Early Triassic brachiopods mainly comprise endemic elements and appear to record strong provinciality in sharp contrast to the current hypothesis based on the observation of other fossil groups.

In addition, significant taxonomic emendation and re-classification of the Brachiopoda, as appearing in the revised Brachiopod Treatises published since 1997, and much improved stratigraphic information obviously re-figure brachiopod extinction, survival and recovery patterns during the end-Permian event. Calibration of both the Permian-Triassic (P/T) boundary and end-Permian mass extinction horizon at the Meishan section as well as global correlations of high-resolution biozones and other geochemical anomaly signals also provide the possibility to elucidate the brachiopod extinction, survival and recovery during the P/T transition.

1. Extinction of brachiopod faunas.

According to the previously published data and our unpublished data, a total of 420 species belonging to 143 brachiopod genera within 50 families have been reported from the pre-extinction Changhsingian Stage worldwide. The new assessment of the "mixed faunas" reveals that 102 species (including 40 indeterminate species) belonging to 43 genera within 27 families are recorded in strata above the end-Permian extinction horizon or their counterparts in P/T boundary sections globally. These taxa include all elements present in the "Mixed Fauna Beds (MFBs) 1-3" above the extinction horizon, so the proportional extinction/survival rates based on these data may

Phases	Number of taxa			Proportional survival rate (%)			Proportional extinction rate (%)			Origination rate (%)		
	Spe.	Gen.	Fam.	Spe.	Gen.	Fam.	Spe.	Gen.	Fam.	Spe.	Gen.	Fam.
MF 3	15	8	7	19.5	36.8	54.5	80.5	63.2	55.5	40	0	0
MF 2	41	19	11	42.3	47.5	44	57.7	52.5	56	19.5	0	0
MF 1	78	40	25	8.8	28.2	50	91.2	72.8	50	52.5	0	0
Pre-ext.	420	143	50									

Table 1. A proportional survival rate equates to the number of survival taxa divided by the number of total taxa

mask the true patterns of brachiopod extinction and survival. To understand the true survival rates of brachiopods in the three survival phases (MF 1-3 phases, corresponding to the conodonts *C. meishanensis*, *H. parvus* and *I. isarcica* zones, respectively), the proportional extinction/survival rates of bra-chio-pods in these three phases are calculated at specific, generic and familial levels, respectively (Table 1).

A proportional extinction rate equates the number of extinct taxa divided by the number of total taxa. An origination rate equates to the number of new taxa divided by the number of total taxa.

The variations in diversity and proportional extinction/or survival rate reveal that a sharp drop in diversity of brachiopod faunas coincides with the widely accepted end-Permian mass extinction horizon, which is calibrated to the base of Bed 25 at Meishan (Jin *et al*., 2000). The generic and familial proportional extinction rates over the event are, apparently, much smaller than current estimates (e.g., Carlson, 1991). Therefore, a greater number of brachiopod genera and families survived the end-Permian mass extinction with proportional survival rates of 28.2% and 50%, respectively. The extremely low proportional survival rate of brachiopod species across the boundary between MFs 2 and 3 (19.5%) is conspicuous. This number is reduced by combining the brachiopods in both MF 1 and 2 [proportional surviving rates of brachiopods in MF 3 are 8.8% (species), 16.7% (genera), and 22% (family)]. This indicates a dramatic turnover of brachiopods across MFs 2 and 3 and corresponds to the boundary between the *H. parvus* and *I. isarcica* conodont zones. A low proportional survival rate coupled with a high origination rate of new taxa characterizes the brachiopod faunas at the aftermath of the end-Permian extinction. These two phases of low survival rates of the survival brachiopods correspond to two extinction events. This fact indicates that the post-extinction brachiopods were also affected by a subsequent crisis corresponding to the boundary between MFB 2 and MFB 3 so that most survivors were extinct approximately less than one myr after the event. This pattern partly supports the hypothesis of 3-phase of biotic extinction within the P/T boundary beds (Yang *et al*., 1993).

Biogeographically, brachiopods were widely distributed at the Austrazean, the Himalayan, Cathaysian, Western Tethyan, and Sino-Mongolian provinces, respectively (Shen *et al*., 2000; this study) during the pre-extinction Changhsingian. Of these, brachiopods habiting the Austrazean and Sino-Mongolian provinces became completely extinct. The former province belonged to the Gondawana realm, and the latter was close to the Boreal realm. The brachiopods surviving the event mainly were in regions near paleo-equatorial areas. Accordingly, the end-Permian extinction resulted in the movement of biogeographic provinces towards the palaeo-equator.

2. Survival strategies of brachiopod faunas.

Global reviews reveal that a great number of brachiopods survived the end-Permian mass extinction in South China, the Himalayan regions (southern Tibet, Nepal, Salt Range and Kashmir), southern Alps (Italy), Arctic Canada, western USA and Western Australia. Of these, the surviving brachiopods are most abundant and widespread in South China where they occur in 32 of the 42 P/T boundary sections around the world. These surviving brachiopods occur in three stratal intervals corresponding to the "MFBs" 1-3 of the P/T boundary beds. The surviving brachiopods were mainly Productida, followed by Spiriferida. In particular, small chonetids, chonetid-like productellids and smooth, thin-shelled ambocollid spiriferids are most abundant. Disaster taxon *Lingula* is extraordinarily abundant and widespread in the aftermath of the greatest extinction when many regions became devoid of articulate brachiopods. Widespread, broadly adapted and small-sized taxa preferentially survived. Frequent intrageneric speciation of widespread, widely adapted generalist genera enabled survival brachiopods to occupy rapidly and efficiently vacant ecospace in the aftermath of the end-Permian extinction. The ecologic habitats of the post-extinction brachiopods are subdivided into nearshore, epeiric sea, restricted carbonate platform, open carbonate platform, ramp and outer shelf environments. Of these, the survival brachiopods are most diverse in the open platform environments. The nearshore zone provided ideal habitats for the nonarticulated brachiopods to occupy; whereas the survivors in the outer shelf are predominantly chonetids and chonetid-like productids. The most successful survivors, the productid brachiopods, are widely distributed in six types of ecological habitats and thus have no apparent preference for specific environments. Biogeographically, brachiopods survived mostly in the palaeo-equatorial provinces and along the southern margins of the Palaeo-Tethys Ocean. Moreover, in both the Himalayan and South China regions where the survivors of the end-Permian extinction are highly diverse, but none of them participated in both post-extinction recovery so that these survivors fall into a pattern that was termed "Dead Clade Walking" (DCW) by Jablonski (2002).

3. Global recovery process and patterns of brachiopod faunas

Apart from the relict Permian elements, the true Mesozoic-type brachiopods (32 species from 20 genera and 12 families) have been reported from the Lower Triassic of the Spitzbergen, Primorye of Russia, Mangyslak of Kazakhstan, Alpine Europe, the Himalaya, South China, western USA and probably New Zealand. Their origination represents the recovery of Early Triassic brachiopods. The Early Triassic recovery of brachiopod faunas is characterized by widespread brachiopod dispersal, multiprovincialism and the presence of rare Lazarus genera at that time. Taxonomic selectivity of the recovery brachiopod faunas favors the rhynchonellides. The re-population of post-extinction brachiopods varies geographically: there is a preference for regions either previously barren of latest Permian taxa and or where rare latest Permian and surviving brachiopods. This unique biogeographic selectivity is probably partly responsible for the depauperate nature of brachiopod faunas in the Triassic (even Mesozoic) oceans. Five intervals of extinction, survival, survival–recovery, recovery–dispersal and radiation, are recognized based on variations in brachiopod faunas of the latest Permian to Early Triassic. A dramatic reduction in brachiopod diversity at the end-Permian mass extin-ction is followed by several stepwise declines in diversity in the survival interval, the time during which the surviving brachiopods are dominated by geographically widespread generalist faunas that adapted to a wide variety of environments. The survival interval was followed by a slow re-population of new lineages dominated by progenitor taxa.

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Progress on the Cisuralian (Lower Permian) time-scale, southern Urals, Russia

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The Cisuralian Series (Lower Permian) has been formally established for the Lower Permian (Jin *et al*., 1994). The southern Ural Mountain region is the type area for the Cisuralian, comprising the Asselian, Sakmarian, Artinskian and Kungurian stages. These stages initially were defined and widely recognized on ammonoid phylogenies (Karpinsky 1889; Ruzhencev 1937, 1950, 1951, 1956). However, stage boundaries and subdivisions were established on the basis of fusulinaceans, the most abundant and best studied upper Paleozoic fossil group of the southern Urals. Body stratotypes for all stages were located in the southern Urals and it is expected that the boundary stratotypes (GSSP) for all Cisuralian stages will be formally established in this region. The Working Group to establish Cisuralian stages has achieved a significant progress in developing time scale (Chuvashov *et al*., 2003). Although GSSP of the base of the lowermost Cisuralian Asselian stage is already established at the Aidaralash section, NW Kazakhstan (Davydov *et al*., 1998), we are proposing to establish auxiliary stratotype section for the Global Stratotype section and Point for the Carboniferous-Permian boundary at Usolka section to adjust some of the features that are not present in Aidaralsh section. Particularly, conodont succession at Carboniferous-Permian boundary beds in Usolka section seems to represent much more details (Chernykh, 2005). Most important is the presence of numerous volcanic ash beds recently recovered in the section what make radiometric control of the most of the Cisuralian boundaries possible (Davydov *et al*., 2002).

The Asselian stage was established by Ruzhenzev (1954), but the stage in the Asselian body stratotype (Assel section, located on the ridge between the Assel and Uskalyk rivers in southern Bashkortostan) is incomplete. Ruzhenzev distinguished the Asselian by a particular ammonoid assemblage which in the Urals corresponds with the entire range of the fusulinid *Sphaeroschwagerina.* The Global Stratotype Section and Point (GSSP) for the base of the Permian and basal Cisuralian Asselian Stage was proposed at Aidaralash Creek, Aktöbe (formerly Aktyubinsk) region, northern Kazakhstan. Asselian in the southern Urals divides into six foraminiferal zones and an equal number of conodont zones (Shamov 1940; Rauser-Chernousova 1949; Davydov 1986, 1996; Davydov *et al*. 1997; Chuvashov *et al*. 1990; Chernykh and Chuvashov 1991). The strata of Late Paleozoic age at Aidaralash Creek were deposited on a narrow, shallow marine shelf that formed the western boundary of the orogenic zone to the east. The fluvial - deltaic conglomerate - sandstone successions grade upwards into transgressive, marginal marine sequences of (beach and upper shore face) that, in turn, grade upwards into massive mudstone-siltstone and fine sandstone beds with ammonoids, conodonts and radiolarians interpreted as maximum flooding units. The maximum flooding zone is overlain by a regressive sequence (progressively, offshore to shoreface to delta front), which in turn is capped by an unconformity with a overlying conglomerate. The critical GSSP interval is completely within a maximum flooding unit; free of disconformities.

The position of the GSSP is at the first occurrence of the conodont *Streptognathodus isolatus*, which developed from an advanced morphotype in the *S. wabaunsensis* chronocline. This is located 27 m above the base of Bed 19, Airdaralash Creek (Davydov *et al*., 1998).

The first occurrences of *Streptognathodus invaginatus* and *S. nodulinearis*, also morphotypes of the '*wabaunsensis*' morphocline, nearly coincide with the first occurrence of *S. isolatus* in many sections, and can be used as accessory indicators for the boundary.

The GSSP is 6.3 m below the traditional fusulinid boundary, i.e. the base of the *Sphaeroschwagerina vulgaris aktjubensis-S. fusiformis* Zone (Davydov *et al*., 1998). The latter can be widely correlated from Spitsbergen, the Russian Platform, Urals, Central Asia, China and Japan, and is of practical value to identify the boundary between the Orenburgian and overlying Asselian stages. The traditional ammonoid boundary, 26.8 m above the GSSP, includes the termination of the *Prouddenites-Uddenites* lineage at the top of Bed 19, and the introduction of the Permian taxa *Svetlanoceras primore* and *Prostacheoceras principale* in Bed 20 (Davydov op. cit., figure 2). The evolution from *Artinskia irinae* to *A. kazakhstanica* maybe a chronocline that crosses the C/P boundary. A problem with the ammonoid taxa is that they are relatively rare, and many taxa may be endemic to the Urals.

Utilization of magnetostratigraphy to assist with recognition and correlation of the C/P boundary is difficult because it is in the Kiaman Long Reversed Polarity Chron. However, Davidov & Khramov (1993) cite reports that show that most of the *Ultradaixina bosbytauensi-Schwagerina robusta* fusulinid zone, just below the C/P boundary in Aidalarash is characterized by normal polarity. That same stratigraphic polarity relationship is also known elsewhere from the southern Urals, and the northern Caucasus and Donetz Basin, and possible correlates to the normally polarized magnetic zone in the Manebach Formation of the Thuringian Forest (Menning, 1987).

The conodont succession observed at Airdaralash is displayed in several sections in the southern Urals, especially the basinal reference section at Usolka. It is also displayed in the Red Eagle cyclothem of the MidContinent of the US (Boardman *et al*., 1998), the West Texas regional stratotype in the Wolfcamp Hills (Wardlaw and Davydov, 2000), and China (Wang, 2000) as well as many other intervening localities and, therefore, serves as an excellent boundary definition.

Base of Sakmarian Stage

Sakmarian (s. s.) in its present context was proposed by Ruzhenzev, 1955 with its stratotype at the Kondurovka section, (Karamuruntau Ridge, southern Orenburg Province) and based on ammonoid and fusulinid assemblages. No ammonoids are known in the lower portion of Sakmarian, and thus the base of this stage traditionally has been defined by first appearance species of *Schwagerina moelleri* ("*Pseudofusulina*" *moelleri* in Russian nomeclature). Because fusulinid species are provincial, this definition is effective only in the Boreal and in the western Tethyan realms. A Sweetognathid (conodont) chronomorphocline exhibiting the evolutionary change from *Sweetognathus expansus* (Perlmutter) to *Sweetognathus merrilli* Kozur at 115 meters above base (mab) (uppermost Bed 11 of Chuvashov *et al*., 1993 The boundary originally proposed by Ruzhencev (1950) was at the base of Bed 11(91 mab) at an unconformable formation break and based on the change in fusulinaceans faunas with *Schwagerina (Pseudofusulina) moelleri* occurring above the break. The actual introduction of the fusulinacean *Schwagerina (Pseudofusulina) moelleri* group occurs in beds 6-12 (Davydov *et al*., 1999), with traditional *Sch. moelleri* occurring in Bed 12, just a few meters above the first occurrence of *Sw. merrilli*. *Sweetognathus merrilli* is widespread and its FAD is well constrained throughout Kansas in the upper part of the Eiss Limestone of the Bader Limestone.

Base of Artinskian Stage

The Artinskian Stage as originally proposed by Karpinsky (1874) included all the Upper Paleozoic clastic deposits of the Preuralian Foredeep (Artinskian Sandstone by Murchison, 1845) overlying Carboniferous carbonates. Artinskian Stage in current context as established by Ruzhenzev (1954) was characterized by ammonoids and fusulinids. The body Artinskian stratotype is in a series of sandstone quarries on Kashkabash Mount near the Arti village on right bank of Ufa River, which actually corresponds only with the upper portion of Artinskian. The taxonomically diverse ammonoid assemblage from the Arty area was distinctly more advanced than the Sakmarian one in terms of cephalopod evolution and this stimulated Karpinsky (1874) to define two belts with ammonoids; the lower at the Sakmara River and the upper at the Ufa River. Most of the characteristics concerning the Artinskian are derived from investigation of clastic-rich sections and ammonoids phylogenies from the Preuralian Foredeep in the southern Urals best represented in Aktasty and Zhiltau sections (Ruzhenzev, 1954) and from carbonate sections and fusulinid phylogenies from the eastern margin of the Russian Platform (Rauser-Chernousova, 1949). Fusulinids and ammonoids species from the Urals are provincial and can not be used for GSSP definition. Conodonts are more appropriate.

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-colored marl, argillite, and carbonate mudstone, or less commonly, detrital limestone with fusulinids, radiolarians, rare ammonoids, and bivalves. The upper part of the Sakmarian includes fusulinids characteristic of the Sterlitamakian Horizon including *Pseudofusulina longa*, *P. fortissima*, *P. plicatissima*, *P. urdalensis* and *P. urdalensis abnormis*.

The best section appears to be the Dal"ny Tulkas section in Russia, a point that potentially defines base of Artinskain located within few meters where the chronomorphocline from *S. binodosus* to the FAD of *Sweetog-nathus whitei* is recovered. A sample from the Dal'ny Tulkas section (5045-8a) includes *S. binodos*us 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* (reported as *S. inornatus*, Ritter, 1986). 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* 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. tschuvaschovi* in synonymy) during the evolution of *Neostreptognathodus pequopensis*. The above-mentioned conodonts occur in the limestone member (Bed 19) at the base of the Tyul'kas Formation (Chuvashov *et al*., 1990). That unit is also characterized by the fusulinids *Psuedofusulina callosa*, *P. urdalensis, P. karagasensis, P. concavatus*, *P*. ex. gr. *jurasanensis*, and *P. uralensis*. Ammonoids from the same unit include *Popanoceras annae*, *P. tchernowi*, and *Kargalites* sp.; the unit, 3.5 m higher than Bed 19, includes the ammonoids: *Neopronorites skvorzovi*, *Popanoceras annae*, and *P. congregale*.

The limestone member (Bed 19) and several levels in the Tyul'kas 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.

The defining chronomorphocline of *Sweetognathus binodosus* to *S. whitei* also can be recognized 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).

Base of Kungurian Stage

The stratotype of the Kungurian Stage was not defined when the stage itself was established (Stuckenberg, 1890). Later on, the carbonate-sulphate section exposed along the Sylva River upstream of the town of Kungur was arbitrarily accepted for the stratotype. In line with a new position of the Kungurian lower boundary at the base of the Sarana Horizon (Chuvashov *et al*., 1999), a stratotype section in this area consists of: (1) the Sarana Horizon including the Sylva Formation of reefal limestones and its lateral equivalent Shurtan Formation composed of marls and clayey limestone, (2) the Filippovskian Horizon, (3) the Iren' Horizon. A disadvantage of the section is the poor paleontologic characteristics of the limy Kamai Formation underlying the Sarana Horizon; it contains only small foraminifers, bryozoans, and brachiopods inappropriate for age determination. Nevertheless, many features indicate that the formation corresponds to the Sarga Horizon.

The Shurtan Formation and lateral facies of Sylva bioclastic limestone yield conodonts of the *Neostreptogathodus pnevi* Zone. However, another section of the Artinskian-Kungurian boundary deposits located near the Mechetlino settlement at the Yuryuzan' River has good faunas both below and above the boundary interval and has been selected for a probable stratotype of the Kungurian lower boundary.

The probable stratotype section (Chuvashov *et al*., 1990, Chuvashov *et al*. 2002) is exposed along the right bank of the Yuryuzan' River downstream of the Mechetlino settlement. Beds 1-18 are Sarga Horizon, Gabdrashitovo Formation. Bed 13 comprises dark grey argillite with irregularly alternating thin layers of fine-grained sandstone and includes ammonoids and conodonts including *Neopronorites permicus*, *Medlicottia orbignyana*, *Uraloceras fedorowi*, *Sweetognathus* aff. *whitei*, and *Stepanovites* sp., all characteristic of the Sarga Horizon. Bed 15 is an olistostrome with a matrix comprising fusulinids, solitary rugose corals, brachiopods, bryozoa, crinoids, and calcareous algae. The fusulinid assemblage includes abundant *Pseudofusulina kutkanensis*, *P.* aff. *kusjanovi*, *P. franklinensis*, *P. postsolida*, *P. makarovi*, and *Parafusulina solidissima*. Bed 17 is composed of highly calcareous, dark grey argillite with grey, calcareous, fine-grained sandstone. This bed has yielded the conodonts *Neostreptognathodus kamajensis*, *N. pequopensis*, *N.* aff. *ruzhencevi*, and *Sweetognathus* ex. gr. *whitei* represented by aberrant specimens with reduced carinae. Bed 18 is a highly calcareous, yellowish-grey sandstone with thin interbeds of greenish-grey argillite and abundant plant detritus, but lacks conodonts and fusulinids. Beds 19-20 are Kungurian Stage, Sarana Horizon, Mysovsk Formation, Transitional Member. Bed 19 comprises steel-grey carbonate mudstone with an admixture of extremely fine-grained clastics and rare argillite interbeds. The basal part includes *Neostreptognathodus clinei*, *N. pnevi*, *N. kamajensis*, *N. pequopensis*, and *Stepanovites* sp. Bed 20 is a yellowish-grey, thin-bedded, fine-grained, calcareous sandstone with thin argillite interbeds and abundant plant debris. Beds 21-22 are Filippovskoe Horizon, Mysovoi Formation, Ismagilovo Member. Bed 21 is composed of steel-grey carbonate mudstone and rare interbeds of microclastic limestone that yield the ostracod *Paraparchites burkemis* characteristic of the *Paraparchites humerosus* Zone and the conodonts *Neostreptognathodus pequopensis*, *N. pnevi*, *N.* aff. *ruzhencevi*, and *N. tschuvashovi*.

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

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

A stratigraphic, biostratigraphic, paleobiologic digital information system: PaleoStrat and the CHRONOS System

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PaleoStrat (www.paleostrat.org) is a digital information system for sedimentary, paleontologic and stratigraphic data that is hosted at Boise State University (Boise, Idaho, USA) and is part of the *CHRONOS System* (www.chronos.org). PaleoStrat provides a sample- and stratigraphically oriented database and visual and analytical tools that deliver detailed information in the context of stratigraphic successions. The PaleoStrat and *CHRONOS System* data include lithostratigraphic, biostratigraphic, taxonomic, sequence stratigraphic, cyclostratigraphic, geochronologic, major, trace, and isotope geochemical, and other data and metadata relevant to sedimentary geology and paleobiology research. These data and tools support a broad array of integrative research projects that need to combine data in a framework of geologic age and stratigraphic succession. Research topics supported by PaleoStrat include the paleobiologic evolution, extinction, radiation and migration, diversity of life, climate change, geochemical cycles, sequence and cyclostratigraphy, paleoceanography, crustal dynamics of orogenic systems, and many other aspects of the Earth system. We enable the deep-time geologic record to be understood within a framework of the chemical, physical, climatic, astronomical, eustatic, and tectonic processes that collectively govern the operation of the Earth system.

Personal Data, Published Data, and Long-term Data Preservation. PaleoStrat and the *CHRONOS System* provide a long-term interactive archive of critical data and will work with other geoinformatics projects, NSF, and other federal agencies to ensure the preservation of these data. PaleoStrat's "My Data" site allows individual users or working groups to store personal data prior to publication or public release while integrating these data with the larger, public data sets in their user space. These data will be accessible to the broader geoinformatics community once the user has indicated they can be made public ("published"), and will always be fully attributed to the person/group that developed the data ("branded"). Because it is part of a public database, the preservation of and access to these data are assured, providing also a mechanism to meet existing and upcoming reporting requirements for data by the US-NSF and other funding agencies.

Data Input. PaleoStrat will allow users to add data in a variety of ways. Data can be input in web forms or uploaded from spreadsheet templates designed on the PaleoStrat data model. As the geochemical and geochro-no-logical communities agree on standards, PaleoStrat could potentially capture data output from mass spectro-meters and other instruments in preliminary databases, then allow the analysts to decide, as they now do manu-al-ly, which data to pass through to the PaleoStrat database. Users who have large amounts of data that are not in digital format or that require reformatting can either send them to PaleoStrat where supervised and trained students, in consultation with the data provider, will digitize the data and metadata information needed for the database, or request support from a funding agency to do it themselves. To make accessible legacy data that do not easily fit into PaleoStrat, "flat" files (e.g., spreadsheets) and related metadata can also be networked (indexed) and made searchable. Some larger legacy data sets may require a small external grant to the individual researchers for local data input in collaboration with the PaleoStrat and *CHRONOS System* team, for which PaleoStrat will provide a letter of support.

Data Searching and Output. Data output can be very simple if: 1) the database remains relatively uncomplicated, and 2) the science question being asked is similarly reasonably straightforward. However, once the database (e.g., PaleoStrat) becomes more complex in terms of schemas (database structure) or their connectivity with other databases (e.g., of the *CHRONOS System*), the issue of searching and data output becomes a significant challenge. Hence, PaleoStrat will continue to evolve its approach to searching and data output. In general, we have considered several approaches to data output, including: 1) form-based, user-defined searches, and 2) GIS-based and TIS-based (Geographic and Timescale Information Systems, respectively) query interfaces, and 3) web service calls. In addition, users can write their own SQL (Structured Query Language) searches into any of the databases in the *CHRONOS System* including PaleoStrat. Because data in PaleoStrat are geospatially and temporally defined, data can be searched based on location and geologic age using GIS- and the temporal equivalent of GIS – TIS-type interfaces – and eventually paleogeographic maps. PaleoStrat provides the ability for stratigraphic sections to be searched for all data within the stratigraphic context of the section (e.g., lithology, geochemistry, biostratigraphy). A Graphical User Interface (GUI) based on location, geologic age, and stratigraphic succession is being developed that will allow the user to perform standard queries and will eventually allow the development of individual complex queries unbound by canned SQL searches. The PaleoStrat web site will allow users to save their searches to make future work easier. Finally, we plan to continue to work with the international community to develop better approaches to searching.

Tools. One of the distinctive aspects of the *CHRONOS System*, as encouraged by the community, is to provide the user with tools to analyze and visualize the data. The user community views the need for data and tools as a single activity, done in parallel, not in sequence or separately. Although this adds to the complexity of development for PaleoStrat the *CHRONOS System*, we have designed the system to provide this critical service. We also are working to accommodate the need to format data so the user can utilize proprietary, com-mercial tools on their own workstations or desktop computers (e.g., software available from RockWare.com).

Fundamental among the tools that PaleoStrat will offer via the *CHRONOS System* are algorithms that estimate the sequence, timing, and correlation of ancient events from the sum total of large amounts of local and potentially contradictory data. These tools enable the user to present the electronic stratigraphic record as a unified composite time line. Time scale data are provided through the partnership with the International Commission on Stratigraphy (ICS, www.stratigraphy.org), the definitive source for up-to-date information on the global time scale. *CHRONOS* also provides access to a suite of time scales (both local and global), translations among the various time scales, and user-generated age models. The community has identified graphic correlation, paleogeographic mapping, and statistical tools as key components of the toolkit. In the proof-of-concept phase, we focused on the “low hanging fruit,” i.e., tools that can be easily modified and adapted for broader accessibility, but the suite of tools will continue to expand. These initial tools include the graphic-correlation tool ADP (age/depth plotting) and the stratigraphic sequencing tool

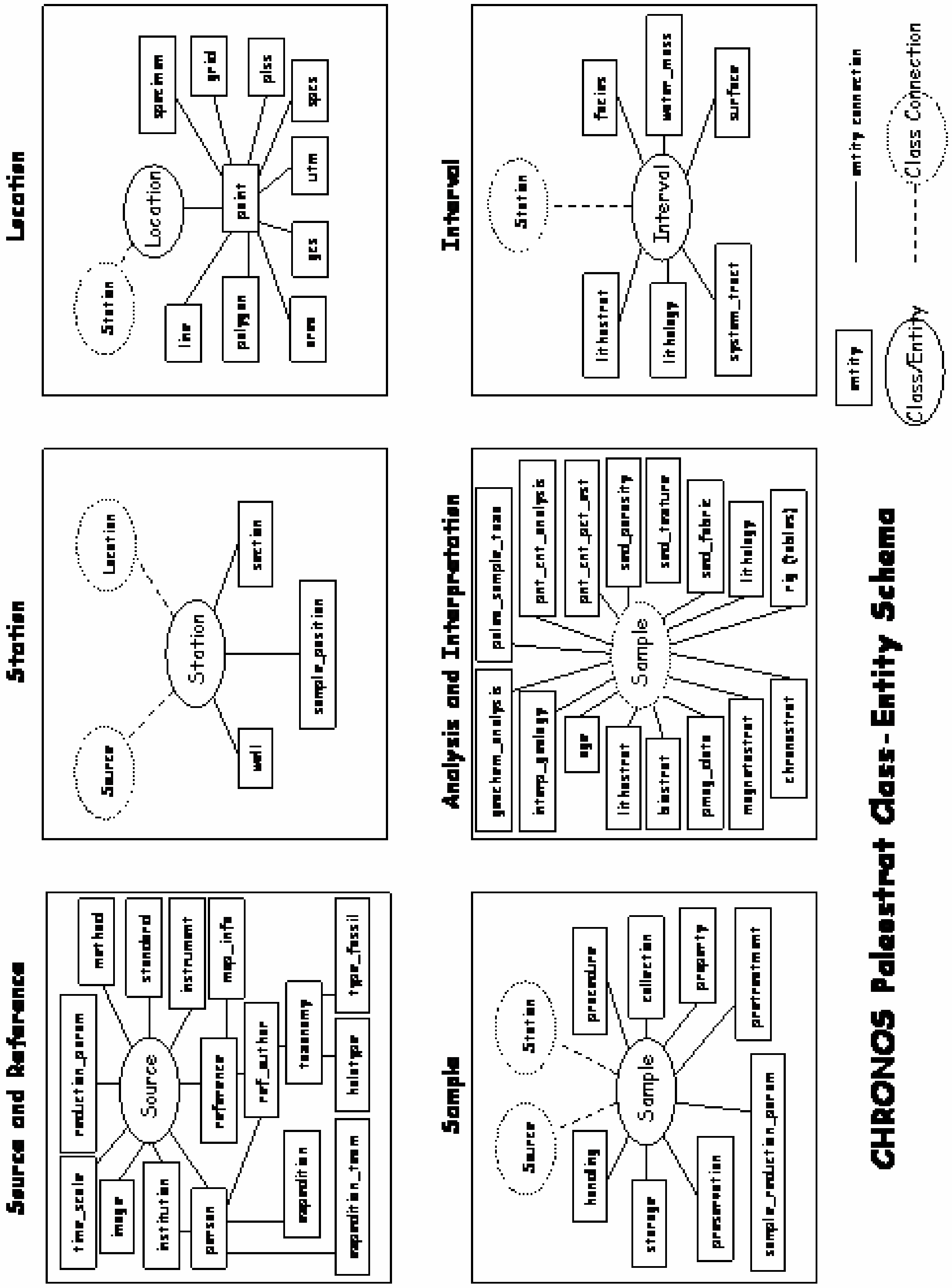

Fig. 1. Simplified database concept for PaleoStrat

CONOP9 (P. Sadler, University of California, Riverside) sequencing tool provided as an integral web service from the *CHRONOS System* and hence to PaleoStrat. It is an extremely flexible solver for the stratigraphic sequencing problem and serves as an exploratory case study for tool implementation in general. Other components of the tool kit will include publication quality graphical and statistical tools (including the packages *PAST* by Øyvind Hammer [University of Oslo, http://folk.uio.no/ohammer/past/] and *Stratistics* by Roy Plotnick [University of Illinois Chicago]), paleogeographic maps, time scale conversion tools (of which two are already available), time series analysis tools (including interpolation, correlation, tuning, spectral analysis, digital filtering, demodulation, and orbital-insolation modeling), stratigraphic section construction tool, in addition to the existing web service that allows visualization of the full or partial 2004 Global Time Scale with the level of detail chosen by the user.

Brachiopod miniaturization in the Permian-Triassic life crisis in South China

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In the Permian-Triassic life crisis in South China, a brachiopod fauna dominated by larger individuals in size, was replaced by the other brachiopod fauna dominated by smaller individuals. It is called brachiopod mini-aturi-zation here.

In South China, Changhsingian strata are mainly deposited in platform facies, basin facies, and shore facies (Yang *et al*., 1991). Meishan and Zhongliangshan sections are deposited in carbonate platform facies, Laibing, Guiding, Dongpan and Longtan sections are deposited in limestone-mudstone-siliceous rock-siliceous limestone basin facies, Qibaoshan section is deposited in shore clastic rock facies.

At Meishan and Zhongliangshan sections, the Changhsingian brachiopod fauna who is from the limestone intervals relatively far below the Permian-Triassic boundary, mainly consists *Spinomarginifera alpha*, *Cathaysia chonetoides*, *Haydenella kiangsiensis*, *Fusiproductus baoqingensis*, *Neowellerella pseudoutah*, *Leptodus* sp., *Meekella* sp., *Perigeyerella* sp., *Martinia* sp., *Araxathysis araxensis*, *Paracrurithyris pigmaea*, *Paryphella obicularia*, and *Waggenites* sp. (Zhao *et al*., 1981; Shen and He, 1991). The elements larger than 1 cm in size account for more than 50%. The brachiopod fauna from the claystone and limestone intervals nearby the Permian-Triassic boundary mainly includes *Crurithyris* sp., *Cathaysia* sp., *Fusichonetes* sp., *Paracru-rithyris pigmaea*, *Paryphella* sp., *Waagenites* sp., *Neochonetes* sp., *Spinomarginifera kueichowensis*, *S. chen-yao-yenensis*, *Lissor-hyn-chia pseudoutah*, *Acosarina* sp., *Araxathyris araxensis*, and *Neowellerella pseudo-utah* (Zhao *et al*., 1981; Shen and He, 1991). The elements smaller than 1 cm in size accounts for 50% to 90%, so brachiopod miniaturization occurred nearby the Permian-Triassic boundary. Besides, at the Meishan section, brachiopod miniaturization is companied by the extinctions of some foraminifera, conodont and ammonoid species. At the Laibing and Guiding sections, the Changhsingian brachiopod fauna who is from the limestone, mudstone and siliceous limestone intervals relatively far below the Permian-Triassic boundary, is dominated by individuals larger than 2 cm in size (Zhao *et al*., 1981; Liao, 1987; Shen and He, 1994). The brachiopod fauna from the limestone and mudstone intervals near the Permian-Triassic boundary is dominated by individuals smaller than 1 cm (Zhao *et al*., 1981; Liao, 1987; Shen and He, 1994). At the Dongpan section, southern Guangxi, the brachiopod fauna from the siliceous mudstone intervals relatively far below the Permian-Triassic boundary, is mainly composed of *Anidanthus* sp. and *Costatumulus* sp., 2 to 3 cm in size. The brachiopod fauna from the siliceous mudstone intervals close to the Permian-Triassic boundary is mainly composed of *Paracru-ri-thyris pigmaea* and *Spinomar-ginifera* sp., smaller than 6 mm in size. Besides, at the Dongpan section, bra-chio-pod miniaturization seems more evident more close to the Permian-Triassic boundary and is companied by the extinctions of some radiolarian and foraminifera species. At the Longtan section, the brachiopod fauna from the mudstone intervals nearby the Permian-Triassic boundary, is characterized by lower diversity and smaller species than the brachiopod fauna from the siliceous rock intervals far below the Permian-Triassic boundary (Liao, 1979). At the Qibaoshan section, Jiangxi Province, the brachiopod fauna from the top part of Changhsingian mudstone and silty mudstone, consists *Orthotetina rubber*, *O. regularis*, *Haydenella subextensa*, *H. kiangsiensis*, *Oldhanina lianyangensis*, *Leptodus* sp., *Waagenenites* sp., *Neochonetes* sp., *Rugoso-mar-gini-fera chenyaoyenensis*, *Spinomarginifera chengyaoyenendis*, *S. kueichowensis*, *Crurithyris* sp., *Martinia* sp. (Yang *et al*., 1991), and the individuals larger than 1 cm account for more than 60%. The brachiopod fauna from the basal part of the Triassic mudstone and silty mudstone intervals only consists *Crurithyris pusilla* (Yang *et al*., 1991), smaller than 5 mm. Besides, in Guangyuan, Sichuan Province, Yongding, Fujian Province, and Zhangyi, Hunan Province, the brachiopod faunas nearby the Permian-Triassic boundary are characterized by small species (Liao, 1979; Zhao *et al*., 1981; Shen *et al*., 1994).

In sum, brachiopod miniaturization happened in either platform facies, basin facies or clastic rock facies during the Permian-Triassic interval, and related to the mass extinction in South China. Besides, whether the rock facies near the Permian-Triassic boundary changes with time going or not, the brachiopod miniaturization occurred. So brachiopod miniaturization is different from community replacement controlled by rock facies, and is related with the Permian-Triassic events.

The Permian-Triassic brachiopod miniaturization is resulted from paleoenvironmental stress, such as sea-level rising, anoxic event, or lack of nutrition in marine water (Liao, 1979; Shen *et al*., 1994; Shen and Shi, 1996; Shen and Archbold, 2002). Brachiopod miniaturization is a special appearance in the Permian-Triassic life crisis. Knowing whether brachiopod miniaturization happened in sudden or step by step and knowing why brachiopod miniaturization happened are very important for understanding the pattern and causes of the Permian-Triassic massive extinction.

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Deep-sea chert and shallow-sea carbonate from the end-Permian mid-Panthalassa

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The Jurassic accretionary complex in Japan contains numerous large allochthonous blocks/lenses of Middle-Upper Permian and Lower Triassic mid-oceanic rocks, i.e., deep-sea chert and shallow-sea atoll carbonates that were derived from the lost superocean Panthalassa (Isozaki *et al*., 1990). Spanning across the Permo-Triassic (P-T) boundary, these accreted oceanic rocks recorded vital pieces of information on the end-Permian global environmental change relevant to the greatest mass extinction in the Phanerozoic. The Permo-Triassic deep-sea cherts in Japan record a unique oceanic episode called the superanoxia, i.e., ca. 20 million year long deep-sea anoxia that continued from the Lopingian to Anisian across the P-T boundary (Isozaki, 1997). It is noteworthy that the onset of superanoxia coincides with another mass extinction at the Guadalupinan-Lopingian (G-L) boundary and that the anoxia culminated at the P-T boundary. Also recognized is remarkable biotic reorganization of radiolarians at the two boundaries. These deep-sea features indicate a two-stepped change in oceanography of the superocean in the Late Permian.

The shallow-sea carbonates primarily deposited on ancient mid-oceanic seamount complexes, on the other hand, record biotic turnover and extinction of fusulinids at the G-L and P-T boundaries (Ota *et al*., 2000; Ota & Isozaki, submitted). Both changes are coupled with negative shift in $\delta^{13}C_{carb}$ (Musashi *et al*., 2001). Thus Panthalassa-derived oceanic rocks, of both deep-sea and shallow-sea facies, demonstrate a significant environmental change in the entire superocean during the Late Permian, particularly in two steps at the G-L and P-T boundaries.

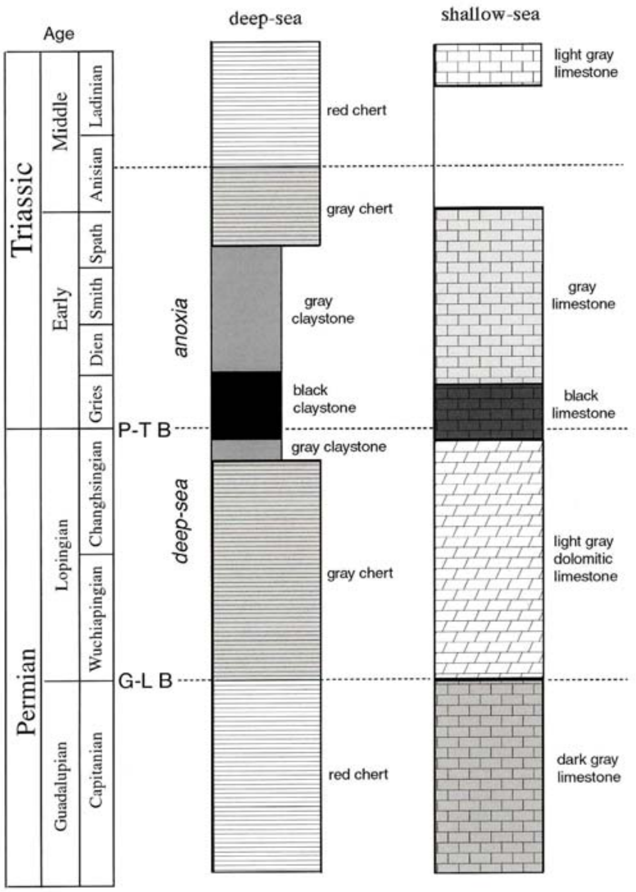

Figure 1. Correlation of the Permo-Triassic mid-oceanic deep-sea cherts and shallow-sea carbonates from mid-Panthalassa

Owing to the difference in lithofacies and fos-sil content, biostratigraphical correlation between the deep-sea cherts and shallow-sea carbonates has a little difficulty; however, another point to be noted is the occurrence of a unique acidic tuff bed at the G-L boundary in shallow-sea paleo-atoll car-bonates (Isozaki & Ota, 2001). This G-L boundary acidic tuff may potentially work as a key bed for regional correlation and strongly suggests that an extensive area, at least western Panthalassa, was influenced by a severe acidic volcanism at the G-L boundary. The rhyo-dacitic geochemistry of the volcanism indicates that the responsible eruption(s) may have been highly violent and thus explosive enough to cover the top of mid-oceanic seamount but also to trigger the global-scale environmental turmoil including superanoxia and relevant mass extinction at the G-L boundary. The P-T boundary in South China is marked by acidic tuff beds (Yin *et al*., 1998; Bowring *et al*., 1998), therefore, both the two Late Permian extinction-related (P-T and G-L) boundary events may have been caused by large-scale acidic volcanism of similar origin.

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End-Permian extinction and biotic recovery: A complete record from an isolated carbonate platform, the Great Bank of Guizhou, South China

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The end-Permian extinction and subsequent Early Triassic biotic recovery are exceptionally well recorded in marine strata of the Nanpanjiang Basin, south China. The Nanpanjiang Basin is a deep-marine embayment in the southern margin of the Yangtze Plate, which was located in the Eastern Tethys near the equator during the Permian and migrated northward to approximately 12°N by the beginning of the Middle Triassic (Enkin *et al*., 1992; Enos, 1995).

Several isolated carbonate platforms within the basin contain conformable Permian-Triassic boundary (PTB) sections and expanded well exposed Lower and Middle Triassic sections. The Great Bank of Guizhou (GBG) is the northernmost platform and it contains the longest uninterrupted Permian and Triassic sections in the basin, spanning the interval from the Upper Permian through the Late Triassic (Lower Carnian). Stratigraphic sections through the PTB and Lower-Middle Triassic recovery interval are exposed in the platform interior, platform margin, and basin margin. A detailed chronostratigraphy for the basin margin sections on the GBG is constrained by conodont biostratigraphy, magnetostratigraphy, carbon isotope stratigraphy, and U-Pb age dates. Exposure of a two-dimensional cross-section enables physical correlation between platform and basin strata.

The GBG nucleated on antecedent topography near the Permian margin of the Yangtze Platform during transgression in the Late Permian. The GBG evolved from a low-relief bank rimmed with oolite shoals and gentle basin-margin slopes during the Early Triassic to a *Tubiphytes* reef-rimmed platform with more than 400 m of relief and steep basin-margin slopes in the Middle Triassic (Anisian - Early Ladinian). Finally, the platform developed a high-relief erosional escarpment before it was drowned and buried by siliciclastic turbidites at the beginning of the Late Triassic, Carnian (Lehrmann *et al*., 1998).

Conformable PTB sections in the platform interior exhibit an upward change from Upper Permian cherty skeletal packstone with diverse open-marine fossils to an interval of microbialite crust (calcimicrobial framestone) 15 m thick with interbeds of grainstone in the basal Griesbachian, followed by microgastropod packstone and lime mudstone. The microbial crust is composed of globular thrombolitic structures resembling *Renalcis* that from a framework with constructional cavities. Lenses of lime grainstone interbedded with the microbial crust contain abundant thin-shelled bivalves. Associated echinoderms and articulate brachiopods indicate open marine conditions during deposition of the microbialite crust (Lehrmann *et al*., 2003). Regional control on genesis of the crust is demonstrated by its presence on all isolated platforms in the basin. Global control is indicated by occurrence of the crust in distant localities in the western Tethys and Panthalassa (cf. Baud *et al*., 1997; Sano and Nakashima, 1997).

The Upper Permian skeletal packstone contains *Palaeofusulina, Colaniela, and Clarkina changxingensis* indicating a Changxingian age. The lowermost sample for conodonts from the microbialite crust was collected 65 cm above the base of the unit and contains *Hindeodus parvus*. Thus, the conformable biostratigraphic PTB is interpreted to occur within the basal 65 cm of the crust. The PTB-event horizon, marking the greatest loss of Permian fossils, is interpreted to occur at the contact between the Upper Permian skeletal packstone and the microbialite crust lacking discernable Permian fossils. *Isarcicella isarcica* first appears immediately above the crust, at the level of the microgastropod packstone. The consecutive first occurrence of *H. parvus* followed by *I. isarcica* thus places the microbialite crust in the basal Griesbachian *H. parvus* zone.

Lower Triassic strata in the platform interior are approximately 400 m thick including: 50 m of thinly bedded lime mudstone and 100 m of dolo-oolite overlying the Griesbachian microbialite crust, followed by 180 m of Dienerian and Smithian peritidal cyclic limestone containing about 30 intervals of calcimicrobial mounds. Fossils are rare. All facies have a low diversity biota dominated by mollusks. Fabrics in the calcimicrobial mounds are identical to those found immediately above the PTB. The Olenekian-Anisian boundary occurs within massively dolomitized peritidal strata in the platform interior. Relative age assignments were made by physical tracing and carbon isotope correlation to basin margin facies at the Guandao section (Payne *et al*., 2004).

The basin margin succession is continuously exposed from the PTB through the Carnian at the Guandao section on the northern margin of the GBG. The Lower Triassic succession consists of 250 m of laminated black pelagic carbonate, subordinate shale, and interbeds of carbonate turbidites and debris flow breccias with oolite clasts. Beginning early in the Anisian strata contain a more diverse skeletal biota including *Tubiphytes* fragments, crinoids, mollusks, and fossiliferous clasts transported from platform margin reefs.

The Guandao section has a well developed chronostratigraphy constrained by abundant conodonts, magnetostratigraphy, and radiometric ages from several volcanic ash horizons. The Olenekian-Anisian boundary is especially well constrained providing a high-resolution record of a critical interval of biotic recovery. Fourteen conodont zones were defined for the Lower Triassic and basal Anisian. The Olenekian-Anisian boundary is characterized by the first occurrence of *Chiosella* *timorensis*. Additional constraints on placement of the boundary include: the last occurrences of *Ns. abruptus* and *Ns. triangularis* (Orchard, 1995) well below the boundary, the occurrence of *Ns. symmetricus* and *Ns. homeri* below and extending slightly above the boundary, and the first occurrence of *Gd. tethydis*, *Ni. germanicus*, and *Ni. kockeli* above the boundary.

Several volcanic ash horizons straddle the boundary. Preliminary U-Pb age dates indicate an age of 248 ma for the O-A boundary. Given that age dates for the end-Permian extinction horizon from independent labs appear to be converging near 252 Ma (see Bowring *et al*., 1998; Mundil *et al*., 2004), the duration of the Early Triassic Epoch and the interval of delayed recovery was approximately 4 million years.

The pattern of biotic recovery was examined in PTB through Ladinian sections in the platform interior and basin margin through analysis of the diversity and abundance of fossil grains. Preliminary results from taxonomic analysis of 608 thin sections, including point counts of 349 thin sections (300 points per slide) represent platform interior and basin margin settings from the Late Permian through the Middle Triassic. Data were compiled at the stage level to obtain broad estimates of the abundance and composition of fossil grains within platform and basin margin strata. The abundance of skeletal grains as a fraction of total rock volume decreased by more than an order of magnitude across the PTB in both platform (31% to 1%) and basin settings (7.4% to 0.005%). Abundance did not increase until the Spathian. The diversity of skeletal grains likewise decreased dramatically across the PTB. The magnitude of the decrease in abundance of fossil grains across the PTB on the GBG cannot be accounted for by changes in sedimentation rate, by changes in local depositional environment, or by taphonomic effects. Instead, we interpret these data to indicate persistently low diversity and abundance of the skeletal biota through the Early Triassic. Accelerated biotic recovery on the GBG began near the end of the Olenekian with a pronounced increase in the abundance of crinoids and the appearance of *Tubiphytes* at Guandao section. In summary, biotic diversity remained low throughout most of the Early Triassic, slow recovery began in the end of the Olenekian and only with accelerated evolution in the Middle Triassic did recovery approach completion.

We also measured carbon isotopes in high-resolution profiles across the PTB and through the Lower Triassic to Middle Triassic recovery interval utilizing the same suite of samples (Krull *et al*., 2004; Payne *et al*., 2004). The carbon isotope results demonstrate that the PTB isotope excursion was not an isolated event. Rather, it was the first in a series of (mostly larger) excursions that continued throughout the Early Triassic and into the early Anisian. The excursions ended in the early Anisian (Bithynian) and were followed by an extended interval of stable values that continued through the remainder of the Middle Triassic and into the Carnian. At least four negative excursions (to as low as -2‰) separated by positive excursions (to as high as +8 ‰) occurred during the Early Triassic. The data corroborate the previous reports of positive excursions at the Smithian-Spathian and Olenekian-Anisian boundaries as well as the general pattern of a composite isotopic profile from Anhui Province (Baud *et al*., 1996; Atudorei and Baud, 1997; Tong *et al*., 2004).

The large perturbations of the carbon cycle coincide with low biodiversity in the Early Triassic aftermath of the extinction, both locally and globally. Middle Triassic diversification of skeletal biota, local increase in fossil abundance, and recovery of metazoan reefs either coincide with or slightly post-date stabilization of the carbon cycle in the Anisian (Payne *et al*., 2004). Notably large negative carbon excursions coincide with the onset of the two episodes of microbialite crust and mound genesis in the platform interior. These observations suggest that repeated environmental disturbances responsible for perturbations of the carbon cycle also directly inhibited biotic recovery. The occurrence of peculiar microbialite crusts and mounds during the period of low biodiversity and carbon cycle instability indicates that the environmental disturbances that retarded biotic recovery may have also stimulated precipitation of the crusts. Therefore, we favor a scenario in which the removal of environmental disturbances allowed biotic recovery to proceed in the Middle Triassic. Characterizing the precise nature and geographic distribution of the environmental controls on biotic recovery may shed light on the nature of interactions between the physical environment and organic evolution that shaped the biotic recovery, and may also constrain interpretations of the mechanism underlying the end-Permian extinction.

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Chronostratigraphic and biostratigraphic control on the Permian- Triassic boundary in the Zhongzhai Section, Guizhou Province, Southwest China.

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The recovery of conodonts associated with ash beds in the key Zhongzhai Section, near Langdai, Liuzhi, Guizhou Province, provides precise and definitive control on both the stratigraphic level and age control on the Permian-Triassic boundary in the transition from marine to non-marine facies of western Guizhou and eastern Yunnan Provinces of southwestern China. In the Zhongzhai section the Triassic Yelang Formation is presumed to rest conformably on either the Longtan or Dalong Formation, depending on the interpretation of the section.

In the Zhongzhai Section the boundary interval consists of a lower limestone, 20 cm thick, that contains fragments of *Hindeodus* sp. and *Clarkina* sp. This is overlain by a 50 cm thick black shale bed containing an abundant brachiopod fauna, but no conodonts. This bed is in turn overlain by a 25 cm thick limestone that contains *Clarkina* sp., *Hindeodus changxingensis*, *H. praeparvus* and *H.* aff. *H. eurypyge*. Directly over this limestone is a 5 cm thick ash bed followed by a 10 cm thick black shale, which is overlain by a second, upper, ash bed that is 3 cm thick. Both ash beds were sampled for zircons study. On top of the upper ash bed is a 15 cm thick silty limestone containing an abundant dwarf conodont fauna, dominated by *Hindeodus*, and containing *H. parvus*. We tenatively place the Permian – Triassic boundary at the level of the black shale located between the two ash beds.

TIMS dates on zircons from ash beds adjacent to the Permian–Triassic boundary in the Zhongzhai Section provide a valuable control section in tracing the distribution of the ash clouds associated with volcanism on the South China Block in the Late Permian and earliest Triassic.

Aligning marine and non-marine Permian-Triassic boundary sections using biostratigraphy and high-resolution eventostratigraphy: An example from western Guizhou and eastern Yunnan, southwestern China

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Both vertically and laterally continuous Permian-Triassic boundary (PTB) sequences from marine via on-shore (marine and terrestrial alternate) to terrestrial facies are well-outcropped in western Guizhou and eastern Yunnan, southwestern China, making this area a potential hotspot for the study of high-resolution subdivision and correlation of the PTB from marine facies to land (Peng *et al*., 2002, 2005). Six PTB sections from marine via on-shore to terrestrial facies in this area are well-studied (Fig. 1). Among them, two (the Chahe and Zhejue sections) are terrestrial PTB sections, two (the Mide and Tucheng sections) are on-shore (marine and terrestrial alternate) ones and the other two (the Zhongzai and Gaowo sections) are shallow marine ones (see Fig. 1 for positions of these sections).

The PTB of these sections from marine to terrestrial facies in western Guizhou and eastern Yunnan can be subdivided and correlated with high-resolution through biostratigraphy as well as eventostratigraphy. Biostratigraphically, plant fossils of the Cathaysian *Gigantopteris* flora are found dominating in the Upper Permian of both the terrestrial and the on-shore PTB sections (Nanjing Inst., 1980; Wang and Yin, 2001; Peng *et al*., 2005), making the Upper Permian of these two facies correlative. Marine fossils found in the on-shore and the shallow marine PTB sections shape another way for the direct biostratigraphic correlation of these sections. As bridge sections, the on-shore PTB ones provide both marine and terrestrial fossil evidences to indirectly correlate the terrestrial PTB sections with their marine counterparts in western Guizhou and eastern Yunnan. Under this biostratigraphic framework control and applying the concept of the Permian-Triassic boundary stratigraphic set (PTBST) composed of PTB clayrocks of volcanic origin in all these PTB sections from marine via on-shore to terrestrial facies (Peng *et al*., 2001, 2005), the PTB in western Guizhou and eastern Yunnan can be subdivided and correlated with high-resolution among these different facies.

The most important evidence for the high-resolution correlation of the PTBST in South China is the finding of the Early Triassic index fossil *Hindeodus parvus* (Kozur and Pjatakova) in the PTBST other than the Meishan Global Stratotype Section and Point (GSSP) section. This time, not just supported by the similar vertical PTBST sequence in western Guizhou and eastern Yunnan, *Hindeodus parvus* was also found in the PTBST of the Zhongzai section (one of the shallow marine PTB sections in western Guizhou and eastern Yunnan, section e of Fig. 1) (I. Metcalfe, 2004, pers. comm. in Florence, Italy). This finding provides strong support not only for the high-resolution subdivision of the PTB in western Guizhou and eastern Yunnan and also for the high-resolution

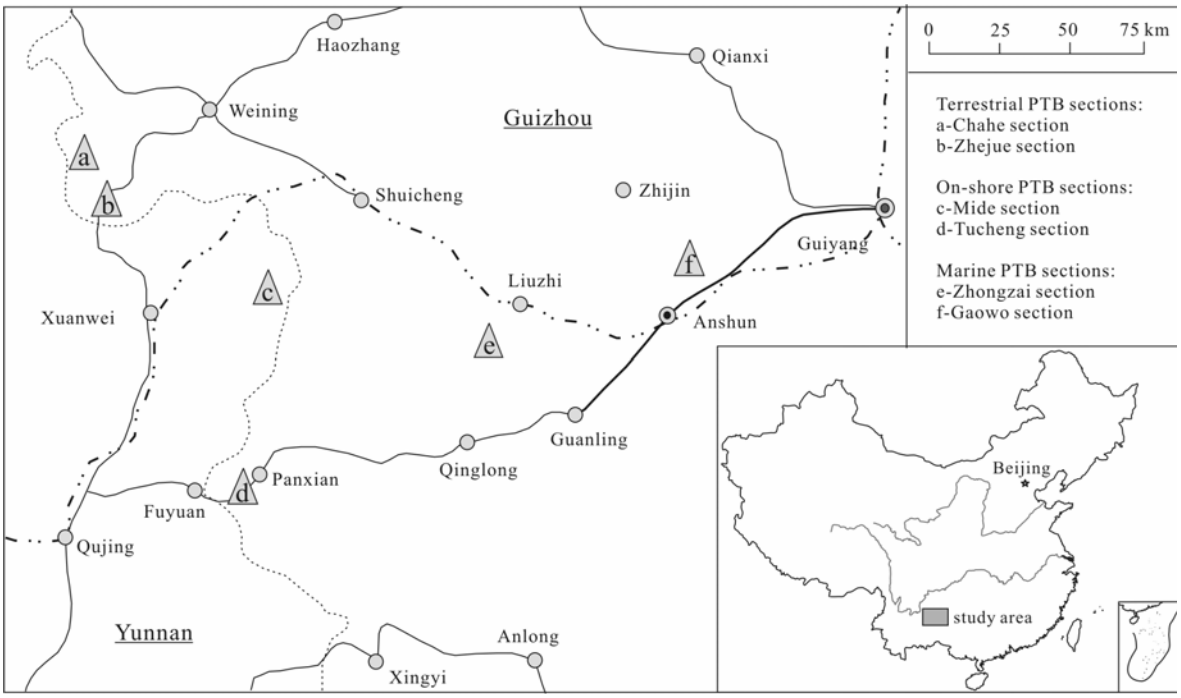

Fig. 1. The geographic position and transportation roots in western Guizhou and eastern Yunnan, southwestern China.

correlation of the PTBST from this area to the other parts of South China, and especially to the Meishan GSSP section.

In the meantime, the carbon isotopic excursions across the PTBST in both marine and terrestrial PTB sections are also correlative in South China, and even worldwide with the reference to the Meishan GSSP section in South China. Three distinct stages of $\delta^{13}C_{org}$ excursion can be identified from the PTB strata of the Chahe section in western Guizhou and eastern Yunnan, i.e. of higher values in the Upper Permian, dropping and forming a main excursion from higher to lower values in the PTBST, and then remaining at lower values and slowly recovering upwards in the Lower Triassic (Peng *et al*., 2005). This serves well for the definition and correlation of the PTB from marine to terrestrial facies in western Guzhou and eastern Yunnan, southwestern China with other biostratigraphic and eventostratigraphic markers (Peng *et al*., 2005). It can also be well correlated with the changing trends in the PTBST at some other well known marine PTB sections (such as the Meishan GSSP section and the Shangsi section) in South China (Yan *et al*., 1989; Xu and Yan, 1993; Cao *et al*., 2002) and worldwide in both marine and terrestrial realms (Baud *et al*., 1989; Wang *et al*., 1994; Macleod *et al*., 2000; Ward *et al*., 2005; and many others). The worldwide drop event in $\delta^{13}C$ is thus usually suggested as one of the auxiliary markers for the demarcation of the PTB when fossil evidences are absent, especially in the terrestrial realm (Peng *et al*., 2005; Ward *et al*., 2005), though actually the sharp negative excursion in $\delta^{13}C$ is slightly older than the formal stratigraphic PTB defined by the first appearance of conodont *Hindeodus parvus* at the Meishan GSSP section (Jin *et al*., 2000; Cao *et al*., 2002).

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End-Permian mass extinction pattern in the northern peri-Gondwanan region

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The Permian-Triassic extinction pattern in the peri-Gondwanan region is documented biostratigraphically, geochemically and sedimentologically based on three marine sequences deposited in southern Tibet and comparisons with the sections in the Salt Range, Pakistan and Kashmir. Results of biostratigraphic ranges for the marine faunas reveal an end-Permian event comparable in timing with that known at the Meishan section in low palaeolatitude and Spitsbergen and East Greenland in northern Boreal settings although patterns earlier in the Permian vary. The previously documented delayed (late Griesbachian) extinction at the Selong Xishan section is not supported based on our analysis. The event is exhibited by an abrupt marine faunal shift slightly beneath the Permian-Triassic boundary (PTB) from benthic taxa- to nektic taxa-dominated communities. The climate in the continental margin of Meso-Tethys before the extinction event was yet cold. However, a rapid climatic warming event was associated with the extinction event as indicated by the southward invasion of abundant warm-water conodonts, warm-water brachiopods, and gastropods. Stable isotopic values of $\delta^{13}C_{carb}$, $\delta^{13}C_{org}$ and $\delta^{18}O$ show a sharp negative drop slightly before the extinction interval. Sedimentologic and microstratigraphic analysis reveals a regression event, as marked by a Caliche Bed at the Selong Xishan section and the micaceous siltstone in the topmost part of the Qubuerga Formation at the Qubu and Tulong sections. The regression event was immediately followed by a rapid transgression beneath the PTB. Alternatively, the “Caliche Bed” may be interpreted as a secondary carbonate deposit precipitated around a solution-collapse breccia, in which case relative sea-level fluctuations are equivocal. The basal Triassic rocks fine upward, and are dominated by dolomitic packstone/wackestone containing pyritic cubes, bioturbation and numerous tiny foraminifers, suggesting that the studied sections were deposited in the initial stage of the transgression and hence may not have been deeply affected by the anoxic event that is widely believed to characterise the zenith of the transgression.

The Wuchiapingian-Changhsingian boundary (Upper Permian) at Meishan of Changxing County, South China

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The Changhsingian represents the second and last stage of the Upper Permian, which is also known as the Lopingian Series. It is officially referred to as an informal chronostratigraphic unit (Remane *et al*., 2000) since formal recognition of this stage boundary has not yet been presented to the International Union of Geological Sciences for ratification. Among the potential candidates for the GSSP of this boundary, Section D at Meishan appears very promising. It not only has historic priority, but is also represented by a fully developed marine sequence with highly diverse faunas and microflora.

Meishan is located between the cities of Nanjing and Shanghai in Changxing County, Zhejiang Province, SE China. Stratigraphic successions of Late Paleozoic and Early Triassic rocks are well exposed and have been extensively studied over the past 25 years. In 2000, the upper part of Section D was ratified by IUGS as the GSSP for the Permian-Triassic boundary (Yin *et al*., 2001). The lower part of Section D has also been well studied in terms of many fossil groups (Sheng *et al*., 1984), magnetostratigraphy (Li and Wang, 1989), chemostratigraphy (Li, 1998), radiometric dating (Bowring *et al*., 1998; Mundil *et al*., 2001) and sequence stratigraphy (Zhang *et al*., 1997). In 1981, Zhao *et al*. (1981) proposed to formally define the base of the Changhsingian Stage at the horizon between the *Clarkina orientalis* Zone and the *C. subcarinata* Zone that is located at the base of Bed 2. They indicated that the base of this stage is also marked by the occurrence of *Palaeofusulina*, along with the tapashanitid and pseudotirolitid ammonoids. Since the well-defined faunal changes in major fossil groups such as conodonts, brachiopods, ammonoids, corals and fusulinaceans across the boundary (Jin *et al*., 1997) may be accentuated by the presence of a significant unconformity, effect have been made to look for a suitable boundary a little higher in the section. Wardlaw and Mei (2000) suggested the First Appearance Datum (FAD) of *Clarkina subcarinata* as a marker for the base of the Changhsingian. Later, Mei *et al*. (2001a, 2001b) found the *C. longicuspidata – C. wangi* lineage in Bed 4, and suggested the FAD of *C. wangi* in the lineage as the lower boundary of the Changhsingian, which is 88 cm above the base of the Changxing Limestone. However, this proposal was disputed by Wang *et al*. (2001), who believed that there is a depositional gap between the Longtan Formation and the Changxing Limestone as previously suggested by others (Zhu and Zhu, 1984).

Meishan Section C, about 300 m west of Section D, was recently excavated. Detailed studies on the lithology and palaeontology of the boundary strata provide strong evidence for a conformable succession from Wuchiapingian to Changhsingian. A complete evolutionary lineage from *Clarkina orientalis - C. longicuspidata – C. wangi* is confirmed at this section and the index fossils of the Changhsingian, *Sinoceltites*, *Tapashanites* and *Palaeofusulina sinensis* are found around the proposed boundary level.

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REPORTS

Report on Oman Permian-Triassic fieldtrip in 2005

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After the 24th IAS Meeting of Sedimentology in Muscat, Sultanate of Oman, 10th-13th January 2005, our team organized a post-meeting Fieldtrip A 13: Birth and Early development of the Tethyan Oman Margin from Middle Permian to Middle Triassic: a geochemical and sedimentological approach. Our team comprised Sylvain Richoz and Aymon Baud, (Lausanne) field leaders, with the help of Leopold Krystyn (Vienna), Jean Marcoux (Paris) and Richard Twitchett (Plymouth). Eight scientists from different countries participated with enthusiasm in the four day excursion, January 14 to 17, 2005.

The magnificent outcrops of the Oman Mountains, provided the participants with unparalleled access to a Permian to Triassic Tethyan platform carbonate, continental slope and abyssal plain deposits.

The mountainous belt located in the eastern part of the Arabian Peninsula, the Oman Mountains, exposes a segment of the Gondwanan margin, interpreted as a flexural upper plate. The Permian-Triassic sequence (platform carbonate) deposited on the inner part of this margin is exceptionally well exposed in the Jabal Akhdar Mountains. New data on the Permian-Triassic sequence stratigraphy and carbon isotope curve were presented in the Wadi Sathan section.

Carbonates derived from the platform represented the major source for the thick sequence of slope carbonates (the Sumeini Group) deposited near the platform margin, cropping out in the Sumeini area near the border between Oman and the United Arab Emirates. The lower part of this group (about 1700 metres thick) is included in the Maqam Formation of Middle Permian to Late Triassic age. A key section of the Oman margin architecture, the Wadi Maqam section, has been re-investigated in terms of biochronology, sequence and isotope stratigraphy and the new data were discussed in the field.

On more distal parts, the basinal and oceanic sedimentation resulted in various types of carbonate, of chert and siliciclastic deposits, presently found in the Hawasina Nappe. The Middle Permian radiolarites (Buday'ah) and red ammonoid limestones (Rustaq) deposited on lavas are cropping out as blocks of various dimensions, the Oman Olistoliths, North or West of the "autochthonous" tectonic window.

Spectacular and well studied outcrops of the Jabal Akhdar Mountains in the Wadi Sathan, of nearby Rustaq, Buday'ah, Wadi Maqam and Jebel Sumeini areas allowed the reconstruction of a correlated facies model, sequence and isotope stratigraphy and the former geometry of the margin from Middle Permian to Middle Triassic time.

A guide book was distributed to the participants and it is expected to be on internet this year on the IAS web site: Richoz, S. and Baud, A., with the help of Krystyn, L., Twitchett, R., and Marcoux, J., 2005, Permo-Triassic deposits of the Oman Mountains: from basin and slope to the shallow platform, 24th IAS regional meeting, Muscat, Oman, Field guidebook A13: 57 pp.

Scientific teams who want to be introduced or guided in their research on Permian-Triassic in Oman, please contact the author at aymon.baud@sst.unil.ch.

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Discussion on Late Permian-Early Triassic conodonts: Morphological variation and evolutionary succession

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1. Introduction

Since Yin *et al*. (1988) proposed the first appearance of *Hindeodus parvus* as a marker of the basal Triassic, the study of conodont faunas near the Permian-Triassic boundary has become increasingly important. In recent years, a large number of articles concerning conodont identification, taxonomy, evolution and provincialism have been published. A brief review of these papers reveals that there are different opinions on how to deal with Permian-Triassic boundary conodonts. This brief report mainly deals with some potential problems and provides an initial discussion on conodont identification, evolution and paleoecology. It is hoped that conodont workers around the world can reach a general agreement after further research and cooperation.

2. Criterion of defining a new species or subspecies

No question in theoretical paleobiology or modern biology has been more controversial or perplexing than "What is a species?" (Wheeler and Meier, 2000). It is easy to claim that the fossil record can say nothing about speciation when using the biological species concept directly because the interbreeding and genetic relationships inherent to the concept cannot be recognized (Benton and Pearson, 2001). In extinct animals such as conodonts, the concept of species cannot be biologically tested and therefore suffers from uncertainty. However, fossilized organisms are often preserved in sufficient abundance for populations of intergrading morphotypes to be recognized, thereby providing a potential biologic approach to the taxonomic analysis. A prerequisite to paleobiologic interpretation is to determine the relevant scale for investigating patterns of size and shape variability that are expressed by various fossilized organisms (Giard *et al*., 2004).

Microfossil groups such as conodonts, frequently show gradualistic patterns of evolution and speciation punctuated occasionally with more rapid evolutionary change. Conodonts were characterized by a complex feeding apparatus, including elements involved in different functions according to their shape and position within the apparatus (Purnell and Bitter, 1992). Among those elements, the Pa or P1 element, which may be concerned with a food-processing function, is considered the most important and diagnostic element (Donoghue and Purnell, 1999; Mei *et al*., 2004) at the species level. The Pa elements of Permian gondolellids are not highly diversified in morphology and therefore are not easy to classify. Rare individuals within a population may exhibit one or several characteristics that are thought to be diagnostic of another species (Wardlaw and Collinson, 1979; Mei *et al*., 2004). Differing taxonomic methods will result in the recognition of either a few species (population approach) or many species and subspecies of Late Permian-Early Triassic conodonts (form species approach). Actually, it's natural to recognize increasing numbers of taxa as a result of intensive research on conodonts at the important P-T interval. The problems are finding a taxonomic philosophy or approach that results in taxa that are as widely recognizable as possible and avoiding the use of taxa defined on single specimens. The point is to find and communicate the correct scale of morphological variation of external details so that various workers can recognize species consistently. Of course, besides stable and minor morphological variation, a clear and appropriate distribution range, evolutionary succession and regional or worldwide correlation should also be emphasized when a new

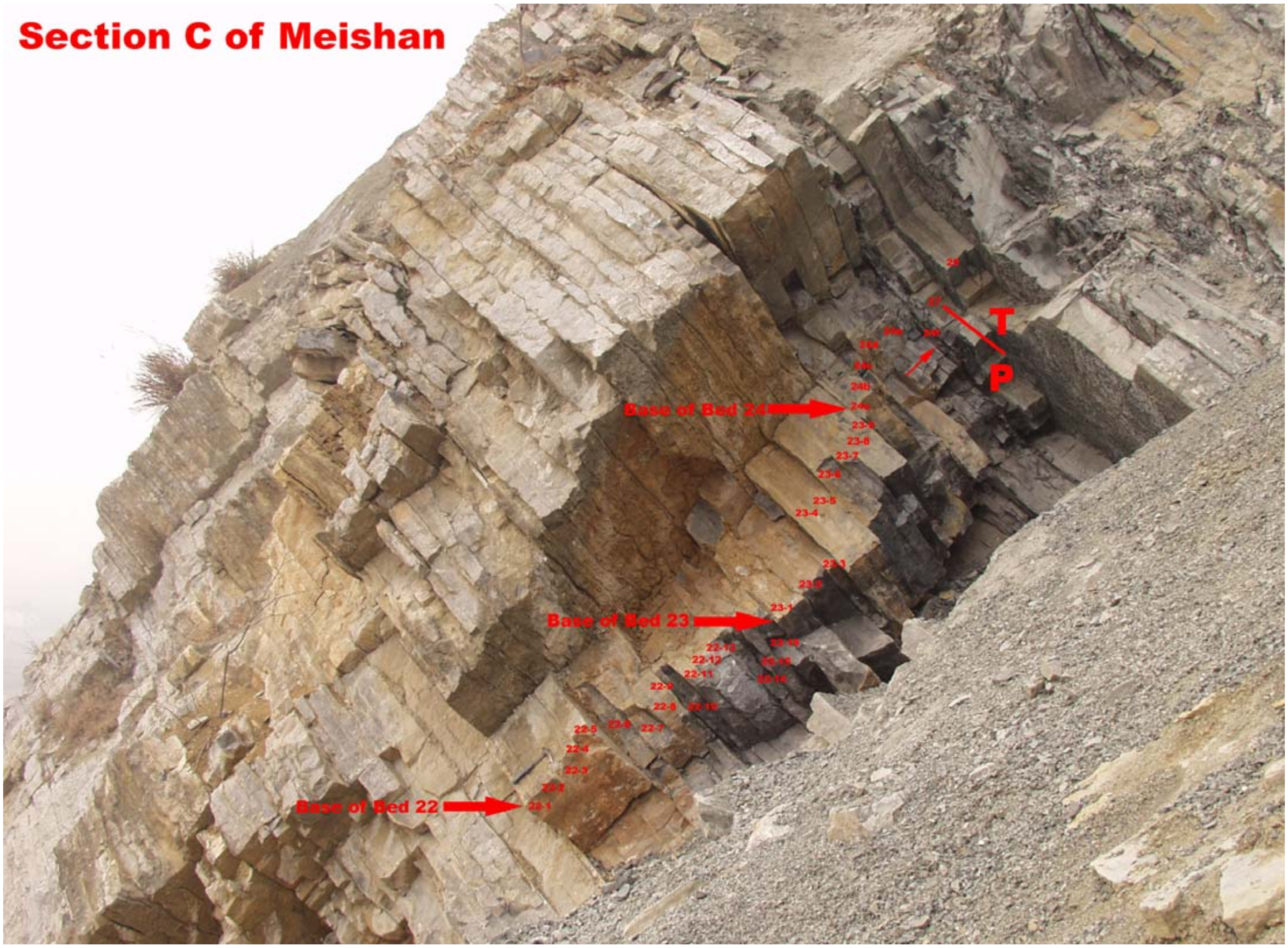

Fig. 1. Permian-Triassic boundary at Meishan section C showing the sample data

species or subspecies is defined.

Several examples are provided below:

1). Different morphotypes of the Genus *Isarcicella*

Lai (1997) mentioned such a phenomenon and used the Triassic conodont *Isarcicella* as an example to support his point of view:

> *Morphologically, e.g.,* Isarcicella isarcica *(Huchriede,1958) has the following morphotypes based on denticle numbers and denticle distribution: (a) one denticle on one side;(b) two denticles on one side; (c) three denticles on one side; (d) more than three denticles on one side;(e) one denticle on each side;(f) one denticle on one side and two denticles on the other side;(g)one denticle on one side and three denticles on the other side; (h) one denticle on one side and a denticle series with more than three denticles on the other side;(i) two denticles on each side;(j) two denticles on one side, three denticles on the other side etc. If we only consider the minor morphological changes of the conodont specimens, there would be more than 10 species within the genus* Isarcicella. *Moreover, if these so-called new species are without a definite distribution, enough materials and correlatable characters, this may evoke confusion on the P/T boundary study.*

2). Appropriate distribution range of Late Permian neogondolellid conodonts

Mei *et al*. (1998) restudied new conodont collections from the Changxing Formation at the Meishan section and presented a refined succession of Changhsingian and Griesbachian neogondolellid conodonts. These new definitions were based on features of both the denticulation and the platform shape. Six assemblage conodont zones were established and included in ascending order: 1) the *C. prechangxingensis-C. subcarinata-C. wangi-C. predeflecta* Assemblage Zone; 2) the Transitional Assemblage Zone; 3) the *C. changxingensis changxingensis-C. parasubcarinata-C. postwangi-C. deflecta* Assemblage Zone; 4) the *C. changxingensis yini-C. meishanensis zhangi* Assemblage Zone; 5) the *C. meishanensis meishanensis* Zone; and 6) the *C. zhejiangensis* Zone.

Recognition of the above taxa was based on features of both denticulation and platform shape (round, square, narrow and transitional forms emphasizing the shape of the posterior margin). Mei *et al*. (1998) found that the most consistent and reliable character in Lopingian neogondolellids is the general configuration of the carinal denticles, which can be used to define a natural population or an apparatus species. We definitely agree with this conclusion. Mei *et al*. (1998) also emphasized that the shape of the platform is of secondary importance, which can be used only to identify form species within a natural population, or a temporal subspecies. Regarding this point of view, we wonder whether it is necessary to separate taxa for pointed and rounded morphotypes when the carinal denticulation patterns are identical; one test would be to count numbers of specimens of different morphotypes from a few successive and highly abundant samples and look for systematic variation. The "species concept" of Mei and Henderson (Mei *et al*., 2004) interpreted platform outline as a plesiomorphic character because pointed, rounded and squared platforms are seen in all *Clarkina* taxa. Platform outline is therefore not suitable for phylogenetic analysis. Since the taxonomic quagmire for the genus *Clarkina* is deep and remains a big problem for all conodont workers on the Late Permian-Early Triassic interval, we are not prepared to discuss the taxonomy of *Clarkina* in detail here, but hope to provide a lengthy description after further work in the near future.

In conclusion, when a new species or subspecies is established, the level of morphologic variation and the distribution range and interpreted evolutionary lineage must be considered carefully and decisions regarding the correct apomorphic characters and regional or cosmopolitan correlation potential must be made. All of these features should be emphasized and tested among one another.

3. Morphological variation and evolutionary succession

Many researchers have intensively studied the conodont biostratigraphy of the Upper Permian to Lower Triassic succession at Meishan (Changxing, Zhejiang Province, China) for several years. Unfortunately, although the FAD of *Hindeodus parvus* has been accepted as the marker of the base of the Triassic system, the evolutionary succession of the genera *Clarkina* and *Hindeodus* is still unsettled or disputed at present. Fortunately, we note that at the Chaohu meeting (May 2005), regardless of evolutionary succession problems, that everyone was using the FAD of *Hindeodus parvus* as the base-Triassic and that this common language is allowing considerable progress to be made, pointing to the value of completing our various GSSP tasks.

Nicoll *et al*. (2002) re-studied the conodonts from the Permian-Triassic transition in South China (Shangsi section and Meishan D section) and re-assessed the evolution of the genus *Hindeodus*. They indicated that, "Analysis of conodont biostratigraphy of the Meishan D section and the Shangsi section suggest significant differences between the two sections. These include the absence of *H. changxingensis* (Wang) from the Shangsi section and the approximately 4.5 m of the Shangsi section that contains *H. priscus* (Kozur), *H. latidentatus* (Kozur) and *H. eurypyge* n. sp. below the FAD of *H. parvus*. These differences may be accounted for most easily by suggesting that there is a minor depositional hiatus at the Permian-Triassic boundary GSSP level as based on the first appearance of the conodont *Hindeodus parvus* at the Meishan D section."

Kozur (2004) discussed several sections from Iran such as Jolfa, Zal (both NW Iran), Shahreza and Abadeh (both central Iran) and described 12 new species and 2 new subspecies and provided a new "complete" conodont succession for the Permian/Triassic transition (Korte *et al*., 2004a, 2004b). In other words, Kozur's conclusion suggests that the conodont succession at Meishan, South China is incomplete and that there may be a hiatus within the P-T boundary GSSP strata?

The above differing interpretations (Metcalfe *et al*., 2001; Nicoll *et al*., 2002; Kozur, 2004) challenge us to wonder how much, if any, of the section is missing at Meishan. How does one ever truly prove continuity of strata? What kind of conodont succession is ever totally complete given facies and paleoecologic controls on distribution? In order to answer these questions appropriately, we must escape from the potential pitfalls of conodont biostratigraphy and emphasize the evolution of conodonts and their synergistic evolution with environmental change. For example, subsequent samples from Shangsi have revealed the presence of *H. changxingensis* (Wang) and graphic correlations reported by Wardlaw (pers. comm. at Chaohu meeting

May 2005) extend the range of *H. parvus* downward through all of that key 4.5 m interval. Henderson in a lecture at Nanjing (Oct. 2004) indicated that Kozur's ranges could be interpreted to correlate well with Meishan and that there were no missing zones, just missing taxa that are apparently endemic to Iran. It is interesting to note that many researchers (Tian, 1992, 1993; Wardlaw *et al*., 2003; Mei *et al*., 2004) have noticed that there is a clear evolutionary progression and a pattern of morphological variation. However, there is still a lot of work needed to complete the evolutionary status of the genera *Clarkina* and *Hindeodus* around the PTB interval and to find consensus among different researchers. We are clearly still in a beginning stage of the evolutionary research on conodonts from Late Permian and Early Triassic rocks.

4. Work plan on Late Permian-Early Triassic conodonts from South China

This report documents results from the preliminary graduate thesis preparation of the first author. A plan for future thesis work on Late Permian-Early Triassic conodont research from South China follows.

1) Materials and methods

About 60 rock-samples have been collected and are being dissolved in the laboratory of Nanjing Institute of Geology and Palaeontology. Most samples are from Meishan section C, between the base of Bed 22 and base of Bed 30 and the total thickness is less than 5 metres (Fig. 1). The others are from Meishan section B, in order to compare with those obtained from section C.

Once the separation and picking work have been finished and all specimens have been collected, a detailed analysis of the conodont succession will be conducted to determine the suite of taxa and establish the zonation. The sample-population based taxonomic approach will be used, which usually views the entire collection within a given sample as a population and recognizes the most consistent and stable characters within that "sample-population" for identification (Mei *et al*., 2004). In particular the carinal development will probably be recognized as an apomorphic character for the conodont genus *Clarkina*. Homeomorphy, ontogenetic variation, and statistical analysis of size and abundances of morphotypes will also be emphasized.

2) Comparison and test for Meishan results

The Meishan section is located on an intra-platform depression between an uplift and platform, and shows transitional aspects in sedimentary facies of platform to slope (Yin *et al*. 2001). It's true that the stratigraphic succession of Late Permian-Early Triassic interval at the Meishan section is very thin. Some workers suspect that important detailed information on conodont evolution is either missing or difficult to recognize in this condensed stratigraphic succession. Therefore, a section with a thicker, possibly more complete succession in the Late Permian-Early Triassic interval should be studied in addition to test the conodont zonation established at Meishan section across the PTB. The Penglaitan section at Laibin area, Guangxi Province, South China and other supplementary sections in this area may satisfy such demands very well. Unfortunately, conodonts from Laibin are not as common as they are at Meishan since the potentially high depositional rates in this interval will have a dilutional effect on abundance. In order to solve this problem, more samples from those sections in Laibin are required.

In addition, remarkable provincialism affects Permian conodont distribution (Mei *et al*. 2001). In order to compare and test our results with different strata around the world, we will also analyze specimens from South Tibet, Iran, Sverdrup Basin (Arctic Canada), and Opal Creek (Western Canada), if possible.

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The Upper Permian in NW Caucasus

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The Upper Permian rocks of the Malaya Laba area south of the village of Nikitino (NW Caucasus) are a classic reference succession for this part of the Permian on the northern shores of the Paleo-Tethys.

Likharev (1926), Robinson (1932) and Miklukho-Maklay (1954, 1956) were the first to describe their geology and fauna, but more recently, a number of papers, (*e.g.* Kotlyar *et al.*, 1983, 1989, 1999, 2004, Boiko *et al.*, 1991; Pronina-Nestell and Nestell, 2001) illustrated these faunas in more detail. The foraminifer content of the Nikitino Formation and Urushten Formation was considered to be Late Changhsingian by Pronina-Nestell and Nestell (2001) and Kotlyar *et al*. (2004), indicating a younger age than previous age assignments.

Previous study of the brachiopod fauna, however, suggests a Capitanian to Changhsingian age (Grunt and Dmitriev, 1973; Kotlyar *et al.*, 1983, 1989; Waterhouse, 1976) and this is supported by previous ammonoid studies from the region, which suggest a pre-Wuchiapingian age (Bogoslovskaya, 1984; Rostovsev, 1984; Zakharov, 1985).

The brachiopods described by Kotlyar *et al.* (2004) chiefly consist of new taxa and differ significantly from the typical assemblages recorded in the Palaeo-Tethys at end-Permian time, except for a few taxa reported by the authors in Table 1, but not figured nor described. The list of taxa indicated as shared with the Late Changhsingian of South China in Kotlyar *et al.* (2004, p. 516) is puzzling as some of them do not occur in South China (Xu and Grant, 1994) or even in NW Caucasus (Kotlyar *et al.*, 2004). Furthermore, most of the main representatives of the Changhsingian brachiopod biofacies of South China (Xu and Grant, 1994, p. 12-13) are absent in the biofacies of NW Caucasus.

The newly recorded brachiopod taxa from NW Caucasus comprise two new genera (*Labaella* and *Licharewiconcha*) belonging to two new families of the Order Productida, both genera are characterized by the type-species only; three new genera (*Tethysiella*, *Nikitinia* and *Licharewina*) characterized by the type-species only, of which two are new; the genus *Caucasoproductus* Kotlyar, 1989 elsewhere recorded only from the Wuchiapingian of South Primorye, far eastern Russia; a new species of *Rhipidomella*, which is a cosmopolitan genus spanning the Devonian-Permian time interval; and a new species of *Cathaysia*, which as a genus ranges from the Early to Late Permian.

The ammonoid taxon described alongside the brachiopods is similarly a new genus, typified by a new species.

The main problem is that it is impossible to identify the exact stratigraphic position of the brachiopods in the sections, as no sample number is indicated on the sections (Kotlyar *et al.*, fig. 3), nor in the systematic palaeontology, which lacks specimen numbers and descriptions of material. This lack of information severely hampers biostratigraphic studies and recognition of brachiopod assemblages through time.

The situation is rather intriguing. A section along the Nikitino Creek, surveyed by M. Gaetani and E. Garzanti in 1997 (Gaetani *et al.* 2005), is as follows, bottom to top:

1. Grey-green thinly bedded metarenites and metasiltites of Paleozoic age, possibly Devonian and Carboniferous, tectonically including also massive rhyolites and bounded at the top by a large cataclastic zone.

2. Grey packstone-wackestone in 10-20 cm thick nodular beds, with brachiopods and echinoderms (> 20 m thick). In thin section *Reichelina cribroseptata* Erk and *Paleofusulina* sp., *Tubiphytes, Permocalculus, Gymnocodium, Mizzia,* and *Vermiporella* were identified by E. Leven of Moscow. They are overlain by light-grey massive packstone and wackestone, locally bindstone with sponges, brachiopods (productids, spiriferids and rarer rhynchonellids) and crinoids. Both levels are referred to the Nikitino Formation [Miklukho-Macklay, 1956]. Total thickness > 100 metres.

3. Locally tectonized, red arenites and conglomerates channelize the Nikitino Formation in a stratigraphic contact. Isolated pebbles up to 50 cm in size of diorites, quartzites, metamorphic rocks and also limestones with the same microfacies of unit 2) were observed in the basal 5 m of this unit. They are overlain by siltites-arenites and conglomerates in a festooned channel/interchannel complex, about 50 m thick. The upper part of the unit consists of red medium to coarse-grained arenites, with low-angle cross-lamination and rare lenses of conglomerates. Total thickness > 100 metres.

The red beds are quartz-rich arkoses, with abundant polycrystalline quartz and K-feldspar prevailing over plagioclase. The lower part of the unit is characterized by more common carbonate grains, including reworked fusulinids. In the upper part of the unit, carbonate, volcanic and chert grains are less common, whereas quartzose terrigenous grains are significant.

Faults occurring toward the top of this level are highly possible, but not recognizable due to the extensive soil cover.

4. Grey and slightly pink massive packstone and more rarely wackestone, with a coarse brecciated structure, forming

small buildups as well. This should be part of the Urushten Formation [Miklukho-Macklay, 1956]. Thickness about 25 metres. Above this unit, outcrops are largely missing and only some small dark grey shale/siltite packages may be observed around the Nikitino and Kurovski villages.

5. Dark grey siltites with thin seams of fine arenites with truncated ripples. This could be the base of the Triassic succession.

The Permian section along Nikitino Creek shows first a shallow water carbonate complex, mostly of low energy environment with sponge mounds and a rich foraminifer-brachiopod assemblage. Due to a subsequent emersion and partial erosion, the sequence braided river-alluvial plain-submerged delta was deposited and may be recognized. Because of poor exposures, the stratigraphic position of the marine aggradational unit with foralgal mounds forming patch reefs (Urushten formation), laterally indented with more shaly interlayers, is not clear, although that facies apparently became dominant in the latest part of the Permian. According to Kotlyar *et al.* (2004), Kutan, Nikitino and Urushten are considered as coeval lithofacies of a carbonate-terrigenous complex, named the Belalabinskaya Group.

Due to the extensive wood cover of the area, correlations between Nikitino Creek and Severnaya Ravine (Pronina-Nestell and Nestell, 2001; Kotlyar *et al.* 2004), where terrigenous facies dominate, are not obvious, due to the very different facies.

Both papers apparently are based on old collections. We think that with new, bed by bed sampling it would be possible to elucidate the age discrepancies between foraminifers and brachiopods.

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Fieldwork in the Bowen Basin kick-starts new international study of the Late Permian – Early Triassic of Australasia-Antarctica

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Recent fieldwork was undertaken in the Bowen Basin, Queensland, Australia (Figs. 1-3) by an international research team as part of a pilot study on Late Permian isotope geochronology that is initiating a much larger five-year multidisciplinary project investigating "**Late Permian-Early Triassic Timescale Calibration and the Permian-Triassic Boundary and Mass Extinction in Australasia and Antarctica**". The pilot study in Queensland, aims to provide new radio-isotopic geochronological timescale calibration for the Late Permian-Early Triassic of the Bowen Basin and identification of the Permian-Triassic boundary and late Permian mass extinction levels in Eastern Australian sequences. The study is undertaking U-Pb

Fig. 1. The pilot study research team at an exposure of Black Alley Shale, Bowen Basin. Left to right: Roland Mundil, Bob Nicoll, Guang Shi, Rob Creaser and Ian Metcalfe.

Fig. 2. Rob Creaser (left) and Bob Nicoll (right) collecting organic-rich mudstones for Re-Os dating.

Fig. 3. Roland Mundil collecting a volcanic ash layer from coal measures in the Bowen Basin.

IDTIMS dating of zircons and Ar-Ar dating of feldspars from volcanic tuffs, and also Re-Os dating of organic-rich mudstones. An important aspect of the study is to further intercalibrate the new innovative rhenium-osmium dating technique with U-Pb and Ar-Ar isotopic systems. Prof. Ian Metcalfe of the Asia Centre, University of New England, Australia, leads the pilot project team and he was joined in the Bowen Basin by Dr Robert Nicoll (Australian National University), Dr Roland Mundil (Berkeley Geochronology Centre, USA), Prof. Robert Creaser (University of Alberta, Canada) and A/Prof. Guang Shi (Deakin University, Australia).

The team also spent time at the Geological Survey of Queensland core library in Brisbane sampling borehole cores with collaborator Dr John Draper (Geological Survey of Queensland). The fieldwork involved sampling of the Late Permian marine to non-marine sequence in the Carnarvon Gorge area of central Queensland where volcanic ashes and mudstones were sampled from the Frietag, Ingelara, Peawaddy, Black Alley, and Bandanna Formations, and in the Moranbah-Blackwater area where volcanic tuffs were sampled from coal measures exposed in the spectacular coal mines of the Bowen Basin, including the important basin-wide stratigraphic marker Platypus and Yarrabbee Tuffs.

The larger five-year multidisciplinary project aims to provide accurate and precise radio-isotopic calibration of the Australian Late Permian-Early Triassic, to understand the nature of the P-T biotic crisis in both marine and terrestrial environments, and to better understand the causes of global extinctions and how life subsequently recovered, by applying a range of globally cutting-edge, innovative, multidisciplinary studies. The project will build on extensive ongoing multidisciplinary work on the P-T transition in China by our group with colleagues from Australia, USA, China, and elsewhere funded between 1999 and 2004 by the Australian Research Council and the National Science Foundation of the USA and will apply innovative new techniques and knowledge acquired from the type P-T transition sequences in China and other parts of the world to Australasia and Antarctica. Studies will involve radio-isotopic geochronology, biostratigraphy, chemostratigraphy, palaeoclimatology, stratigraphy and sedimentology, magnetostratigraphy, impact tracer studies and impact structure assessment, and palaeogeography. The geographic area of focus is Australasia-Antarctica with specific targeted field areas including Eastern Australia (shallow marine-continental sequences of the Bowen and Sydney basins), Western Australia (marine sequences in the Perth, Canning, Carnarvon and Bonaparte basins), East Timor (marine sequence), New Zealand (arrow rocks deep-marine oceanic section), and Antarctica (non-marine sequence, Prince Charles Mountains). A large international research team has been assembled for this umbrella project, which includes twenty-five scientists from Australia, USA, Canada, U.K., New Zealand, Russia and Japan. The expected outcomes from this project will be:

- An accurate, high-precision, robust radio-isotopic numerical timescale calibration and chronostratigraphic framework for the Late Permian-Early Triassic of Australasia-Antarctica.
- Improved correlation of P-T biostratigraphic schemes across Australia, within Australasia and Antarctica and, via West Australia and Timor biostratigraphic gateways, to the rest of the world.

- Accurate constraints on the position and nature of the P-T boundary and mass extinction levels in Australasia and Antarctica.
- Improved correlation of marine and terrestrial P-T mass extinction events within and between marine and non-marine environments constraining temporal coincidence or diachroneity.
- Better understanding of the relationship between the P-T boundary and mass extinction and biostratigraphic and depositional facies changes in Australia, the region, and globally.
- Enhanced understanding of the probable causative mechanism(s) of the mass extinction.
- Better understanding of the systematic bias between and calibration of U-Pb IDTIMS, U-Pb SHRIMP, Ar-Ar and Re/Os isotopic decay systems and further assessment of Re-Os dating for Phanerozoic timescale calibration.

Symposium on the Permian and Triassic Playas at Montpellier, France, May 10-12, 2005

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A European Symposium on the "Permian and Triassic playas of South France, physical and biological environments: comparisons with other areas" was held in Montpellier (Languedoc, France) from 10th to 12th May 2005. It was organized by the "Association des Géologues du Permien et du Trias" (A.G.P.T.), in co-operation with the University of Montpellier, and was also inspired by the research activities on the continental deposits, which were solicited by the IUGS Subcommission on Permian Stratigraphy (SPS) during the XIII International Congress on the Permian and Carboniferous Systems, in 1995 in Kraków, with the view to promoting non-marine and marine correlations.

The Symposium consisted of a scientific conference of two-days in the University of Montpellier, and a preliminary field trip in the close Permian Lodève Basin and its Triassic cover. Over 50 participants, in large part working on the topics of the meeting, came generally from Europe, and in particular from France, Germany, Italy and Spain.

The pre-symposium excursion led to the publication, by M. Lopez, G. Gand, J. Garric, J. Galtier and many other contributors, of a well depicted field guidebook of 54 pages devoted to the geology of the above-mentioned area, which can be considered as one of the most complete and best exposed Lower to (?)Upper Permian profiles in Europe with facies transition from fluvial-lacustrine grey sediments to alluvial and playa redbeds, and up to about 2500 metres thick. Therefore this guide, as well as the observations and explanations in selected stops, permitted the participants to achieve a better confidence with the unusual subjects of the meeting.

A volume-abstract also assembled the oral and poster presentations of the symposium, of which the proceedings will be published in a special volume of the Spanish "Journal of Iberian Geology" review.

The Conference was focused on the following topics: i) what is a playa? (with presentations of Durand, Schneider, and Deroin); ii) Permian and Triassic playas (Argyriadis, Schneider, Lopez, Körner, Hübner, Stapf, Schneider, Perotti, Ronchi, Lopez, and Théry), iii) playa life (Galtier, Gand, Schneider, Béthoux, Gand, Werneburg, Steyer, Martin-Closas and Gand). Authors and titles of the above contributions are indicated at the end of this report.

Generally, the first topic highlighted location, environments, climate, formation, case-histories of some current playas in the world; the second one displayed their geological features, physical makeup and formation processes, from the Lodève and other Permian and Triassic basins; the third and last topic dealt with the flora and fauna related to playa environments from the aforementioned basins.

Further, an assessment of the Symposium and a workshop on the differing depositional ages of the Lodève Basin formations concluded the work.

In conclusion, the recent meeting of Montpellier improved our knowledge about the Permian-Triassic sequence of the investigated region, and specifically emphasized some significant geological features of particular environments, such as those pertaining to the playa-like deposits; thus, the respective lithological and palaeontological characteristics of the Lodève Basin and its cover can be considered as an important reference for studies carried out on vast scale.

List of contributions (alphabetic order):

Argyriadis, I. – La paléogéographie du Permien supérieur ed du Trias inférieur méditerranéens: interprétation gédynamique.

Béthoux, O. – The insect fauna from the Permian of Lodève (Hérault, France): summary and prospects.

Carruba, S., Cassinis, G. and Perotti, C.R. – Geodynamics and structures of the Permian playa-type basins in the central Southern Alps.

Deroin, J.-P. – Permian and Quaternary playa environments as paleogeographic and paleotectonic markers: a comparative approach.

Galtier, J. and Broutin, J. – La végétation des playas de Lodève.

Gand, G., Demathieu, G., Vianey-Liaud, M. and Lopez, M. – The palichnofauna of the Middle to Upper Triassic playa environments from the Lodève and Cévennes regions.

Gand, G., Garric, J., Lapeyrie, J., Walther, H. and Schneider, J. – Triopsid (Crustaceans, Branchiopoda) biocoenoses in the Permian playa environment of the Lodève basin (France), climatic and palaeoecologic results.

Garric, J. – Fossiliferous rills in playa environment from the Permian Lodève basin (Languedoc, France).

Hübner, N., Körner, F., Schneider, J.W., Gand, G., Garric, J., Gebhardt, U. and Kleeberg, R. – The Permian of the St.-Affrique basin (Southern France): Stratigraphy and facies analysis.

Körner, F., Schneider, J.W., and Gand, G. – Sedimentology and geochemistry of the Permian red beds of the Lodève Basin: Implications for palaeoenvironment and climate.

Legler, B. and Schneider, J.W. – Playa/Sabkha environments of the Soutnern Permian basin, North Germany.

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Martín-Closas, C. and Guarinos, A. – Taphonomy of the “Autunian” flora of Baro (Catalan Pyrenees).

Nel, A., Fleck, G., Garrouste, R. and Gand, G. – The Late Permian *Odonatoptera* of the Lodève Basin.

Ronchi, A. and Santi, G. – Playa to lacustrine episodes and associated biofacies fom the Lower Permian of the Orobic Basin (Southern Alps, Italy).

Rocher, M. and Schneider, J.W. – Carboniferous/Permian climate development.

Schneider, J.W. – Playas present and past – examples from Europe and Arabia.

Schneider, J.W. and Lapeyrie, J. – Permian Blattida (Insecta) and Conchostraca (Spinicaudata and Laevicaudata) of the Lodève basin.

Stapf, K.– Les sabkhas dans le Permien du détroit de Rodez (Massif Central, France).

Steyer, J.S., Damiani, R., Sidor, C.A., Smith, R.M.H., O’Keefe, F.R., Larsson, H.C.E., Ide, O. and Maga, A. – New temnospondyl amphibians from the Permian of Sahara and palaeobiogeographical implications.

Thery, J. M. – Les playas du Permian terminal du Parana (Brésil).

Werneburg, R., Schneider J.W., Gand, G. , Vianey-Liaud, M., Körner, F. and Steyer, J. S. – New pelycosaurian and amphibian remains from the La Lieude Formation, Lodève Basin (Late Permian of Southern France).

Workshop: The difficulty in dating the continental Permian Formations. Contribution to the discussion about the Lodève basin. (Gand, G.).

Isotopic chemostratigraphy of the Permian-Triassic boundary in Zagros Mountains, Aligoudarz, Iran

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Abstract

Lithological sequences from the Permian-Triassic transition in Middle Zagros, Iran are composed of the Dalan Formation limestone with shelly fauna, Khaneh Kat Formation with two stromatolite units at the lowermost part as well as 250 m of dolostone with rare fossils in the upper part, and shale with typical Lower Triassic fossils including *Claraia* in ascending order. The biostratigraphic succession has not been worked out yet. However, carbon and strontium isotopic results strongly show potential global event correlation. Carbon isotope excursions range from more positive values in the Upper Permian with a depletion upward around the boundary, and a lower value in the Lower Triassic. It demonstrates that higher values of 3‰ ~ 5‰ and 1‰ ~ 2‰ mostly concentrate within the main parts of the Permian Dalan Formation and the Lower Triassic Khaneh Kat Formation respectively; in contrast, dramatic depletion to -0.5‰ spans the Permian-Triassic boundary. Strontium isotope values in the upper Dalan Formation are 0.7074 and match the model of dramatic depletion of carbon isotope. This synchronous and unique depletion at the end of the Permian is a fact. Thus, it is more likely to assign the Permian-Triassic boundary at the interval of the two notable stromatolite units. Such a proposal is quite different to the former scheme that the P-T boundary was assigned to the base of stromatolite units based on lithostratigraphic change only.

1. Introduction

Even through multiple mechanisms cause the variety of carbon isotopes of carbonate ($\delta^{13}C$ for this paper) during earth history (Kump, 1999; Holser, 1997; Wignall and Hallam, 1992) $\delta^{13}C$ still has considerable potential as an application to study bioevents and correlate stratigraphy in the latest decade (Holser, 1989; Kump, 1991, Hayes, 1999). As a proxy of the carbon cycle, original $\delta^{13}C$ evolution in earth history has two types: secular and transient variation. Secular shift is generally caused by changes in the fractional burial of organic carbon and transient shift by abrupt changes of biological productivity in the surface photic zone (Holser, 1995, 1997). The fluctuation spanning the PTB is regarded as transient shift under overprint of secular fluctuation (Holser, 1995, 1997) and of course includes an overprint by selective weathering (Jin et al., 2000, Cao, 2002). Comparing with that of other geological episodes, research on $\delta^{13}C$ of the Permo-Triassic transition is one of the most studied (Jin et al, 2000; Baud, 1989). It is based on a uniform worldwide dramatic depletion close to the boundary and the interpretation of the process for the biggest extinction event in earth history (Hsu, et al 1985; Erwin, 1993; Jin

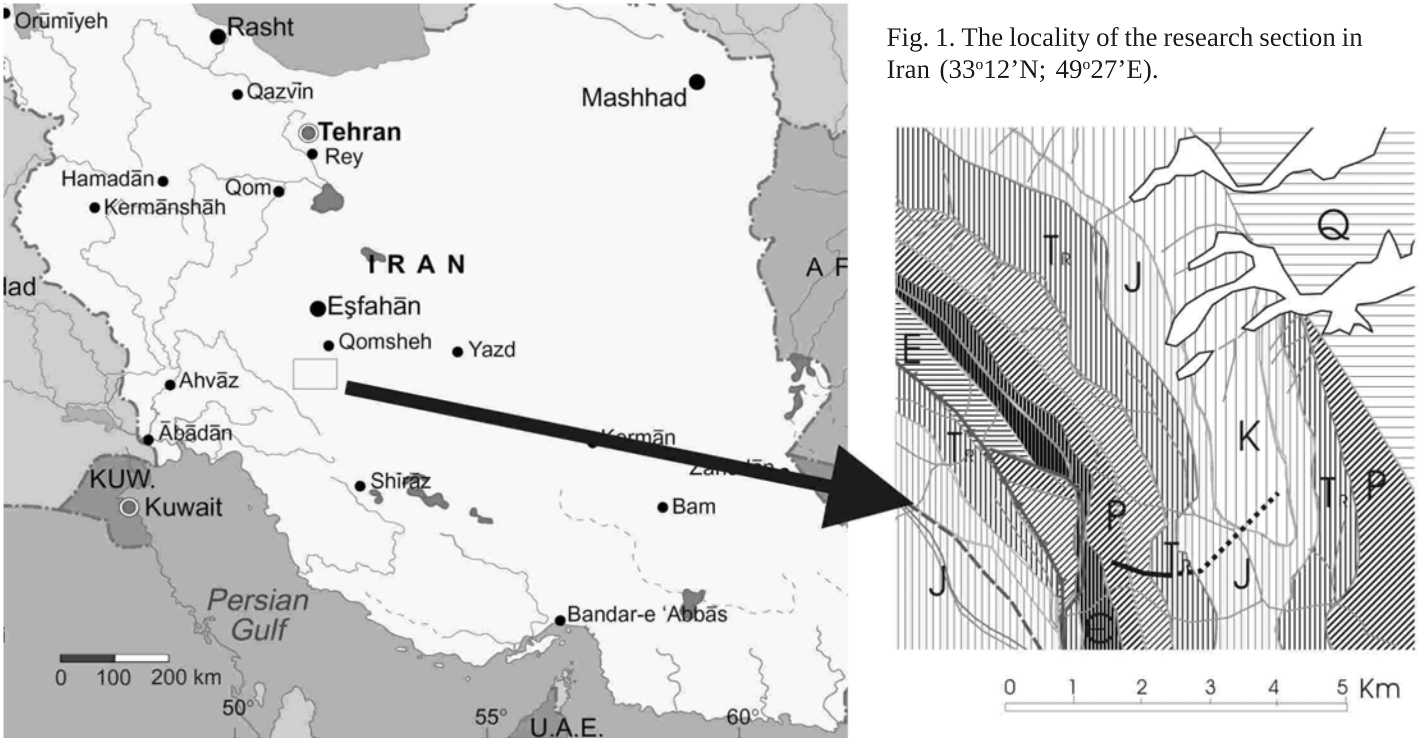

Fig. 1. The locality of the research section in Iran (33°12'N; 49°27'E).

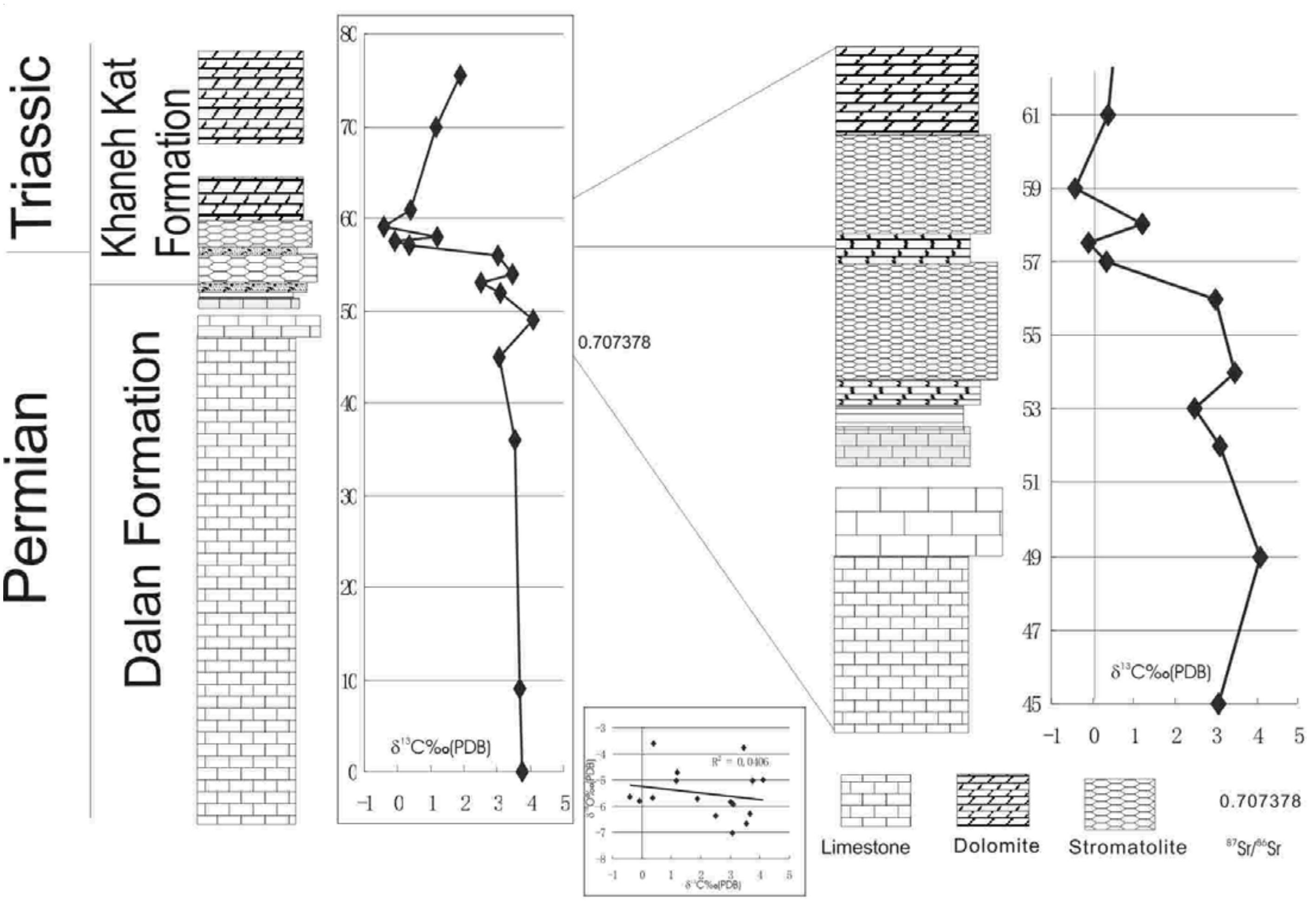

Fig. 2. Carbon isotope excursion on Permo-Triassic boundary section at Aligoudarz, Iran.

et al., 2000); therefore, this dramatic depletion of ä^{13}C is also unique in Upper Permian rocks worldwide (Wang, 2004; Baud, 1989).

The Alpine-Himalayan Orogenic System represents a classic continental collision belt from the Mesozoic onward (Windley, 1984). The Iranian (or Persian) plate and Arabian plate are considered as the corridor connecting the eastern and western parts of the system. In addition, the Iranian part of the Zagros foothills and Persian Gulf are one of the most prolific oil and gas provinces. The Middle Zagros Mountain region is significant for research of the orogenic history of the Tethys and has an important role controlling the tectonic pattern of the oil-bearing basin. Stratigraphic correlation of the Paleozoic rocks, including the definition of the Permo-Triassic boundary (PTB as follow) in Zagros basin in Iran Plate, has been well documented (Heydari, 2003, 2000; Baud, 1989). Compared to that in the Iranian Plate area, study on the PTB in the Zagros area or Arabian Plate is still at an early stage with only a simple biostratigraphic framework, except a few sections reported from Oman (Krystyn, 2003). Thus, a more exact identification of the PTB with special reference to its dramatic paleo-oceanographic changes by means of chemostratigraphy is necessary. The chemostratigraphy on the PTB in Zagros area is important for the stratigraphic correlation and the palaeoenvironmental succession in the south Tethys.

2. Geological setting and lithological sequences

Detailed regional geological descriptions of the Zagros Mountains are given by several authors concerning aspects of stratigraphy, sedimentary and tectonic evolution (Kashfi, 1976; Farhoudi, 1978; Alavi, 1980; Ghavidel-Syooki, 1995). The consensus is that convergence of the Arabian and (Iranian) Persian plates started during Early Mesozoic time, resulting from a gradual closure of the Tethys ocean basin and subsequent subduction of the Arabian plate beneath the stable Persian plate.

During Paleozoic time, the Zagros sedimentary basins were part of the main Tethys geosynclinal system (Kashfi, 1976). This area maintained a stable epeiric sea character as illustrated by shallow water carbonates during the Permian. Such a pattern continued into the Late Cretaceous until it was succeeded by chalk, marl and limestone of Eocene age. The Paleozoic rocks of southwest Iran are mainly exposed close to the Main Zagros Thrust. Paleozoic units outcropping beyond the Main Zagros thrust are of Ordovician and Permian age essentially. The strata exposed in the Aliguodarz area include Late Paleozoic, Mesozoic and Cenozoic sediments (Fig. 1).

The Upper Permian and Lower Triassic sequences were named as the Dalan Formation and it is overlain by the Khaneh Kat Formation (Fig. 2). The Dalan Formation consists of laminated limestone, thin beds of dolomitic limestone, dolostone, carbonaceous brown-red sandstone and, in some cases, gypsum and marl lithologically. Horizontally, lithologic variety of the Dalan Formation is from dolostone to dolomitic limestone and limestone in the Zagros area. This formation can be subdivided as a lower member of dark grey limestone and upper member of light grey dolomitic limestone respectively based on the present section. The upper member of the Dalan Formation occurs as grainstones rich in calcareous algae-foraminifera and yielding a typical Changhsingian fauna including species of *Palaeofusulina*, *Nanlingella*, *Paradagmarita* and *Paraglobivalvulinoides* together with high diverse benthic elements represented by corals, crinoids, brachiopods *etc*. In contrast to the greater lithologic variety exhibited by the Dalan Formation, the Khaneh Kat Formation is more likely to include a uniform dolostone succession. A brown-red stromatolite unit at the lowermost part of the Khaneh Kat Formation conformably overlies the Dalan Formation. Furthermore, the stromatolite unit can be subdivided as two beds vertically with a half metre thick unit of thin-bedded grey dolostone between. The lower stromatolite bed is about 1 m thick, and the upper stromatolite bed about 1.5 metres thick. The PTB in this area traditionally has been defined at the lithologic boundary between the Dalan Formation and the Khaneh Kat Formation (or coeval Kangan Formation) (Baghbani, 1992). However, The FAD of the typical Triassic index fossil of *Claraia* (Scythian) occurs at a much higher dolostone horizon, 250 m above the stromatolite unit at the base of the Khaneh Kat Formation. Obviously, the resolution of the biostratigraphy in this study is not precise enough to identify the boundary for hundreds of metres across the lithological unit. Thus, a more exact dating of the PTB from a 250 m thick interval between the base of the stromatolites and FAD of *Claraia* is necessary. Carbon and Strontium isotopic data will provide the necessary information for correlation.

3. Methodology

Carbon isotope excursion chemostratigraphic research is a possible approach to the problem. Standard chemical processes were applied to the samples; the method included phosphoric acid evolution for one week and subsequent mass spectrometry (MAT 252) of evolved CO_2 as measured ($\delta^{13}C$, all standardized by PDB ‰) at the University of Tokyo, Japan. Before measurement, all samples are selected from deep within the cut piece across the centre of a hand sample, as well as a detailed check to make sure the sample lacks diagenetic veins or sharp colour change on polished surface; this screening was rigorously conducted in the lab and field. Data with $\delta^{18}O$ value lower than -7‰ will be re-evaluated, and consequently, $\delta^{18}O$ value from only one sample was -7.01 with $\delta^{13}C$ of 3.07‰ (‰ relative to the Peedee belemnite, PDB). Meanwhile, $\delta^{18}O$ values from most samples were around a typical range of -3‰ to -5‰. Comparing with traditional strontium isotope preparation, our method of sample dissolution for $^{87}Sr/^{86}Sr$ measurement has been updated with an acetic acid-acetic ammonium buffer system. Samples were washed with $1MNH_4Cl$ and have been dissolved by 1M acetic acid-acetic ammonium buffer (pH=4.5) in 60^{o}C ultrasonic system for 3 hours. Strontium isotopes were measured at Ryukyu University, Japan, on MAT 262 via a standard resin cation exchange process. $\delta^{13}C$ vs $\delta^{18}O$ statistical analysis shows that the R-squared value is as low as 0.04; therefore, the statistical relationship between these data is not remarkable. All of above evidence indicate that the samples were not weathered too deeply to mislead the interpretation and conclusion (Holser, 1997).

4. Excursions of $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ values on the PTB section of Aligoudarz in Zagros

Values of $\delta^{13}C$ show a typical excursion in this section that coincides with that of universal results. Values range from 3‰ to 4‰ within the upper part of the Dalan Formation, which comprises a typical Permian fauna. Around the middle of stromatolite unit, $\delta^{13}C$ represents a dramatic depletion to values around -0.3‰ to -0.5‰. It is compatible with well-documented ä^{13}C dramatic depletion at the PTB globally. In the lower-middle part of the upper stromatolite bed, ä^{13}C recovers gradually to 1‰ to 2‰, and remains at such a range onward into the overlying dolostone system. This ä^{13}C excursion is also potentially correlated with that of the PTB elsewhere (Baud *et al*., 1989; Cao, 2002). In detail, δ^{13}C value is enhanced in the dark grey member of the Upper Dalan Formation as a range variation from 3‰ to 4‰. There is a possible sedimentary hiatus 2 m below the top of the Dalan Formation; however, the ä^{13}C value has similar behavior throughout this possible hiatus and above a 2-m thick unit with a little decreasing trend from 4‰ to 2.5‰ at the top. Upward, δ^{13}C is a little enhanced to 3‰ to 4‰ in the lower stromatolite bed, the lowermost of the Khaneh Kat Formation. There is a dramatic depletion of the ä^{13}C value to around 0‰ in the dolostone interbedded between the upper and lower beds of the stromatolite unit. Spanning this dolostone, δ^{13}C values appear to rise a little at the base of the upper stromatolite bed to 1.2‰. In the middle part of the upper bed of the stromatolite unit, ä^{13}C values deplete again to -0.5‰. Finally, δ^{13}C values show a gradual recovery from 1.5‰ to 2‰ in the overlying dolostone of the lower Khaneh Kat Formation.

In summary, based on the documented sections, ä^{13}C values are positive in the Upper Permian at 3‰ to 5‰, and then follow a depleting trend from the uppermost Permian. Around the stromatolite unit, ä^{13}C values present a more positive shift at the top the Permian, and dramatic depletion to -0.5‰ in the middle of the unit, and then they stay low with a little recovery in the upper bed of the stromatolite unit. This database from the present section shows a significant excursion that coincides with equivalent sequences world-wide. Thus, the lower bed of stromatolite unit should be considered as top of Permian.

^{87}Sr/^{86}Sr of one sample from the upper member of the Dalan Formation shows that they keep an original Upper Permian value of 0.707378, which was normalized by NBS987 (0.710235±0.000015), and the samples is dated by Changhsingian fossils (Veizer *et al*., 1999). On the other hand, Holser (1997) suggested that ^{87}Sr/^{86}Sr values are easily altered by weathering processes than are ä^{13}C values from carbonate rocks, but this value is comparable with documented values of the Late Permian (Denison *et al*., 1995; Veizer *et al*., 1999). It is possible to conclude that both carbon and strontium isotopes keep their original values.

5. Chemostratigraphic correlation and discussion

ä^{13}C PTB have been reported from many stromatolite bearing units in the south Tethys area, such as Abadeh in Iran (Baud, 1989; Heydari, 2000), Vedi in Armenian, Curuk Dag in Turkey (Baud, 1989), Wadi Wasit in Oman (Krystyn, 2003). Stromatolite beds in all of these sections are regarded as the base of Triassic, or a little above of PTB on biostratigraphy and δ^{13}C values in these sections also support such an interpretation. δ^{13}C values show a dramatic depletion from 3‰ to 5‰ in top of Permian to around 0‰ or negative values across the PTB, and is generally below the stromatolite beds. This model is regarded as biomass extinction related with dramatic changes in the carbon cycle from the end of the Permian, which results in a dramatic depletion of ä^{13}C. The lower value of ä^{13}C and its depletion spans the PTB, and upward the Lower Triassic also encountered a lower biomass after the extinction when a dominant stromatolite system survived in severe environment.

However, the ä^{13}C excursion from this research is unique compared with previously documented sections. In nearly all documented sections, ä^{13}C excursions mostly represent typical lowest Triassic value around 0‰ or negative, after 3-5‰ dramatic depletion from higher value in the Upper Permian. The lowest value of ä^{13}C is just a little below or at the PTB, and it decreases gradually from higher value of top of Permian to the lowest value at base of Triassic. The δ^{13}C values of the documented sections have lower value around 0‰ or negative in the stromatolite unit that is typically assigned to the lowermost Triassic. The biostratigraphic boundary of Permo-Triassic is regarded as coinciding around the last decreasing excursion value of δ^{13}C (Krystyn, 2003; Heydari, 2000; Jin, 2000; Erwin, 1993; Holser *et al*., 1985; Baud, 1989) from documented sections with good biostratigraphy. No change was found at the base of the Triassic; therefore, it has a similar value to the Upper Permian. The reason why δ^{13}C excursions spanning the PTB is considered as important index data for the PTB confirmation is that it could be well correlated with biostratigraphic results (Jin, 2000; Baud, 1989).

Based on the excursion of δ^{13}C across the PTB of the present section, the boundary should be located at the top of the lower stromatolite bed or the overlying dolostone bed. The overlying bed of the lower stromatolite bed is thin-bedded with light grey dolostone and has δ^{13}C values from 0.2‰ to -0.2‰; this overlying dolostone unit has a typical value matching the lowermost Triassic. It is hard to believe that the lower layer of the stromatolite could be defined as the lowermost Triassic since its δ^{13}C value is more likely to be attributed as typical of the topmost of Permian. Thus, the middle to lower part of the stromatolite layer should be more reasonably considered as uppermost Permian.

The data show a typical excursion to that in sections with stromatolites from elsewhere in the Tethys. Most stromatolite bearing PTB sections have a little higher δ^{13}C value of 3‰ to 5‰ in uppermost Permian, and follow a gradually or dramatic depletion to 0‰ to negative below or at the base of stromatolite unit. Finally, ä^{13}C values stay low around 0‰ or negative upward into the Lower Triassic (Krystyn, 2003; Heydari, 2000; Baud, 1989). This excursion spanning the PTB is regarded as indicative of the mass extinction at the end of Permian and synchronous with a dramatic depletion of carbon isotopes, and the lower values of ä^{13}C in the Lower Triassic indicates a lower biomass after the extinction (Cao, 2002; Jin, 2000, Erwin, 1993; Baud, 1989; Holser *et al*., 1985). The documented stromatolite-bearing PTB sections are depleted of ä^{13}C and commonly regarded in the Early Triassic as a lower biomass oceanic background after the extinction. However, the present section differs from the other documented stromatolite-bearing sections and shows that δ^{13}C values are typically higher as 3‰ to 4‰ at the top of the Dalan Formation and in the lower stromatolite bed. It may promote two possible interpretations. First, based on traditional PTB located at the base of stromatolite unit, the depletion of δ^{13}C values in this area initiates from the Early Triassic instead of the Late Permian, and the δ^{13}C has higher values as 3‰ to 4‰ around the PTB. It does not match the other sections that δ^{13}C depleting starts from the uppermost Permian. Secondly, based on carbon isotopic chemostratigraphy, the stromatolite developed in the Upper Permian in this area and does not match to other documented stromatolite-bearing sections of the Lower Triassic. However carbon isotope data could be affected by local marine conditions and cannot be correlated by absolute values, which is quite different to that of the strontium isotope system. Nevertheless, the model and trend are same and/or correlatable with the δ^{13}C depletion from the Upper Permian. Moreover, δ^{13}C is a proxy of carbon cycle with CO$_2$ in atmosphere and the dramatic depletion just across the boundary has a global significance for paleoenvironmental change as well as correlation. The possible reason is that the carbon isotope ratio of CO$_2$ in the atmosphere is similar globally and the trend or model is correlatable and synchronous. However, paleoenvironmental changes triggering end Permian extinction happened just at or a little in advance of the boundary since higher δ^{13}C values of 3‰ to 5‰ occur in Late Permian. This higher value takes into account higher bioproductivity or higher organic matter burial. Values as high as 3‰ to 4‰ in the lower stromatolite bed hints that higher bioproductivity and/or organic matter burial might be maintained for a relative long duration. For this reason, δ^{13}C value does not exactly corresponding to the base of the stromatolite unit or below as PTB elsewhere.

Without exception world wide, ä^{13}C has a dramatic depletion around PTB, and PTB (biostratigraphic boundary) is suggested at the end of this depletion (Cao, 2002; Jin, 2000, Erwin, 1993; Baud, 1989; Holser *et al.*, 1985). ä^{13}C value represent a synchronous excursion with biostratigraphy, especially based on conodont definition. Thus, the ä^{13}C excursion of a Permo-Triassic section indicates that the biostratigraphic boundary is being approached. In the Iran Plate, the PTB locates below the base of stromatolite unit, such as Abadeh section (Baud *et al.*, 1989; Heydari *et al.*, 2000, 2003) or is just at the base the stromatolite units such as Wadi Wasit block section in Oman (Krystyn, 2003).

However, the case of the present study with the PTB rising into the lower-middle part of the stromatolite unit is somewhat different to those in the west Tethys area showing a diachronous occurrence. The sequence of the appearance was developing gradually from the research section (earlier) to Oman section (middle) and Abadeh section (later).

In other words, the stromatolite unit is diachronous with respect to the PTB from below the base of stromatolite (Abadeh section) to the base (Oman section), and even to lower middle part of the stromatolite unit (this studied section). All of Iranian PTB sections, mostly in the Iranian Plate, represent this depletion at the boundary (Holser, 1987; Baud, 1989; Heydari, 2001).

One possibility is that the extinction initiated from the south margin of Tethys since the stromatolite could be considered as an oceanic anomalous parameter especially if the end Permian extinction was really a gradual progress on some scale. In contrast, it can be interpreted as local severe paleoenvironment in south of Tethys. The disaster taxa of the stromatolite unit originated from end Permian in Zagros area, and expanded eastward from Gondwana to the Tethys neighboring areas of Oman and then to Arabian Plate in south Tethys.

Comparing to the data of δ^{13}C in this section, evidence of strontium isotopes also suggest its notable importance for chemostratigraphic correlation and paleoenvironmental interpretation. ^{87}Sr/^{86}Sr ratio from the dark grey limestone, where dated by Changhsingian index fossils, 7 m below the base of lower stromatolite layer is 0.707378. The uppermost part of the Permian is documented as 0.7082 to 0.7078, and about 0.7070 at the Early Lopingian (Dension *et al.*, 1995; Veizer *et al.*, 1999). ^{87}Sr/^{86}Sr values show a rapid increase in the Lopingian from 0.7070 (early Lopingian) to 0.7080 (the Permo-Triassic interval). As Sr isotope ratio is 0.707378 in this section, it means this horizon is not correlated to the uppermost part of the Permian, but later than Early Lopingian. It is possibly similar with the value of deposits of middle to early Changhsingian age. Even the boundary of Guadalupian-Lopingian has a ä^{13}C depleting in South China, which is suggested to correspond with a pre-Lopingian bioevent (Wang, 2004), but not only the ä^{13}C depletion is minor, but also ^{87}Sr/^{86}Sr values suggest that the horizon 7 m below the stromatolite is coeval to the early-middle Changhsingian, or later. In conclusion, strontium and carbon isotope excursions hint that the dramatic depletion of ä^{13}C happened around the PTB.

Biostratigraphically typical Permian fossils appear in the upper part of the Dalan Formation, described as above, and *Claraia sp.* occurs from the thin-bedded dark grey dolomitic limestone member in the Khaneh Kat Formation about 250 m above the base of the stromatolite. A possible fault inserts in this 250 m thick dolostone unit. Nevertheless, this thin-bedded, light grey to light brown dolostone sequence lacks any database of index fossils. The present study emphasizes that the chemostratigraphic method may be of benefit to confirm a more exact correlation scheme of this 250 metre thick interval, including the stromatolite unit. Based on the δ^{13}C excursion, this 250 m thick dolostone including the upper stromatolite bed just 3 m above the base of the Khaneh Kat Formation should be considered as Lower Triassic, and the basal 3 m of the Khaneh Kat Formation should be assigned to the top of the Permian. δ^{13}C has a typical model with PTB close to the boundary of Dalan and Khaneh Kat Formation, moreover, such a kind of δ^{13}C excursion has never been reported from the Permian sequences previously. We suggest that the lower layer of the stromatolite unit is latest Permian in age.

6. Summary

PTB chemostratigraphy based on the excursions of carbon and strontium isotope from limestone of the upper Dalan Formation to dolostone of the Khaneh Kat Formation in Zagros area, Aligoudarz, Iran make possible an exact correlation globally. δ^{13}C values show a typical model of PTB with higher values of 3‰ to 5‰ in the upper Dalan Formation including the lower stromatolite bed at the base of Khaneh Kat Formation (uppermost Permian), and lower values about 0‰ to less than 2‰ from the lower part of the Khaneh Kat Formation (Lower Triassic) including the upper stromatolite bed. A dramatic depletion occurs near the PTB and coincides with a similar curve of δ^{13}C values of worldwide tendency. Furthermore, we suggest that the initiation of stromatolite formation from the Zagros section is earlier than those from other areas, because the PTB should be located at between the upper and lower stromatolite bed or the top of the lower stromatolite bed. It could be interpreted as the local development of the stromatolitic succession in the uppermost Permian.

Acknowledgments

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Progress report of the Permian-Triassic Time Slice Project

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The Permian-Triassic Time Slice Project is a test of the CHRONOS chronostratigraphic information system that will develop a high-resolution, integrated global chronostratigraphic framework to resolve the sequence of events, thereby constraining the causes of the catastrophic Late Permian extinction and Early Triassic recovery. The project was established in a workshop at Boise State University in May, 2004. The first year goals of the Permian-Triassic Time Slice project were:

1). Compile and re-evaluate enough section data to run a test in CONOP (Constrained Optimization), a newly available CHRONOS correlation tool.

2). Develop a true taxonomic dictionary with dynamic synonymy.

1. CONOP

32 of the proposed 50 targeted sections were compiled with partial to full datasets for a test run in CONOP (Table 1). Meishan and Shangsi were concentrated on as major “standard” correlation sections because of the number of dated tuffs and fairly good conodont control.

Initial results indicate:

1). Radiometric ages in Meishan and Shangsi are consistent relative to each other.

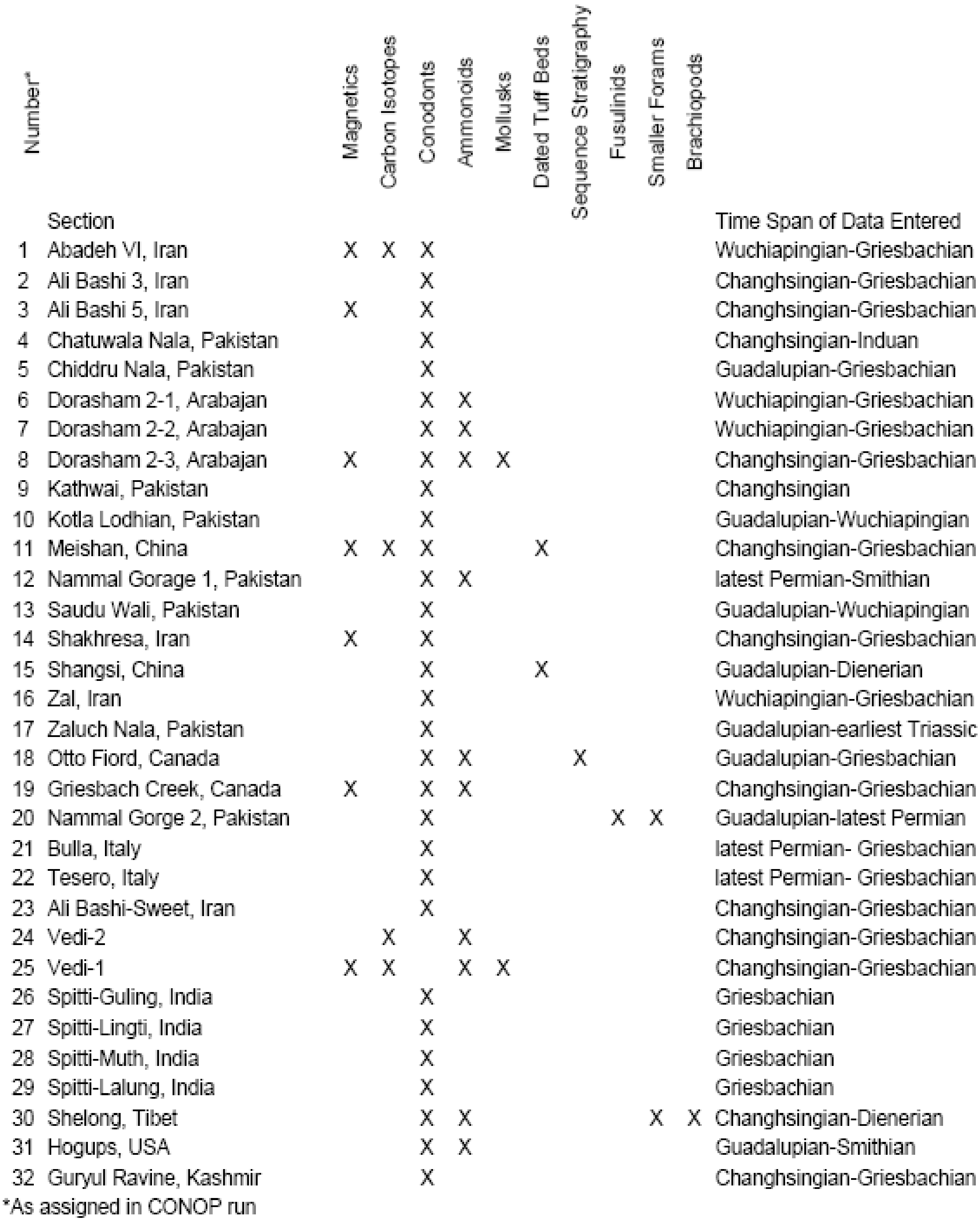
2). Extinction events in both sections are isochronous and consistent with the biostratigraphic data.

3). Extinction (based on data from Meishan and Shangsi sections) occurs in a very short time span.

4). The sedimentation rate at the Permian-Triassic transition in Iran is reported to be significantly higher than in South China making these sections critical for further studies in the Permian-Triassic time slice project.

5). The known paleomagnetic events are not isochronous—all paleomagnetic events in the Permian-Triassic transition should be re-evaluated individually, especially in relation to the new improved biostratigraphy.

Of the four targeted Iranian sections (Abadeh, Jolfa, Shahreza, and Zal), new material was collected and processed to complement



Number*	Section	Magnetics	Carbon Isotopes	Conodonts	Ammonoids	Mollusks	Dated Tuff Beds	Sequence Stratigraphy	Fusulinids	Smaller Forams	Brachiopods	Time Span of Data Entered
1	Abadeh VI, Iran	X	X	X								Wuchiapingian-Griesbachian
2	Ali Bashi 3, Iran			X								Changhsingian-Griesbachian
3	Ali Bashi 5, Iran	X		X								Changhsingian-Griesbachian
4	Chatuwala Nala, Pakistan			X								Changhsingian-Induan
5	Chiddru Nala, Pakistan			X								Guadalupian-Griesbachian
6	Dorasham 2-1, Arabajan			X	X							Wuchiapingian-Griesbachian
7	Dorasham 2-2, Arabajan			X	X							Wuchiapingian-Griesbachian
8	Dorasham 2-3, Arabajan	X		X	X	X						Changhsingian-Griesbachian
9	Kathwai, Pakistan			X								Changhsingian
10	Kotla Lodhian, Pakistan			X								Guadalupian-Wuchiapingian
11	Meishan, China	X	X	X			X					Changhsingian-Griesbachian
12	Nammal Gorage 1, Pakistan			X	X							latest Permian-Smithian
13	Saudu Wali, Pakistan			X								Guadalupian-Wuchiapingian
14	Shakhresa, Iran	X		X								Changhsingian-Griesbachian
15	Shangsi, China			X			X					Guadalupian-Dienerian
16	Zal, Iran			X								Wuchiapingian-Griesbachian
17	Zaluch Nala, Pakistan			X								Guadalupian-earliest Triassic
18	Otto Fiord, Canada			X	X			X				Guadalupian-Griesbachian
19	Griesbach Creek, Canada	X		X	X							Changhsingian-Griesbachian
20	Nammal Gorge 2, Pakistan			X					X	X		Guadalupian-latest Permian
21	Bulla, Italy			X								latest Permian- Griesbachian
22	Tesero, Italy			X								latest Permian- Griesbachian
23	Ali Bashi-Sweet, Iran			X								Changhsingian-Griesbachian
24	Vedi-2		X		X							Changhsingian-Griesbachian
25	Vedi-1	X	X		X	X						Changhsingian-Griesbachian
26	Spitti-Guling, India			X								Griesbachian
27	Spitti-Lingti, India			X								Griesbachian
28	Spitti-Muth, India			X								Griesbachian
29	Spitti-Lalung, India			X								Griesbachian
30	Shelong, Tibet			X	X					X	X	Changhsingian-Dienerian
31	Hogups, USA			X	X							Guadalupian-Smithian
32	Guryul Ravine, Kashmir			X								Changhsingian-Griesbachian

*As assigned in CONOP run

Table 1. Data entered for initial run in CONOP

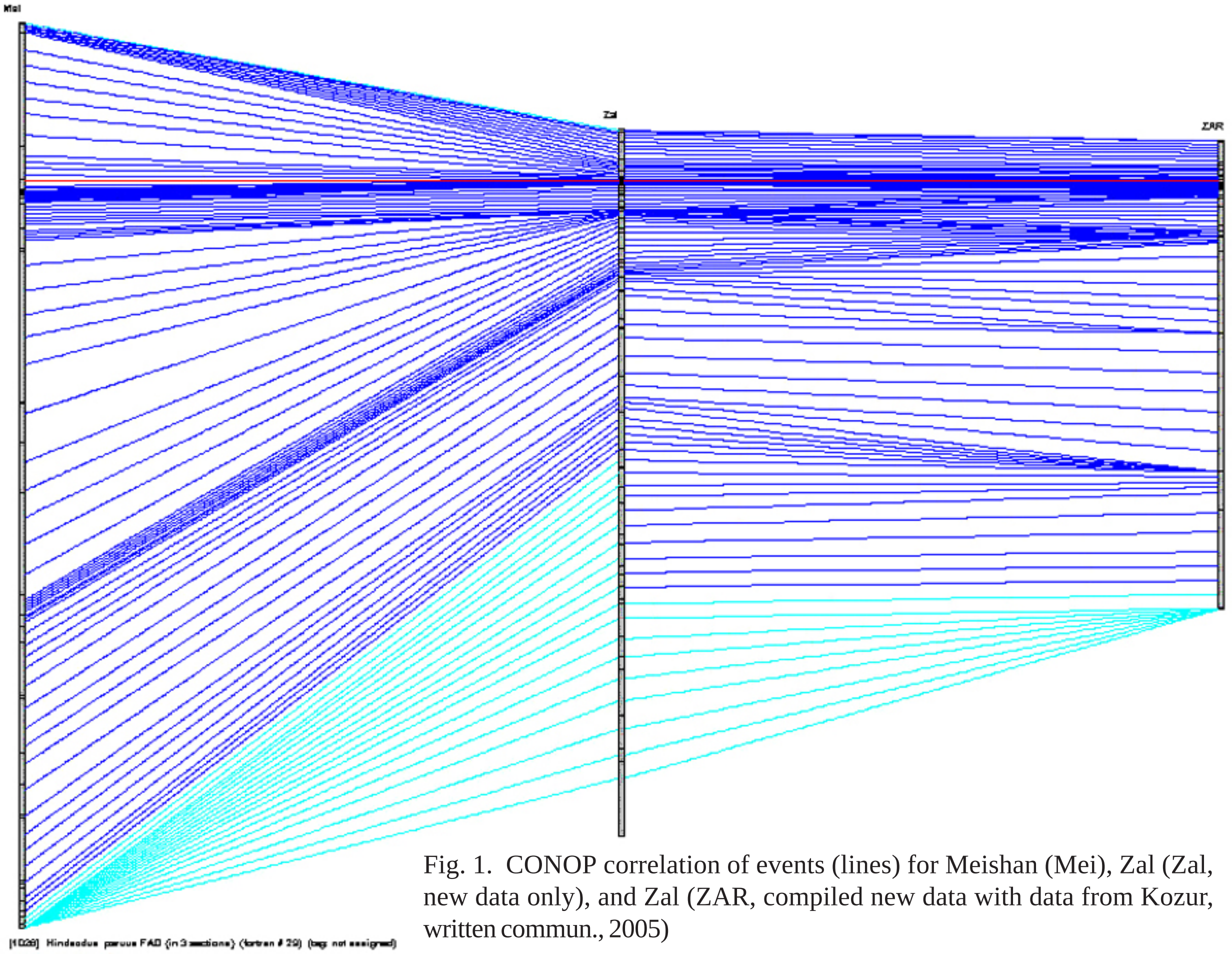
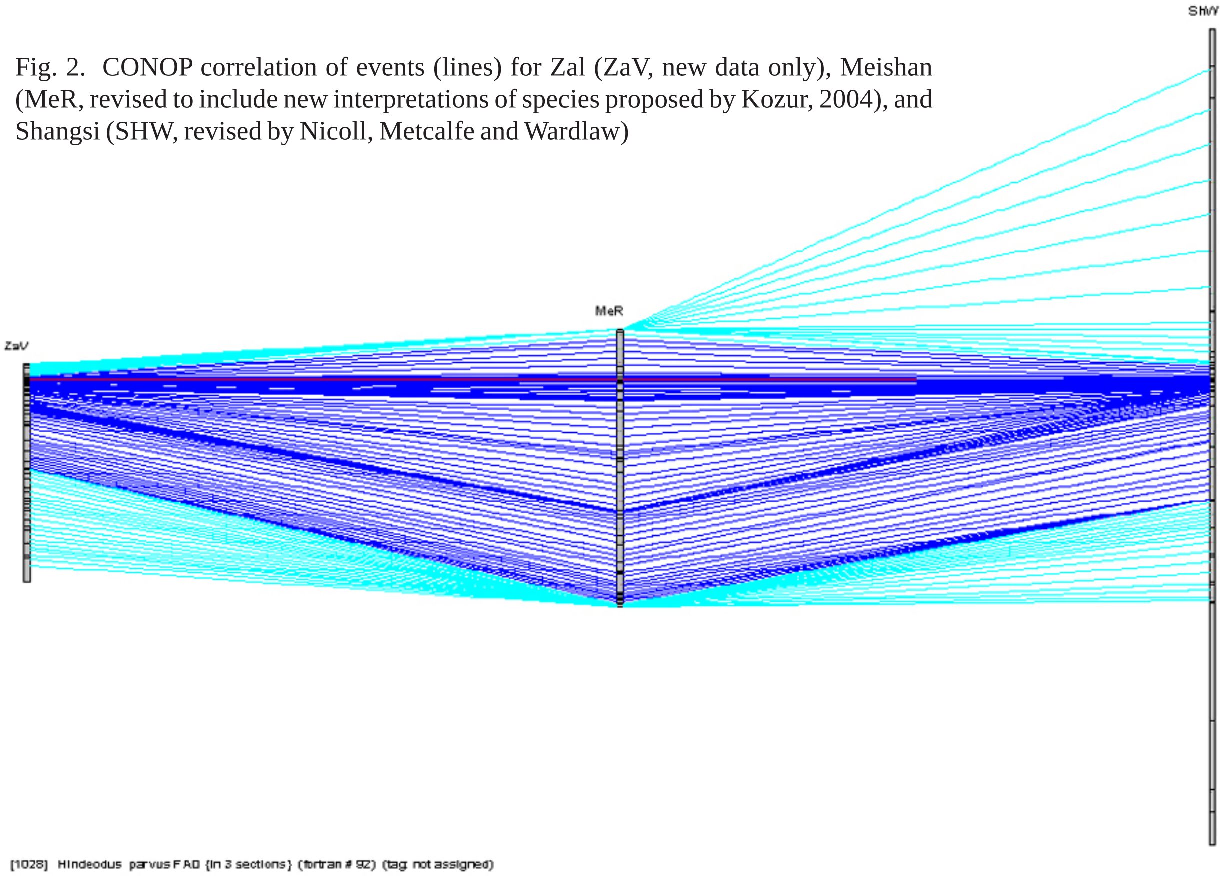


Fig. 1. CONOP correlation of events (lines) for Meishan (Mei), Zal (Zal, new data only), and Zal (ZAR, compiled new data with data from Kozur, written commun., 2005)

Fig. 2. CONOP correlation of events (lines) for Zal (ZaV, new data only), Meishan (MeR, revised to include new interpretations of species proposed by Kozur, 2004), and Shangsi (SHW, revised by Nicoll, Metcalfe and Wardlaw)



and improve the material reported on by Kozur (2004). Zal was picked and sorted in time for a new CONOP run for an annual report at the International Symposium on Triassic Chronostratigraphy (Chaohu City, China) and this issue. The correlation of events (lines in Fig. 1) shows the obvious, the Zal section contains most of the Wuchiapingian and Changhsingian sediments of the Permian; whereas, the Meishan section only the uppermost Wuchiapingian and Changhsingian, resulting in a convergence of correlation lines at the base of the Meishan section. However, the correlation lines are much more expanded for Meishan for that part in common with Zal, indicating that the sedimentation rate is greater at Meishan, contrary to reports that Iranian sections are more expanded. Also, all events are consistent relative to each other and there is no missing zone or sedimentation. The new data correlates excellently with Meishan; however, when compiled with existing data reported by Kozur (written commun., 2005) it shows gaps (event correlation lines converging to a point) and inconsistencies that we are currently re-evaluating, but it appears the ranges given by Kozur (written commun., 2005) are unreliable. The material for Shangsi was re-evaluated and reclassified by Nicoll, Metcalfe, and Wardlaw. It was compared to both Meishan and Zal and shows excellent correlation (Fig. 2). Based on the distribution of all conodont species, graphic correlation places the position of the first appearance datum of *Hindeodus parvus* at Meishan (the base of the Triassic) at 100.25 mab in the Shangsi section. Amazingly, CONOP places that event correlation at 100.26 mab supporting the use of both methodologies in correlation. The observed first occurrence of *H. parvus* at Shangsi was reported by Nicoll *et al*. (2002) from a sample at 104.49 mab. The CHRONOS system tools (CONOP or graphic correlation) greatly improve the correlation.

2. Taxonomic Dictionary

To jump start the Permian-Triassic time slice project the goals for developing a taxonomic dictionary were very specific.

1. Develop a conodont catalogue with digital images of holotypes and original descriptions of Pennsylvanian-Lower Triassic species.
2. Develop a conodont taxonomic dictionary for late Guadalupian through early Olenekian (Smithian) with digital images of all figured specimens and available material for all *Clarkina, Hindeodus, Merrillina, Neospathodus*, and *Isarcicella* species.
3. Help establish the template for other fossil groups (radiolarians, brachiopods, ammonoids, *etc*.). All the above are available in various states of controlled access at http://www.PaleoStrat.org.

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ANNOUNCEMENTS

IPC Beijing 2006

SECOND INTERNATIONAL
PALAEONTOLOGICAL CONGRESS
(IPC2006)
BEIJING, PEOPLE'S REPUBLIC OF CHINA
JUNE 17–21, 2006

ORGANIZING COMMITTEES

International Palaeontological Association
Palaeontological Society of China
Nanjing Institute of Geology & Palaeontology, CAS
Institute of Vertebrate Palaeontology & Palaeoanthropology, CAS
School of Earth & Space Sciences, Peking University

GENERAL INFORMATION

The Organizing and Executive Committees of the *Second International Palaeontological Congress* (IPC2006), representing the relevant Chinese governmental agencies and scientific institutions, under the scientific sponsorship of the International Palaeontological Association (IPA), cordially invite you to participate in the **SECOND INTERNATIONAL PALAEONTOLOGICAL CONGRESS** which will be held in Peking University, Beijing, China between **June 17–21, 2006.** This congress follows the highly successful first IPC2002 held in Sydney, and will focus on a series of scientific sessions and symposia to discuss new research findings relating fossil organisms, with emphasizing upon the convention theme "***Ancient Life and Modern Approaches***".

CALL FOR ABSTRACTS

Researchers are invited to submit abstracts in all areas related to aspects of paleontology for the IPC2006. For organizational purposes it would be appreciated if you could indicate your intention to present a paper in a related symposium/topic either orally or by poster on the accompanying form. Abstracts will be due for submission prior to 1st March 2006. Abstracts are preferred to be sent via e-mail to IPC2006@nigpas.ac.cn or Dr. Yongdong Wang (ydwang@nigpas.ac.cn). Further details regarding guidelines for abstract and paper submission will be available in the second circular.

CONGRESS LOCATION – PEKING UNIVERSITY

The congress sessions will be held on the campus of Peking University in Beijing. Founded in 1898, Peking University (PKU) is the first national university in Chinese modern history with a history of more than one hundred years. Standing at the frontline of history, Peking University has been the most famous and the most prestigious university in China. After more than a century of transformation and expansion, the university now consists of five faculties (Humanities, Social Sciences, Sciences, Medicine, and Information Technology and Engineering) with more than 30,000 students, of which approximately 4,000 are international students. The beautifully landscaped campus of Peking University, "Yan Yuan", is located in what used to be part of an ancient royal garden near the Yuanming Gardens and the Summer Palace.

SCIENTIFIC PROGRAMS

The following lists of plenary lectures, sessions and symposia are provisional. The congress is seeking suggestions about the titles of plenary lectures and speakers, and proposals on the sessions and symposia. Persons wishing to recommend plenary talks and speakers, or/and organize sessions, symposia, workshops and special group meetings should write to Jin Yugan (ygjin@nigpas.ac.cn), Co-Chairman of International Scientific Committee or Yang Qun, Chairman of Executive Committee (qunyang@nigpas.ac.cn) no later than June 1st, 2005.

Plenary session: Lectures for 30 minutes each will be invited to provide a general review of the fields with most prominent advance recently. Proposed plenary lectures include:

1. Molecular signatures of microbial life
2. In search of life's deepest roots
3. Embryo fossils
4. The Cambrian radiation
5. Origin of deuterostromes
6. Early land life
7. The great Permian-Triassic catastrophic events
8. New discoveries of the Jehol Biota: biological and geological implications

Special sessions: These are designed to address broad fundamental and interdisciplinary issues in paleontology today. Each session may include keynote talks, invited talks and volunteer talks.

S1. Earth system history
S2. Geo-biodiversity: taxa, morphology and ecology
S3. New earthtime system
S4. Geological records of astronomical processes and their impact to biological evolution
S5. Fossil microbial communities and their geological processes
S6. Past and present global changes and biotic saltations

General symposia: These will focus on branch disciplines of paleontology and will mostly be consisted of volunteer oral and poster presentations.

G1. Paleobotany
G2. Microflora
G3. Invertebrate paleontology
G4. Vertebrate paleontology
G5. Fossil lagerstätten
G6. Trace fossil and ichnofacies
G7. Paleoecology, paleobiogeography, paleogeography and paleoclimate
G8. Reef evolution
G9. Computer analysis of fossil data & morphometrics
G10. Impact stratigraphy, chemostratigraphy
G11. High resolution biostratigraphy
G12. Integrative stratigraphy
G13. Paleoanthopology
G14. Micropaleontology.

Topical symposia: These will provide with opportunities to exchange information of the major international projects, which are in planning, on going or just in conclusion.

T1. Archean paleobiology and implications for astrobiology,
T2. Neoproterozoic paleobiology and geobiology
T3. Cambrian radiations and extinctions
T4. Ordovician World: temporal and spatial changes in physical and biotic environments (IGCP 503)
T5. Middle Paleozoic vertebrate biogeography, paleogeography and climate (IGCP 491)
T6. Diversity and environmental interactions of early land vascular plants
T7. Devonian land-sea interaction: evolution of ecosystems and climate (IGCP 499)
T8. Late Paleozoic: the end-Permian extinction following a 100 m.y. long stability
T9. Mesozoic marine revolution
T10. Life and environment of Triassic Time (IGCP 467)
T11. Triassic-Jurassic boundary events (IGCP 458)
T12. Reconstructing the Lower Cretaceous terrestrial ecosystem-evidence from the Jehol Biota in China and its lateral equivalents in other areas
T13. The evolution of grass-dominated ecosystems during the Late Tertiary
T14. Mammals: phylogeny, divergence and biogeography
T15. Late Neogene climatic change of East Asia in the global context
T16. Molecular clock vs. lineage divergences from fossil record
T17. Black smokers & cold seep faunas£¬
T18. Evolution of the pelagic realm
T19. Stratigraphy of orogeny belts
T20. Paleontological education in university, fossils & museums in the 21st Century
T21. Protection of endangered fossil sites
T22. Sharing information sources of paleontology and stratigraphy

T23. The past, present, and future of paleontology in China

PROPOSED FIELD EXCURSIONS

A. Pre-Congress excursions:

A1. Proterozoic – Early Paleozoic strata and fossils in the Yangtze Gorge and western Hunan

A2. The marine Devonian and Lower Carboniferous of Guangxi, S.W. China

A3. Permian-Triassic sections from shallow marine, slope to intra-platform basin in eastern part of South China

A4. Triassic ichthyosaurus, thalattosuaus and other marine reptiles, buried *in situ* crinoid fauna and stratigraphy in Guizhou and Yunnan, S.W. China

A5. The Mesozoic Jehol Biota in western Liaoning Province and neighboring areas of Inner Mongolia, highlighted by occurrence of feathered dinosaurs, early birds, early mammals, and primitive angiosperm etc.

A6. Early Cenozoic vertebrates and associated animal fossils in Inner Mongolia

A7. Paleontological and archiological sites in Ningxia, NW China

B1. Mid-Congress Excursions:

B1-1 Zhoukoudian in the suburb of Beijing: the cave home of Peking Man (One day).

B1-2 Cambrian and Ordovician successions in Xishan of Beijing (One day)

B2. Mid-Congress Fossil Exhibitions

B2-1 Exhibition of Marine Triassic Vertebrate Fossils from Guizhou in Geological Museum, Beijing

B2-2 Exhibition of fossil collections of Early Cretaceous Jehol Biota in Geological Museum, Beijing

B2-3 Exhibition of vertebrate fossil collections in IVPP, CAS, Beijing

C. Post-Congress excursions

C1. The extraordinarily preserved fossil localities of the Chengjiang Biota, Early Cambrian, and the Neoproterozoic-Cambrian sequences in the vicinity of Kunming, Yunnan Province

C2. The Neoproterozoic embryo fossils from the Doushantuo Formation, the early Cambrian sponge fauna from the Niutitang Formation and the Middle Cambrian Burgess-type fossils from the Kaili Formation in Guizhou Province

C3. Silurian - Devonian plant and fish fossils in Yunnan Province, Southwest China

C4. Late Devonian sections with a new perspective of the Frasnian-Famenian extinction and subsequent recovery, and the geological records of the end-Permian mass extinction in the continental sequence of northern Xinjiang

C5. Upper Paleozoic to Triassic successions of Tibetan Himalayas and their Paleontological contents

C6. The geological records of the end-Permian mass extinctions in the sections of coastal, shallow marine and slop facies in western part of South China.

C7. Jurassic and Cretaceous dinosaurs in Sichuan and Yunnan provinces; fossil site of Yuanmou hominoids.

C8. Late Neogene Red Clay and classical Hipparion fossil localities (plus Xi'an and the Terra Cotta)

IMPORTANT DATES

July 31, 2005:	Deadline for retuning the Reply Form of 1st Circular
October 31, 2005:	Second Circular available online and distribution
March 1, 2006:	Deadline for abstract submission
March 1, 2006:	Deadline for pre-registration
April 30, 2006:	Distribution of the Third Circular to participants

CORRESPONDANCE

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ANNOUNCEMENTS

Second Circular
THE NONMARINE PERMIAN
Albuquerque, New Mexico USA
21-29 October 2005

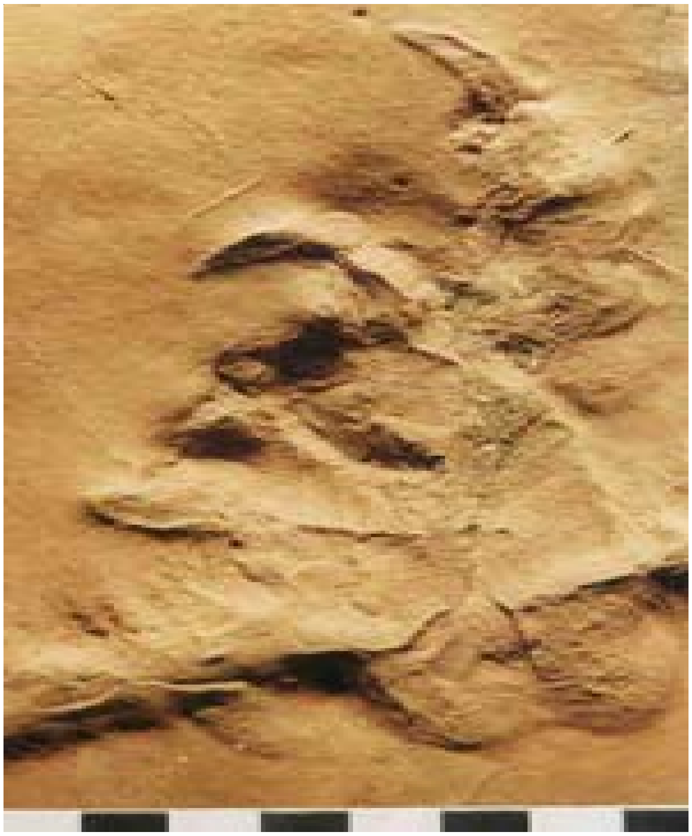
Hosted by the New Mexico Museum of Natural History and Science (NMMNH) Organizing Committee: S. Lucas, A. Heckert and A. Hunt (Albuquerque); W. DiMichele (Washington, D.C.); V. Lozovsky (Moscow); K. Krainer (Innsbruck); C. Sidor (Old Westbury); M. Steiner (Laramie); G. Cassinis (Pavia), L. Buatois (San Miguel de Tucumán)

GENERAL

An international symposium on the nonmarine Permian will cover all aspects of the subject, including tectonics, paleogeography and sedimentation, paleoclimatology, biostratigraphy and biochronology, ichnology, paleobotany, invertebrate paleontology and vertebrate paleontology. A special session devoted to the current status of the Permian timescale will be held in conjunction with the Subcommision on Permian Stratigraphy of the IUGS. Two field trips will be held, one before and one after the meeting. Attendance on the trips is optional for those who can only participate in the symposium.

TIME AND LOCATION

The meeting will follow the Annual Meeting of the Geological Society of America, which will be in Salt Lake City, Utah, 16-19 October 2005 , so attendance at both meetings is possible. Albuquerque is a city of about half a million people on the Rio Grande in central New Mexico. It is easily reached via its international airport or by train, bus or auto. The NMMNH houses the world's largest Permian footprint collection in addition to large regional collections of fossil plants, insects, invertebrates and vertebrates of Late carboniferous-Permian age.



SCHEDULE

- 21-22 October Premeeting fieldtrip to southern NM to examine Lower Permian tracksites interbedded with marine strata in the Robledo Mountains, and to examine the mixed marine-nonmarine Carboniferous-Permian boundary interval of the Bursum Formation.
- 22 October (evening) Opening night party at NMMNH, Albuquerque
- 23-25 October Platform presentations and posters, NMMNH
- 25 October (evening) Banquet
- 26-28 October Postmeeting fieldtrip to northern NM to examine nonmarine red beds and classic fossil localities of the Cutler depositional system.

PUBLICATIONS

The proceedings of the symposium will be published as a Bulletin of the New Mexico Museum of Natural History and Science at the time of the symposium. Participants are encouraged to submit abstracts, extended abstracts or articles (up to 20 pages, double-spaced typescript) for the volume. Deadline for submission is 1 April 2005. Consult S. Lucas for format. All submitted materials need to be in electronic format.

FURTHER INFORMATION

Watch this website for further information. http://www.nmmnh-abq.mus.nm.us/nmmnh/permianmeet.html

PRE-REGISTRATION

Registration for the symposium will be $50 USD before 1 May 2005, and $100 USD after 1 May 2005. Registration for fieldtrips will be possible at the third circular

REGISTRATION FORM in Adobe Acrobat PDF format

If you wish to make registration payments by credit card, please consult the following link to our Online Museum Store

http://www.nmmnh-abq.mus.nm.us/nmmnh/permianmeet.html

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