

# ALBERTIANA



## Contents

Executive Notes	Pages
From the Chair .....	3
 <b>Correspondence</b>	
New information on biostratigraphy of the Mud section, Spiti, Himalayas by <i>Zakharov</i> .....	4-7
The “golden spike” for the Ladinian is set by <i>Brack</i> .....	8-10
Decision report on the defining event for the base of the Rhaetian stage by Krystyn .....	11-12
 <b>Obituaries</b>	
Zunyi Yang by <i>Hongfu</i> .....	13
 <b>Past Meetings</b>	
Report on the first IGCP 572 field workshop in Antalya, S Turkey by <i>Baud et al.</i> .....	14-15
 <b>Scientific Reports</b>	
Conodont and ammonoid assemblages from the Permian/ Triassic boundary interval: new evidence from the Dorasham area, Transcaucasia by <i>Zakharov &amp; Kozur</i> .....	16-22
Triassic Ammonoid Succession in South Primorye: 5. Stratigraphical position of the Olenekian Meekoceras fauna by <i>Zakharov et al.</i> .....	23-33
Stratigraphic potential of the Upper Triassic benthic foraminifers by <i>Rigaud et al.</i> .....	34-39
Re-evaluating the correlation between Late Triassic terrestrial vertebrate biostratigraphy and the GSSP-defined marine stages by Irmis et al. ....	40-53
 <b>New Triassic Literature</b>	
Triassic Bibliography by <i>Warrington</i> .....	54-74
 <b>Future Meetings</b>	
Prague 2010 - ICS Workshop: The GSSP Concept, Prague, Czech Republic, 30 May – 3 June 2010 .....	
New Developments on Triassic integrated Stratigraphy 12-16 September 2010, Palermo, Sicily, Italy .....	

---

The primary aim of ALBERTIANA is to promote the interdisciplinary collaboration and understanding among members of the I.U.G.S. Subcommittee on Triassic stratigraphy. Within this scope ALBERTIANA serves as the newsletter for the announcement of general information and as a platform for discussion of developments in the field of Triassic stratigraphy. ALBERTIANA is available as PDF at <http://www.uu.nl/EN/faculties/science/organisation/depts/biology/research/chairs/Palaeoecology/projects/ALBERTIANA/Pages/default.aspx>

---

**Editor**

Dr. Wolfram M. Kürschner, Palaeoecology, Laboratory of Palaeobotany and Palynology, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands, [w.m.kuerschner@uu.nl](mailto:w.m.kuerschner@uu.nl);

**Editorial Committee**

Dr. Aymon Baud, Musée de Géologie, BFSH2-UNIL, 1015 Lausanne, Switzerland, [aymon.baud@sst.unil.ch](mailto:aymon.baud@sst.unil.ch);

Prof. Dr. Hans Kerp, WWU, Abt. Palaeobotanik, Hindenburgplatz 57, 48143 Münster, Germany, [kerp@uni-muenster.de](mailto:kerp@uni-muenster.de);

Dr. Spencer G. Lucas, New Mexico Museum of Natural History, 1801 Mountain Road N. W., Albuquerque, NM 87104, USA, [slucas@nmmnh.state.nm.us](mailto:slucas@nmmnh.state.nm.us);

Dr. Mike Orchard, Geological Survey of Canada, 101-605 Robson Street, Vancouver, British Columbia, V6B 5J3, Canada, [morchard@nrcan.gc.ca](mailto:morchard@nrcan.gc.ca);

Dr. E. T. Tozer, Geological Survey of Canada, 101-605 Robson Street, Vancouver, British Columbia, V6B 5J3, Canada, [etozer@nrcan.gc.ca](mailto:etozer@nrcan.gc.ca);

Prof. Dr. Henk Visscher, Palaeoecology, Laboratory of Palaeobotany and Palynology, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands, [h.visscher@uu.nl](mailto:h.visscher@uu.nl).

---

**Cover:** The “golden spike” (GSSP) of the base of the Ladinian Stage in the Buchenstein Formation at Bagolino (northern Italy), see also report on page 8.

## Executive Notes

### From the Chair

The 2010 is a crucial year for the Subcommittee. We are in the middle of the river, between the Oslo 33° IGC and the next IGC that will be held in Brisbane (Australia) in August 2012, and it is time to take stock of the situation. The goal of the STS for the years 2008-2012 is the completion of the definition of the GSSP for four stages of the Triassic, namely the Olenekian, Anisian, Norian and Rhaetian. Unfortunately we have no elements to estimate the time we need to achieve our goal. This statement is rather severe, but that is the situation.

The Induan/Olenekian boundary Working Group has been reactivated after the summer 2009, because the stratigraphic position of the primary marker event voted by the Working Group at the end of 2007 has been revised and modified (see the report by Y. Zakharov). Yuri Zakharov has accepted to lead the WG, whose composition has been updated. Several people are working on the boundary interval in the two best sections under study since the 2000, then the final decision is a matter of data comparison and agreement. However, so far it is impossible to estimate the time necessary to come to an agreement.

Totally different is the state of the art of the definition of the base of the Anisian. The section Desli Cairra (Romania) is under investigation by an international group lead by E. Gradinaru since the mid of 90's and in 2002 the Olenekian/Anisian WG selected the as marker event the first occurrence of the conodont *Chiosella timorensis*. A pre-proposal has been published in *Albertiana* 36 (2008), but this seems to be the last formal activity of the WG. Such a silent situation cannot be accepted, not for such a long time. We all know that the Olenekian/Anisian boundary is often recorded in not very good sections. Some sections are condensed, some others show a poor fossil record, at least of one of the key groups. However, if we really believe that there is a boundary between the Olenekian and Anisian, i.e., the Lower and Middle Triassic Series, well, after 15 years of investigations we MUST find out a way to define it.

The Carnian/Norian and Norian/Rhaetian boundaries are hopefully, not far from a vote. In the last years, especially after the definition of the GSSP of the Carnian Stage (2007 by the WG, 2008 by STS, ICS and IUGS), the focus on the Upper Triassic Series has moved to the Norian and the Rhaetian Stages. A lot of work has been done at Black Bear Ridge (British Columbia) and at Pizzo Mondello (Sicily) for the definition of the base of the Norian and this issue will be discussed in depth during the Palermo Workshop planned for mid September 2010. The two candidate sections show uniform facies and relatively high sedimentation rate, as well as good conodont and pelagic bivalve record. However, up to now there is not yet consensus on the primary marker event to be used for the definition of the GSSP.

Rather opposite situation is the one of the Norian/Rhaetian

boundary. For this boundary the WG has selected the FO of the conodont *Misikella posthernsteini* as best marker event, and Leo Krystyn is working to demonstrate the value of the candidate section Steinbergkogel by correlation with other sections. Such a part of the work is rather complex as, again, good sections with good bio-chronostratigraphic record are extremely rare.

Apart from the specific activity focused on the GSSPs definitions, scientific research on Triassic stratigraphy seems to be heavily influenced by the economic crisis, at a global level. At least this is the feeling I have from the e-mails I have got from several Triassic specialists from all over the world. Most of them seems to have even problems to get funds for travelling in their home country.

What to do in these very difficult circumstances? Well, there is no one and easy solution. Together with the STS Executives, we do not have so many tools. I emphasize here three possibilities:

1) We can try to motivate WG leaders and members. For this reason I have warmly suggested Peter Brack to write the report of the inauguration ceremony of the Bagolino Geosite (July, 2009) with the fixing of the "golden spike" of the Ladinian Stage. This really very well organized event might be considered as a good example of interaction between scientists, Institutions and local authorities.

2) We can try to stimulate contacts and meetings. We are advertising the meetings of the 2010: Prague ICS meeting (end of May 2010), the 7<sup>th</sup> International Triassic Field Workshop in the Dolomites (September 2010) and the Palermo workshop (September 2010; see the information at the end of this issue). For 2011 I am starting to organize a calendar of meetings sponsored/organized by the STS. I have contacted the STS Voting Members, but in the last two weeks no suggestions have been made. Well, we will do our best but it is very important to have at least one meeting in the year before the 2012 IGC.

3) We can also invest for the future, as many business companies usually do in bad times. In this direction we are starting a review of the composition of the STS, with the addition of new corresponding members, especially of young age. This process will take a couple of months and is necessary also because several experienced members are retired or close to retirement, then they will have to be replaced in 5 to 10 years.

The ICS is expecting results and the state of the art of the GSSP definition will be discussed during the Prague workshop. Very few STS members are attending this workshop, but I will provide a summary in the next issue of *Albertiana*.

*Marco Balini*

---

---

**Correspondence**

---

---

**New information on  
biostratigraphy of the Mud  
section, Spiti, Himalayas**

**(To the members of the IOBWG)**

*Yuri D. Zakharov*  
*IOB task group Chair*

Dear all,

Marco Balini, STS Chairmen, has informed me that according to Orchard and Goudemand's data representatives of *N. waageni sensu lata* in the Mud section, Himalayas, occur about 1 m meter below the level M04-13A3 and therefore the GSSP proposal to define the base of the Olenekian with the first occurrence of *N. waageni sensu lata* at the mentioned level of the Mud section voted by majority of the IOBG member cannot be forwarded to the Voting Members of the STS now. It seems to be confirmed by Bucher's et al. data on Flemingitid ammonoids recently obtained from this section.

The situation of this impasse has been recently discussed by Marco together with the STS vice chairmen Mark Hounslow, who is a new IOBWG member now, and Tong Jinnan, the STS secretary C. McRoberts, the past chairmen of the STS Mike Orchard, and Leo Krystyn. They all agree on the decision to reactivate the IOBWG, proposing its 2-year mandate.

Because the GSSP selection would require apparently more than one ballot, Marco recommends me to motivate the IOBWG members with the first ballot to be possibly scheduled around the mid-term of the mandate, i.e. by the end of 2010, with discussion before it.

I consider that our discussion must be opened by Hugo Bucher, Nicolas Goudemand Leo Krystyn et al., who recently prepared their very important paper on I/O interval of the Mud section (Bucher et al., in press), based on their new data on ammonoids and conodonts from Himalayas and Salt Range. I would like also to receive fuller information on I/O conodont succession in Mud from Mike Orchard and Nicolas Goudemand. Additional information will help to decide what to do in our first steps. I offer to open our discussion just after the Russian New Year holidays, i.e. just after January 10 2010.

I would appreciate hearing your views, comments and proposals after the distribution of the additional information by Hugo Bucher, Leo Krystyn, Nicolas Goudemand or Mike Orchard.

Revised list of IOBWG (up to December 2009)

aymon.baud@unil.ch, charles.henderson@ucalgary.ca, ehoro@mail.tains.tohoku.ac.jp, dinos@geol.ku.dk, abafan@hotmail.com, goudemand@access.uzh.ch, Hugo.fr.bucher@pim.unizh.ch, jean.guex@unil.ch, korte@geol.ku.dk, kozurh@helka.iif.hu, leopold.krystyn@univie.ac.at, spencer.lucas@state.nm.us, sylvain.richoz@uni-graz.at, morchard@nrca.gc.ca, peter.hochuli@erdw.ch, renato.posenato@unife.it, szshen@nigpas.ac.cn, shigeta@kahaku.go.jp, jntong@cug.edu.cn, hfyincug@gmail.com, peter.hochuli@erdw.ch, m.hounslow@lancaster.ac.uk, Ck@geo.ku.dk, buryi@mail.ru, vlozovsky@mtu-net.ru, popov\_alexander@list.ru, schsz@orc.ru, valery\_vuks@vsegei.ru

	Name [specialization]	Address	E-mail	Fax	Comments
1	<b>Baud</b> , Aymon (Dr.) [litho- and chemostratigrapher]	Parc de la Rouvraie 28, CH-1018, Lausanne, Suisse, Switzerland	aymon.baud@unil.ch	41-21-647- 8973	Vice- Chairman of the IOBWG
2	<b>Bucher</b> , Hugo (Prof.) [ammonoid biostratigrapher]	Univ. Zuerich, Palaeontol. Institut und Museum, Karl Schmidt- Strasse 4, CH-8006 Zuerich, Switzerland	Hugo.fr.bucher@pim.unizh.ch	41 44634 49 23	-
3	<b>Buryi</b> , Galina I. (Dr.) [conodont biostratigrapher]	FEGI FEB RAS, Pr. Stoletia 159, Vladivostok, Russia	buryi@mail.ru	(4232) 317847	-
4	<b>Goudemand</b> , Nicolas (Dr.) [conodont biostratigrapher]	Paläontologisches Institut and Museum der Universität Zürich, Karl Schmidt-Strasse 4, 8006 Zürich	goudemand@access.uzh.ch	+ 41(0)44634 4923	<i>New member recom. by Mike</i>
5	<b>Guex</b> , Jean (Prof.) [ammonoid biostratigrapher]	Institut de geol. paleont., Univ. de Lausanne, BFSH2, CH- 1015 Lausanne, Switzerland	jean.guex@unil.ch	-	-
6	<b>Hansen</b> , Hans J. (Prof.) [magneto- and chemostratigrapher]	Copenhagen Univ., Geological Institute, Oster Voldgade 10, DK-1350, Copenhagen, Denmark	dinos@geol.ku.dk	-	-
7	<b>Henderson</b> , Charles M. (Prof.) [conodont biostratigrapher]	Univ. of Calgary, Dep. of Geoscience (Stratigraphy), 2500 University Drive NW, Alberta, Canada	charles.henderson@ucalgary.c a	(403)284 -0074	-
8	<b>Hirsch</b> , Francis (Prof.) [conodont biostratigrapher]	159-23 Aza Hanamen, Satoura, Narutoshi, 772-0021, Tokushima prefecture, Japan	abafran@hotmail.com	+81886867 723	-
9	<b>Hochuli</b> , Peter A. (Prof.) [palynostratigrapher]	Paläontologisches Institut Universität Zürich, Karl Schmid- Strasse 4, CH-8006 Zürich	peter.hochuli@erdw.ch	++41 44 634 49 23	<i>New member recom. by Mark</i>
10	<b>Hounslow</b> , Mark (Prof.) [magnetostratigrapher]	Centre for Environmental Magnetism and Palaeomagnetism, Lancaster Environmental Centre, Farrer Avenue, Gordon Manley Building (A 26), Lancaster University, Lancaster, UK, LA1 4YQ	m.hounslow@lancaster.ac.uk	+44(0) 1524 510269	<i>New member recom. by Jinnan</i>

	Name	Address	E-mail	Fax	Comments
	[specialization]				
11	<b>Korte</b> , Christoph (Ass. Prof.)  [chemostratigrapher]	Department of Geography and Geology, Oster Voldgade 10, DK-1350 Copenhagen K, Denmark	(1) korte@geo.ku.dk (2) Ck@geo.ku.dk	+45 35 322 501	<i>New member recom. by Hongfu</i>
12	<b>Kozur</b> , Heinz (Prof.)  [conodont biostratigrapher]	Rezsú u. 83, 1029 Budapest, Hungary	kozurh@helka.iif.hu	-	-
13	<b>Krystyn</b> , Leopold (Prof.)  [ammonoid biostratigrapher]	Dep. Of Palaeontology, Vienna Univ., Universitätsstr. 7, A- 1010, Wien, Austria	leopold.krystyn@univie.ac.at	0043- 7277933 5	-
14	<b>Lozovsky</b> , Vladlen R. (Prof.)  [vertebrate biostratigrapher]	Bolshaya Chernigovskaya Str., 9, korpus 1, kv. 53, Moscow, 107392 Russia	vlozovsky@mtu-net.ru	-	-
15	<b>Lucas</b> , Spencer G. (Prof.)  [vertebrate biostratigrapher]	New Mexico Museum of Natural History, 1801, Mountain Road N.W., Albuquerque, New Mexico 87104- 1375, USA	spencer.lucas@state.nm.us	505-841- 2886	-
16	<b>Orchard</b> , Michael J. (Dr.)  [conodont biostratigrapher]	Geol. Survey of Canada, 101-605, Robson St., Vancouver B.C., V6B 5J3, Canada	morchard@nrcan.gc.ca	1-604- 666-0409	-
17	<b>Posenato</b> , Renato (Dr.) [bivalve biostratigrapher]	Departimento di Scienze della Terra. Universita di ferrara Polo scientifico tecnologico via saragat 1, 44100 Ferrara	renato.posenato@unife.it	+39 0532 974767	<i>New member recom. by Marco</i>
18	<b>Popov</b> , Alexander M. (Dr.)  [brachiopod biostratigrapher]	FEGI FEB RAS, Pr. Stoletia 159, Vladivostok, Russia	Popov_alexander@list.ru	(4232) 317847	-
19	<b>Richoz</b> , Sylvain (Dr.)  [chemostratigrapher]	Institute for Earth Sciences, Karl- Franzens University at Graz. Heinrichstrasse 26, 8010 Graz, Austria	sylvain.richoz@uni-graz.at	++43316 380-9871	<i>New member recom. by Marco</i>
20	<b>Shigeta</b> , Yasunari (Dr.)  [ammonoid biostratigrapher]	National Science Museum (Tokyo), Dep. Of Geology, 3-23-1, Hyakunincho, Shinjuku-ku, Tokyo, 169-0073. Japan	shigeta@kahaku.go.jp	81-3- 3364- 7104	-

	Name	Address	E-mail	Fax	Comments
	[specialization]				
21	<b>Shishkin</b> Michael A. (Prof.)  [vertebrate biostratigrapher]	Paleontological Institute RAS, Profsoyuznaya St. 123, Moscow B-321, GSP-7, 117868 Russia	schsz@orc.ru	-	-
22	<b>Tong</b> , Jinnan (Prof.)  [invertebrate biostratigrapher]	China Univ. of Geosciences, Wuhan 430074, China	1) jntong@cug.edu.cn  2) jntong@public.wh.hb	+8627- 8780 1763	-
23	<b>Vuks</b> , Valery J. (Dr.)  [foraminifera biostratigrapher]	FGUP "VSEGEI", Srednij Prospect 74, S.- Peterburg, 199106 Russia	valery_vuks@vsegei.ru	7 812 3213023  (or 328982)	-
24	<b>Yin</b> Hongfu (Prof.)  [bivalve biostratigrapher]	China Univ. of Geosciences, Wuhan 430074, China	<a href="mailto:hfyincug@263.net">hfyincug@263.net</a>  hfyin@cug.edu.cn	+86-27- 8748 1030	-
25	<b>Zakharov</b> , Yuri D. (Prof.)  [ammonoid biostratigrapher]	FEGI FEB RAS, Pr. Stoletia 159, Vladivostok, Russia	yurizakh@mail.ru	(4232) 317847	Chairman of the IOBWG

## The “golden spike” for the Ladinian is set!

On July 18, 2009, an inauguration ceremony was conducted for a new geosite, and a (symbolically) golden spike was fixed at the exact stratigraphic location of the GSSP-Site for the Ladinian Stage. This site is located in the pelagic carbonates of the Buchenstein Formation, exposed in the bed of the river Caffaro, below the village of Bagolino in the Southern Alps of northern Italy. Within the Triassic System, the base of the Ladinian was the first GSSP defined and ratified by IUGS (see Episodes 28/4, 2005).

The area around the GSSP-outcrop is now a geosite that includes a visitor’s platform with posters displaying information on the local geology, the peculiarities of the Anisian-Ladinian boundary succession, and the significance of a GSSP. This is permanently open to the public, with explanations given in both English and Italian. The site was established over the last two years thanks largely to the support of the municipality of Bagolino and with the scientific cooperation of Paolo Schirolli from the Natural History Museum of Brescia. Numerous local

companies and workshops helped construction of a proper access, transported representative rock specimens to the site, produced impressive pewter replicas of Buchenstein Fm. ammonoids and, last but not least, manufactured the “golden” spike itself.

The opening ceremony started with a series of presentations in the town hall. Thereafter, on the outcrop and with ecclesiastic blessing, the symbolic nail was driven into the rock. This now marks the position of the boundary together with replicas of two age-diagnostic ammonoids from the immediate boundary interval: the latest Anisian *Chieseiceras chiesense* and the earliest Ladinian *Eoprottrachyceras curionii*. The opening ceremony attracted well over one hundred visitors. In addition to the local authorities, prominent members of the Italian stratigraphic community including Marco Balini (chairman of the Subcommittee on Triassic Stratigraphy), Maria Bianca Cità (University of Milan), and former ‘competitors’ for the boundary position Paolo Mietto and Piero Gianolla (Universities of Padova and Ferrara respectively) were welcomed. Visitors were invited to follow the official ceremony by sampling local culinary products, including the renowned “Bagoss” cheese, arguably one of the world’s



Photo 1 - The “golden spike” (GSSP) of the base of the Ladinian Stage in the Buchenstein Formation at Bagolino (northern Italy) is located at the base of the bed stratigraphically overlying a distinct groove (“Chiesense groove”) of limestone nodules in a shaly matrix. The pewter replicas of ammonoids attached to the rock are *Chieseiceras chiesense* (left; latest Anisian) and *Eoprottrachyceras curionii* (right; earliest Ladinian).





Photo 2 - View of the new geosite at Bagolino. The GSSP is located on the strata visible in the riverbed.  
most expensive milk products.

The successful geosite project and its opening event are an exemplary instance of productive interaction between science and local public institutions, who recognized the potential of a GSSP-site as both an educational and touristic attraction.

Peter Brack



Photo 3 - From the visitor's platform numerous participants observe the positioning of the "golden spike" during the opening ceremony. View back from the GSSP.



Photo 4 - Stratigraphers at the new GSSP-site of the Ladinian Stage. From left to right: Marco Balini (chairman of the Subcommittee on Triassic Stratigraphy), Peter Brack (co-author of the GSSP-report) and Paolo Schirolli (director of the Natural History Museum of Brescia).

# Decision report on the defining event for the base of the Rhaetian stage.

Leopold Krystyn

Department of Palaeontology – Geozentrum,  
Althanstrasse 14, A-1090 Wien, Austria leopold.  
krystyn@univie.ac.at

The Task Force on the placement of the GSSP for the Norian-Rhaetian boundary has recently finished a vote between two proposed conodont datums (*Misikella hernsteini* vs. *M. posthernsteini*) resulting in a

## 61 % majority for the *posthernsteini* datum as base of Rhaetian definition

[base *hernsteini* Zone – 5 votes, base *posthernsteini* Zone – 14 votes, Abstain – 2]

Taking aside the 2 Abstains, the majority for the *posthernsteini* datum would have reached 66% – demonstrating the high level of support for this datum within the Task Force.

*Misikella posthernsteini*, as phylogenetic descendent of *M. hernsteini*, offers a well-established first appearance date (FAD) both in the proposed GSSP candidate Steinbergkogel, Austria (Krystyn et al., 2007; Krystyn, 2008) and throughout LPL Tethyan sediments. However, since *M. posthernsteini* is very rare at the beginning, large conodont quantities may be needed (at least 50 p-elements of the genus) for a safe recovery of the FAD of the species and thus for an exact placement of the Norian-Rhaetian boundary (Krystyn et al., 2007). In cratonic America, *Misikella posthernsteini* is rather rare and may appear much later, already in the late Rhaetian (Orchard et al., 2007). Therefore it should be mentioned that in biofacially and biogeographically less favourable environments/regions, use of this event without additional control may cause uncertainties in regional or intercontinental correlations.

### Proxies for the *posthernsteini* datum

A corresponding low latitude pandemic proxy is the FO of the heteromorphic ammonoid *Paracochloceras suessi* (and the closely allied genus *Cochloceras*) and of sagenitid ammonoids of the *Sagenites reticulatus* group (Krystyn, 2008) as well as the disappearance of the genus *Metasibirites* (Krystyn et al., 2007). The *posthernsteini* datum may also correlate to the FO of the conodont *Epigondolella mosheri* morphotype B sensu Orchard as well as to that of the radiolarian *Precitriduma mostleri*, respectively to the base of this zone – a possible first-order intercontinental marker tool (Orchard et al., 2007) though this is in part questioned (Kozur, written comm.). Of more regional value may be the entry of dwarf monotids in parts of the Tethys around this time (McRoberts et al., 2008) as well as the disappear-

ance of monotid bivalves in the Boreal Realm (Dagys & Dagys, 1994). The *posthernsteini* event follows relatively closely above the FO of its forerunner, *M. hernsteini*, and that of several ammonoid taxa (*Tragorhacoceras occultus*, *Rhaetites gigantogaleatus*, *Stenarcestes ptychodes*), all common and helpful tools for recognizing proximity to the Norian-Rhaetian boundary in the Tethys Realm (Krystyn, 2008). Palynological proxies (FO of *Rhaetogonyaulax rhaetica* and/or *Rhaetipollis germanicus*) with importance for marginal marine and continental cross-correlations are more difficult to establish but may appear not far below the *posthernsteini* datum. Several other presumed typical Norian elements (*Granuloperculatipollis rudis*, *Enzonalosporites vigens*, *Vallasporites ignacii*) otherwise occur still in the early Rhaetian (Kuerschner et al., 2008) and form therefore no suitable boundary markers.

A prominent magnetic polarity change from a long Normal to a distinct Reversal occurs closely below the *posthernsteini* datum. This reverse interval is intercalated between a stratigraphically thicker (below) and a significantly thinner (above) normal magnetic polarity interval, which constitutes a relatively distinctive magnetic zonation (Krystyn et al., 2007). It can be recognized in other Tethyan magnetostratigraphies such as the Austrian Scheibelkogel, the Italian Pizzo Mondello and the Turkish Oyuklu sections (Gallet et al., 1996; 2007; Muttoni et al., 2004); its comparability to the polarity signature of the lacustrine Newark APTS magnetochronology is, however, disputed (Gallet et al., 2007 vs. Muttoni et al., 2009).

The  $\delta^{13}\text{C}_{\text{carb}}$  curve shows no significant variations around the *posthernsteini* datum. For a detailed discussion of the carbon isotope record see Richoz et al. (2007) and Krystyn et al. (2007).

### References

- Dagys, A. S. & Dagys, A. A., 1994: Global correlation of the terminal Triassic: Mem. Geol. (Lausanne), v. 22, 25-34.
- Gallet, Y., Besse, J., Krystyn, L. and Marcoux, J., 1996: Norian magnetostratigraphy from the Scheibelkogel section, Austria: constraint on the origin of the Antalya Nappes, Turkey: Earth and Planetary Science Letters, v. 140, 113-122.
- Gallet, Y., Krystyn, L., Marcoux, J., Besse, J., 2007: New constraints on the End-Triassic (Upper Norian-Rhaetian) magnetostratigraphy: Earth and Planetary Science Letters, v. 255 (3-4), 458-470.
- Krystyn, L., Bouquerel, H., Kuerschner, W., S. Richoz and Gallet, Y., (2007): Proposal for a candidate GSSP for the base of the Rhaetian stage. New Mexico Museum of Natural History and Science, Bulletin 41, 189-199.
- Krystyn, L.: The Hallstatt pelagics – Norian and Rhaetian Fossilageraetaeten of Hallstatt. - Berichte der Geologischen Bundesanstalt, v. 76, 81-98.
- Kürschner, W. M., Krystyn, L., Richoz, S., 2008: An integrated palaeontological, geochemical & palynological study of the Rhaetian Zlambach marls in the Northern Calcareous Alps (Austria). - Berichte der Geologischen Bundesanstalt, v. 76, 13-14.

- McRoberts, C.A., Krystyn, L., and Shea, A., 2008. Rhaetian (Late Triassic) *Monotis* (Bivalvia: Pectinacea) from the Northern Calcareous Alps (Austria) and the End-Norian crisis in Pelagic faunas: *Journal of Paleontology*, v. 51, 721-735.
- Muttoni, G., Kent, D.V., Olsen, P., di Stefano, P., Lowrie, W., Bernasconi, S., Martin Hernandez, F., 2004: Tethyan magnetostratigraphy from Pizzo Mondello (Sicily) and correlation to the Late Triassic astrochronological polarity time scale, *Geol. Soc. Am. Bull.* v.116, 1043-1058.
- Muttoni, G., Kent, D.V., Flavio, J., Olsen, P., Rigo, M., Galli, M. T. and Nicora, A., 2009: Rhaetian magnetostratigraphy from the Southern Alps (Italy): constraints on Triassic chronology. *Palaeogeography, Palaeoclimatology, Palaeoecology*, online.
- Orchard, M.J., Carter, E.S., Lucas, S.G., and Taylor, D.G., 2007, Rhaetian (Upper Triassic) conodonts and radiolarians from New York Canyon, Nevada, USA: *Albertiana* v. 35, 59-65.
- Richoz, S., Krystyn, L. and Spötl, C., 2007: Towards a carbon isotope reference curve of the Upper Triassic. *New Mexico Museum of Natural History and Science, Bulletin* 41, 366-367.

## Obituaries

### In Memoriam

#### Zunyi Yang (1908-2009)

We mournfully inform you that Professor Zunyi Yang diseased away on September 17, 2009, aged 101 (1908-2009). Professor Yang graduated from and became a faculty member of the Department of Geology, Qinghua University in 1933. In 1935 he got a government award to study in the Yale University, and obtained the doctor degree there in 1939. He returned China and was engaged as professor and department head of the Zhongshan University (Guangdong), and later professor of the Qinghua University. In 1952, the geological departments of Qinghua University, Beijing University and other universities were incorporated to establish a new independent college—the Beijing College of Geology. He was nominated as one of the organizers of that college, which was later renamed as the China University of Geosciences (1987-), and remained there until his death.

As the founder of the Chinese education of paleontology and stratigraphy, he was the author of the first Chinese “Textbook on Paleontology”(1956), the initiator of the first Chinese university speciality of paleontology and stratigraphy(1960), and teacher of the first Chinese course on “Biostratigraphy”. A half century after Li’s introduction on Chinese geology to international readers, Yang, Chen and Wang published “The Geology of China” (1986) in the series of Oxford Monographs on Geology and Geophysics. As a paleontologist and teacher, he is well-known of his broad knowledge on various fossil taxa and different stratigraphic periods. His special interests, however, was focused on Permian-Triassic stratigraphy and mollusk and brachiopod fossils. He has published a number of paleontological works on the two fossil categories. He set up the Chinese panel of Triassic stratigraphy and published papers and special chapters on the Triassic stratigraphy of China. Particularly, he organized the Chinese working group on the Permo-Triassic Boundary and was the leader of IGCP 203 (Permo-Triassic events of East Tethys region and their intercontinental correlation) and coleader of IGCP 272 (Late Paleozoic and Early Mesozoic Circum-Pacific events and their global correlation). Results of these projects were published in Cambridge University Press. His works greatly contributed to the final establishment of the GSSP of Permian-Triassic boundary at Meishan section, Zhejiang Province, China.

Professor Yang’s social services and honors include Member of the Academician of China, Vice-Chairman of the Paleontological Society of China, executive council member of the Geological Society of China, chief editor of the *Acta Paleontologica Sinica*, deputy chief editor and editorial members of various journals. He has also won

several national and societal awards. His decease is a great loss to China’s geological society and to the paleontological circle of the world. The task force of Permian-Triassic boundary pays its sublime respect to his long and faithful service.

Task force of Permian-Triassic Boundary

Chairman: Hongfu Yin

## Past Meetings

### Report on the first IGCP 572 field workshop, Sept. 2-6, 2009, in Antalya, southern Turkey

By Aymon Baud, Sylvie Crasquin and Steve Kershaw

The IGC Programme 572 aims to investigate the recovery of ecosystems following the end-Permian mass extinction through analyses of the rock and fossil records via studies of biostratigraphy, paleontology, paleoecology, sedimentology, geochemistry and biogeochemistry.

A one-day meeting, Sept. 3, was organized at the Engineering Faculty Akdeniz University in Antalya with the help of E. Kosun, assistant-professor. The participants (about 30) were welcomed by the Dean of the Faculty and the Director of the Geological Institute. The opening of the session was dedicated to the Memory of Jean Marcoux with a reminder of his entire scientific career and his works on the Permian and Triassic of the area.

A. Baud presented the first talk with an introduction to the field trip and the main topics that were discussed on the

Permian-Triassic transition outcrops.

The basal Triassic recovery of ostracods was the subject of the second conference by M-B. Forel, with examples taken from Çürük dağ.

After lunch, S. Kershaw gave a talk on the microbialites and discussed with the participants about the link or not with the oolite deposits.

Finally, A. Poisson presented an overview of the geology of the area focused on neo-tectonic and recent deposits.

A. Baud, S. Crasquin and S. Kershaw led the three days field workshop, Sept. 4-6. Fifteen participants attended this field trip with great interest and took part in the lively discussions on the outcrops. Firstly, the geology of the Mountains located West of Antalya was introduced. One of the best exposure of the Permian-Triassic transition is at the Çürük dağ, a section more than 1000m thick of shallow water carbonate (middle-upper Permian to lower Triassic) situated at about 15km NW of Kemer. In this section, the Pamučak Formation is represented by a thick cyclic succession of inner to outer platform facies (Guadalupian to Lopingian). These spectacular and recently re-studied outcrops of the Çürük dağ allowed reconstruction of the first steps of the Triassic transgression and the microbialite development. The 4 stops of the day were made on the crest of the Çürük dağ, the first one at the Permian-Triassic transition (Coord. N 36° 41' 32", E 30° 27' 40", alt.



Photo 1: Participants to the IGCP 572 one day meeting at the Engineering Faculty Akdeniz University in Antalya, south Turkey.

1425 m), the second one a little higher at the thrombolite facies, the third one at the oolite facies and the fourth at the overlying marly limestones and yellow shales. Extensive discussions were developed about unconformities, and subaerial exposures versus submarine dissolution.

For the second day, the participants moved to the locality of Demirtaş, SE of Alanya. The Antalya Nappes of the southern allochthons of the central Taurides (upper diagenesis grade) appears as a tectonic window below the metamorphic Alanya Nappes that are up to blue schist grade. The section is situated NE of Demirtaş, just above the paved road leading to the village of Kasiaglu (coord.: N 36°28' 96" E 32°14' 99", alt. 150m). The Lower Triassic Sapadere Formation overlies the Upper Permian Yüglüktepe Formation. The basal domal stromatolites are also present at this locality. Small carbonate precipitated fans (< 0.5 m) that resemble abiotically precipitated stromatolites were found in one limestone bed. No large carbonate mounds were preserved at this locality. The capping unit at this locality is an 8 m thick cross-bedded oolite.

For the last day, the participants went to the locality of Oznur Tepe located about 10km NE of Gazipaça on the eastern side of Antalya bay (Coord. N36°19'58", E32°21'32"). The Oznur Tepe site and sections are exposed in a river cut, and dip steeply, so a vertical section

of outcrop was easily accessed along the river path. At the base of the section is a nice outcrop of a Late Permian erosion surface overlying thick Late Permian shallow water carbonate. Above the erosion surface a skeletal grainstone marks the beginning of transgression leading to the earliest Triassic small domal stromatolites. Above, the main development of thick tabular and domal stromatolites dominate the facies throughout the microbialite unit, with only small amounts of thrombolitic microbialite in contrast to the interlayered thrombolites and stromatolites of Çürük dağ. The differences between Çürük dağ and Oznur Tepe / Demirtaş suggests the conditions of formation were. The reasons for these differences were discussed on the outcrop.

At the end of the day, all the participants came back to Antalya, with a lot of outcrop pictures and collected samples, very happy as a result of lively discussions.

#### Reference:

Crasquin, S., Baud, A., Kershaw, S., Richoz, S., Kosun, E., and Forel, M. B., 2009, The Permian-Triassic transition in the Southwestern Taurus Mountains (South Turkey), in Baud, A., editor, IGCP 572 annual Meeting & Field Workshop in southern Turkey, Antalya, Sept. 2-6, 2009: Field guide book. 48 p.



Photo 2: Participants to the IGCP 572 Field trip in the Demirtaş Quarry, SE of Alanya.

## Scientific Reports

# Conodont and ammonoid assemblages from the Permian/ Triassic boundary interval: new evidence from the Dorasham area, Transcaucasia

Yuri D. Zakharov<sup>1</sup> and Heinz Kozur

<sup>1</sup>yurizakh@mail.ru

**Abstract** - Judging from revision of Permo-Triassic (P-T) conodonts from the Dorasham II-3 section, the stratotype of the Dorashamian regional stage in Transcaucasia, its P-T boundary seems to be located between beds 11 and 15, which is in accordance with palaeontological data obtained from the Armenian Sovetashen section, revised by us earlier (Zakharov et al. 2005), and P-T boundary transition at Zal, Iran (Kozur, 2007).

### Introduction

The essential features of the Permo/Triassic (P/T) ammonoid succession at the Dorasham II area were described by Stoyanov (1910), Ruzhencev (1962, 1963), Shevyrev (1965, 1968) and Zakharov (Kotlyar et al., 1983; Zakharov, 1985, 1986, 1992; Zakharov and Rybalka, 1987). The occurrence of conodonts at the Dorasham II railway station area was first reported by Kozur et al. (Kozur et al., 1975; Kozur and Pyatakova, 1976; Kozur et al., 1978) and Grigoryan (1990a,b).

The aim of this paper is to describe in detail, taking into account new data on conodont assemblages, the P/T boundary transition at the Dorasham II-3 section, which is considered a stratotype section for the Dorashamian regional stage (Kotlyar et al. 1983; Zakharov, 1986), and to establish the correlation between neighboring areas in Transcaucasia and Iran and South China region (Meishan), where the Global Stratotype Section and Point (GSSP) for the P/T boundary is located.

### Dorasham II-3 section

In 1990, Grigoryan (1999a,b) described in his doctoral thesis the latest Permian and earliest Triassic conodont assemblages of the Dorasham II-3 section, using 43 Zakharov's (1985, 1992) samples, taken from the 14-meter P/T boundary interval. Revision of the main part of conodonts, described by Grigoryan (1999a,b), permits us to show the next conodont and molluscan assemblages from 35 beds of the uppermost part of the Akhura and the lowermost part of the Karabaglyar formations at the Dorasham II-3 section (in descending order):

Karabaglyar Formation (lowermost part)

#### *Lytosphiceras medium* Zone

35. Yellowish grey, medium bedded limestone with thin mudstone interbeds in the lower part (9.0 m). Apparently from the lowermost part of this interval are conodonts *Hindeodus parvus* (Kozur and Pjatakova), *Isarcicella*

*isarcica* (Huckriede), *I. ? turgida* (Kozur, Mostler and Rahimi-Yazd) (= " *H. turgidus* "), and the species firstly determined as *Anchignathodus minutus* (Ellison) (Kozur et al. 1978). H. Kozur considers now that *A. minutus* of the Dorasham II-3 section corresponds to *H. typicalis* (Sweet) and *H. praeparvus* Kozur.

34. Grey mudstone with interbeds of medium bedded, light grey and pink marl limestone (0.60 m). Conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet), *Hindeodus* sp., *Isarcicella isarcica* (Huckriede), *I. ? turgida* (Kozur, Mostler and Rahimi-Yazd), (Grigoryan 1990b).

33. Light grey, massive marl limestone (0.17 m). Conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet) (Grigoryan 1990b). Apparently from the bed 33 are conodonts *Hindeodus parvus* (Kozur and Pjatakova), *Isarcicella isarcica* (Huckriede) and *I. ? turgida* (Kozur, Mostler and Rahimi-Yazd) described by Kozur et al. (1978).

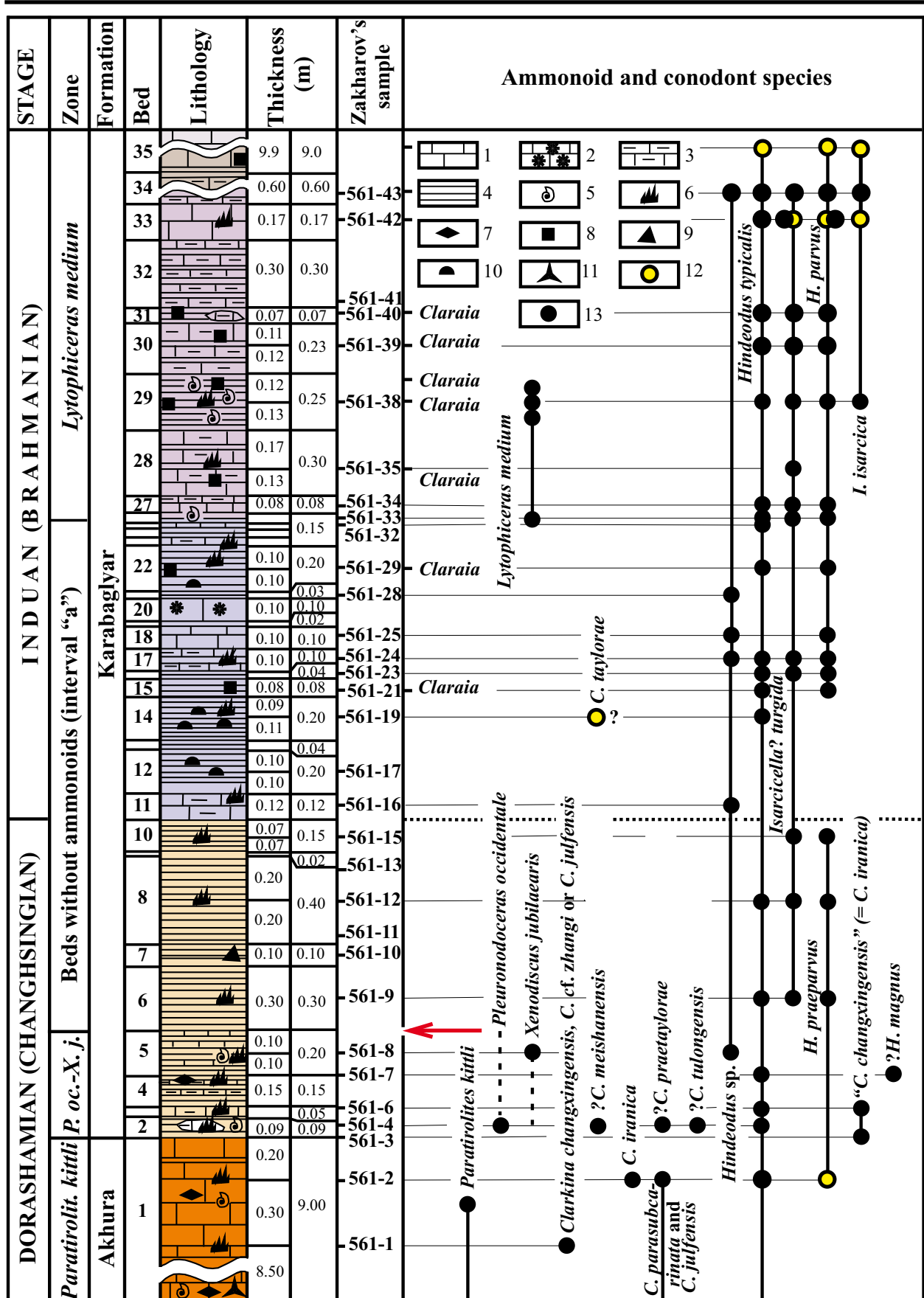
32. Thin intercalation of greenish grey marl and mudstone (0.30 m).

31. Greenish grey mudstone with thin lenses of marl (0.07 m). Bivalve *Claraia intermedia* Bittner (Zakharov, 1985), conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet), *Isarcicella ? turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

30. Greenish grey, clayey marl with thin mudstone interbeds (0.23 m). Bivalves *Claraia stachei* Bittner (Kotlyar, 1991), *C. intermedia* Bittner (Zakharov, 1985); conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet), *Isarcicella ? turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan 1990b).

29. Greenish grey mudstone (0.25 m). Ammonoid *Lytosphiceras* sp; bivalves *Claraia intermedia* Bittner (Zakharov, 1985) and *C. stachei* Bittner (Kotlyar, 1991) and conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H.*





**Figure 1.** Stratigraphical ranges of principal ammonoids and conodonts through the P/T boundary interval at the Dorasham-II-3 section, stratotype of the Dorashamian (Dzhulfa area, Transcaucasia). 1 – limestone, 2 – algal limestone, 3 – marl, 4 – mudstone, 5 – ammonoids, 6 – conodonts, 7 – brachiopods, 8 – *Claraia* bivalves, 9 – gastropods, 10 – ostracods, 11 – fishes, 12 – determinations from Kozur's et al. (1978) collection, 13 – determinations from samples collected by Zakharov (1985). Abbreviations: *Paratiroilit. kittli* - *Paratiroilites kittli*, *P. oc.-X.j.* – *Pleuronodoceras occidentale* – *Xenodiscus jubilaearis*. The arrow indicates of the P/T boundary in Gigoryan's (!990) and Kotlyar's (1991) sense.

*typicalis* (Sweet), *Isarcicella isarcica* (Huckriede), and *I. ? turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

28. Greenish grey marl with thin interbeds of greenish grey mudstone (0.30 m). Bivalve *Claraia stachei* Bittner, *Claraia* sp. (Kotlyar, 1991); conodont *Isarcicella ? turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

27. Reddish brown marl and limestone (0.08 m). Conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet), *Isarcicella ? turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

26. Reddish brown mudstone (0.04 m). Ammonoid *Lytosphericeras* sp. (Zakharov, 1985); conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet), and *Isarcicella ? turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

Beds without ammonoids

25. Reddish brown, lumpy limestone (0.03 m). Conodont *Hindeodus typicalis* (Sweet) (Grigoryan 1990b).

24. Greenish grey mudstone (0.04 m).

23. Greenish grey marl (0.04 m).

22. Reddish brown mudstone (0.20 m). Bivalve *Claraia* sp., ostracods (Zakharov, 1985) and conodonts *Hindeodus parvus* (Kozur and Pjatakova) and *H. typicalis* (Sweet) (Grigoryan, 1990b).

21. Greenish grey mudstone (0.03 m). Conodont *Hindeodus* sp. (Grigoryan, 1990b).

20. Smoke-coloured algal limestone (0.10 m).

19. Dark grey and greenish grey mudstone (0.02 m).

18. Light grey limestone (0.10 m). Conodonts *Hindeodus parvus* (Kozur and Pjatakova) and *Hindeodus* sp. (Grigoryan, 1990b).

17. Thin intercalation of yellowish green mudstone and light grey marl (0.10 m). Ostracods (Zakharov, 1985) and conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet), *Hindeodus* sp. (Kozur, Mostler and Rahimi-Yazd), *Isarcicella? turgida* (Kozur, Mostler and Rahimi-Yazd), (Grigoryan, 1990b).

16. Light brown limestone with sandy admixture (0.04 m). Ostracods (Zakharov, 1985); conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet), *Isarcicella ? turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

15. Light green mudstone partly kaolinized in the middle and upper parts (0.08 m). Bivalve *Claraia intermedia* Bittner (Zakharov, 1985); conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H. typicalis* (Sweet) (Grigoryan, 1990b).

14. Reddish brown mudstone (0.20 m). Ostracods (Zakharov, 1985); conodont *Hindeodus typicalis* (Sweet) (Grigoryan, 1990b). Apparently from Bed 14 is conodont

firstly described as *Clarkina* ex gr. *orientalis* (Barskov and Korolev) (Kozur *et al.*, 1978). *C. ex gr. orientalis* from this level is now considered to be *C. taylorae* Orchard.

13. Greenish grey mudstone (0.04 m).

12. Reddish brown mudstone with thin (2-3 cm) lens of greenish grey mudstone in the middle part (0.20 m).

11. Brown and dark grey marl (0.12 m). Conodont *Hindeodus* sp. (Grigoryan, 1990b).

10. Reddish brown mudstone (0.15 m). Conodonts "*Hindeodus parvus* (Kozur and Pjatakova)", *Isarcicella ? ex gr. turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

9. Light green mudstone (0.02 m).

8. Reddish brown, thin bedded mudstone with thin (2 cm) lens of light green mudstone (0.40 m). Conodonts "*Hindeodus parvus* (Kozur and Pjatakova)" (= *H. praeparvus* Kozur), *H. typicalis* (Sweet), *Isarcicella ? ex gr. turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

7. Reddish brown thin bedded mudstone (0.10 m). Gastropod *Bellerophon?* sp. (Zakharov, 1985).

6. Reddish brown, unconsolidated mudstone (0.30 m). Conodonts "*Hindeodus parvus* (Kozur and Pjatakova)" (= *H. praeparvus* Kozur), *H. typicalis* (Sweet), *Isarcicella ? ex gr. turgida* (Kozur, Mostler and Rahimi-Yazd) (Grigoryan, 1990b).

## ***Pleuronodoceras occidentale* - *Xenodiscus jubilaearis* Zone**

5. Reddish brown mudstone with reddish brown clay-calcareous interbeds (0.20 m).

Ammonoid *Xenodiscus jubilaearis* Zakharov (Zakharov, 1990; Zakharov and Rybalka, 1987), brachiopods *Haydenella minuta* Sarytcheva, *Araxathyris minor* Grunt (Kotlyar 1991), and conodont *Hindeodus* sp. (Grigoryan, 1990b).

4. Thin intercalation of greyish brown marl and reddish brown mudstone (0.15 m). Gastropods (Zakharov, 1985) and conodonts "*Hindeodus* aff. *parvus* (Kozur and Pjatakova)" (= ? *H. magnus* Kozur) and *H. typicalis* (Sweet) (Grigoryan, 1990b).

3. Greyish brown marls (0.05 m). Conodonts "*Gondolella subcarinata* Sweet", *H. typicalis* (Sweet) and *H. julfensis* (Sweet) (Grigoryan, 1990b).

2. Dark grey and brown (at the top) mudstone with thin lens of light grey marl (0.09 m). Ammonoid *Pleuronodoceras occidentale* Zakharov (Zakharov, 1986; Zakharov and Rybalka, 1987); conodonts "*Gondolella subcarinata* (Sweet)", "*G. planata* Clark", "*G. deflecta* (Wang and Wang)", *Hindeodus julfensis* (Sweet), *H. typicalis* (Sweet) (Grigoryan, 1990b).

## **Akhura Formation**

**Paratirolites kittli Zone**

1. Brick-red and reddish-brown, lumpy limestone with thin (to 1 cm), fawn mudstone (4.0 m). Macrofossils in the uppermost part of this interval (0.20-0.30 m below the top): ammonoid *Paratirolites* sp. (Zakharov, 1985); brachiopod *Araxathyris minor* Grunt (Kotlyar, 1991; an intermediate conodont form between *Anchignatodus minutus* (Ellison) to *Anchignathodus parvus* Kozur and Pjatakova (= *H. praeparvus* Kozur) (Kozur *et al.* 1978). Zakharov's (1985) samples contained conodonts "*Gondolella subcarinata* (Sweet)", "*Gondolella changxingensis* (Wang and Wang)", "*G. planata* Clark", and *Hindeodus typicalis* (Sweet) (Grigoryan, 1990a, b). These samples (samples 561-2 and 561-1) were collected in 1984 from two different levels: respectively at 0.20 m and 0.50 m below the top of the *Paratirolites kittli* Zone.

**Correlation and conclusions****Correlation by conodonts**

**Note 1.** The level 20 cm below the top of the *Paratirolites kittli* Zone in the Dorasham II-3 section belongs in the adjacent Iranian sections (including Zal) to the *C. iranica* Zone and often also to the upper *C. yini*-*C. zhangi* Zone (Kozur, 2004, 2007). Grigoryan (1990b, Pl. 2, Figs. 7, 8) determined *C. iranica* Kozur of the Sovetashen section in Transcaucasia as *Gondolella changxingensis* (Wang and Wang), whereas the other specimen (1990b, Pl. 2, Fig. 6) he correctly determined in species level as "*G.*" *changxingensis*. We expect that "*G. changxingensis*" discovered in Transcaucasia, 20 cm below the top of the *P. kittli* Zone, is also *C. iranica*.

Grigoryan (1990b) assigned different *Clarkina* species to "*G. subcarinata*", among them are also juvenile *C. changxingensis* (Grigoryan, 1990b, Pl. 1, Fig. 7) and *C. cf. zhangi* Mei (Pl. 1, Fig. 6) from the Vedi section in Transcaucasia. Both these species may occur in the level at 50 cm below the top of the *P. kittli* Zone (the upper part of the *C. yini*-*C. zhangi* Zone). Sweet (1973) and Grigoryan (1990b) assigned two upper Dorashamian *Clarkina* species of the upper *Paratirolites* Limestone to *C. carinata* (Clark) or *C. planata* (Clark). Later for these forms two different species were proposed by Mei *et al.* (1998) and Kozur (2004): *C. parasubcarinata* Mei, Zhang and Wardlaw and *C. julfensis* Kozur, both of which may occur in the level 50 cm below the top of the *P. kittli* Zone.

In both the Dorasham II-3 and the Sovetashen sections, representatives of unpublished "*Gondolella*" sp. nov. (Grigoryan 1990b, Pl. 2, Fig. 1-3) were discovered within the upper 4 m of the *Paratirolites* Limestone. The illustrated forms from the Sovetashen section are *C. nodosa* Kozur (2004), a guide form of the *C. nodosa* Zone of the Iranian sections which occurs in different sections around 2-3 m below the top of the *Paratirolites* Limestone.

**Note 2.** Conodonts from Bed 2, identified by Grigoryan (1990b) as *H. julfensis*, may be *H. changxingensis* Wang and Wang. In the Dorasham II-1 section (stratotype of the Dzhulfian) located 50 m to the west, "*Gondolella*" *chang-*

*ingensis* Wang and Wang was discovered at the same level (Grigoryan, 1990b). Bed 2 corresponds to similar beds of the same thickness between the *Paratirolites* Limestone and the Boundary Clay in the Zal section of NW Iran (Kozur, 2004) which belong to the *Clarkina hauschkei* Zone. The gondolellids of Bed 2 determined but not illustrated by Grigoryan (1990b) can be assigned to gondolellids of the *C. hauschkei* Zone. *Clarkina cf. changxingensis* occurs in the *C. hauschkei* Zone, and therefore the determination of this species by Grigoryan (1990b) may be correct. "*G. deflecta*" is surely *Clarkina tulongensis* (Tian), which is common in the *C. hauschkei* Zone and the only platform conodont of this level, which resembles *C. deflecta*, a species which does not occur in the *C. hauschkei* Zone. Grigoryan (1990) illustrated as *C. subcarinata* some different species from Sovetashen, among them only *C. changxingensis* is present in the *C. hauschkei* Zone. Moreover, he assigned *Clarkina meishanensis* of the lower Boundary Clay (Bed 3) to "*G. subcarinata*" (see above). *C. meishanensis* begins in the Iranian sections within the *C. hauschkei* Zone. *C. hauschkei borealis* Kozur which is present in the *C. hauschkei* Zone of Iran and in the lower *O. boreale* Zone of Arctic Canada (Henderson, pers. comm.) and of Greenland (Kozur, 2004) was assigned by Henderson and Baud (1997) to *C. cf. subcarinata*. Also this taxon may be a part of "*G. subcarinata*" in Bed 2. *C. planata* is not yet present in the *C. hauschkei* Zone but *C. praetaylorae* Kozur (2004) which is similar to *C. planata* is common in this zone. Most probably "*G. planata*" sensu Grigoryan (1990b) of Bed 2 corresponds to *C. praetaylorae*.

**Note 3.** Bed 3 corresponds to the lower Boundary Clay. The only gondolellid platform conodont which occurs in the adjacent NW Iranian sections in this level is *Clarkina meishanensis* Zhang, Lai, Ding and Liu. Thus, it is most probably that the unillustrated "*Gondolella subcarinata*" from Bed 3 is in reality *C. meishanensis*. *C. subcarinata* is nowhere present in this level but only in the lower Dorashamian. Also *H. julfensis* is not present in this level but the similar *H. changxingensis* Wang is. Therefore we assume that in Bed 3 *H. changxingensis*, but not *H. julfensis*, is present. It corresponds to *C. meishanensis*-*H. praeparvus* Zone in Iran (Kozur, 2007) and apparently *H. latidentatus*-*C. meishanensis assemblage* from the Meishan section (Yin *et al.*, 1996).

**Note 4.** *H. parvus* in Grigoryan's sense of Bed 10 (Fig. 1) seems to be *H. praeparvus* Kozur, because in the same level at the Sovetashen section (CHK-8/7g) conodonts of the upper *C. meishanensis*-*H. praeparvus* Zone are present. The conodont specimen 15/15, Fig. 1 in the Plate 3 of Grigoryan's thesis, which was determined as *H. parvus* has been re-determined as *H. praeparvus*. In the Zal section the level of the bed 10 comprises conodonts of the uppermost *C. meishanensis*-*H. praeparvus* Zone immediately below the FAD of *H. parvus*. For this reason it can be assumed that the base of the Triassic in the Dorasham II-3 section is close to the top of Bed 10. As *H. parvus* from this bed was not illustrated by Grigoryan (1990b), it cannot be excluded that primitive representatives of this species are already present in the uppermost part of Bed 10. In all cases, the

Changhsingian		Induan		Stage	
Changx.	Yinkong			Formation	
<i>C. changxingensis</i>		<i>H. parvus</i>	<i>I. isarcica</i>	Conodont zone	Bed
<i>C. changxingensis</i> - <i>C. deflecta</i> - <i>C. subcarinata</i> assemblage	<i>H. typicalis</i> assemblage				
		a	b	c	d
	25	26		27	
Hambast		Elikah		Formation	
Unit 7		Unit a		Unit	
<i>C. changxingensis</i> - <i>C. deflecta</i>	<i>C. zhangi</i>	<i>C. yini</i>	<i>C. iranica</i>	<i>C. hauschkei</i>	<i>I. isarcica</i>
					<i>I. parvus</i>
					<i>M. ultima</i> - <i>S.? mostleri</i>
					<i>C. meishanensis</i> - <i>H. praeparvus</i>
Akhura		Karabaglyar		Formation	
<i>Paratritolites kithi</i>		<i>Pleurodoceras occidentale</i> - <i>Xenodiscus jubilearis</i>		Ammonoid zone	
<i>C. changxingensis</i> - <i>C. deflecta</i>	-	<i>C. iranica</i>	-	<i>C. meishanensis</i> - <i>H. praeparvus</i>	<i>I. isarcica</i>
					<i>I. parvus</i>
					Interval a (beds without ammonoids)
					<i>Lytphiceras medium</i>
					12-13
					11
					10
					9
					8
					7
					6
					5
					4
					3
					2
					1
				Sovetashen (Zakharov et al., 2005)	
				Dorasham II-3	
				Bed	
				11-25	
				26-35	
				3-10	
				2	
				1	

Figure 2. Biostratigraphical correlation of the P/T boundary interval among the GSSP at Meishan and the proposed auxiliary sections at northwestern Iran and Transcaucasia.

FAD of *H. parvus* is close to the top of Bed 10 and therefore the base of the Triassic in the Dorasham II-3 section is situated somewhat higher (Fig. 1) as it was indicated by Grigoryan (1990b), who assumed the base of the Triassic at base of Bed 6. Earliest Induan conodont zones (*H. parvus* and *I. isarcica*) easily recognised in both western (Iran-Transcaucasia area) and eastern (south China) Tethys, as well as in the Himalayas (Orchard and Krystyn, 1998).

### Correlation by ammonoids

**Note 1.** Abundant *Paratirolites* fauna, represented in the Dorasham II-3 section by *Paratirolites kittli*, *P. waageni*, *P. vediensis*, *P. trapezoidalis*, *P. dieneri*, *Abichites mojsisovicsi*, *A. stoyanowi* (Kotlyar et al., 1983) is easily recognized in all Late Permian sections of Transcaucasia, including the Sovetashen section (Shevyrev, 1968; Kotlyar et al., 1983), as well as in many contemporaneous sequences in northwestern (Teichert et al., 1973) and central (Bando, 1979; Taraz et al., 1981) Iran. In Transcaucasia this fauna is common for the *Paratirolites kittli* Zone, overlying the middle Dorashamian *Shevyrevites shevyrevi* Zone. Dorashamian faunas of Transcaucasia, NW and Abade in central Iran had very close connections (Zakharov et al., in press), however, *Paratirolites* fauna has not been found in the Meishan region of South China (Yin et al., 1996).

**Note 2.** Depressed latest Dorashamian *Pleuronodoceras-Xenodiscus* fauna at the Dorasham II-3 section is represented by rare *Pleuronodoceras occidentale* Zakharov and Rybalka and *Xenodiscus jubilaearis* Zakharov and Rybalka (*Pleuronodoceras occidentale-Xenodiscus jubilaearis* Zone) (Zakharov, 1986; Zakharov and Rybalka, 1987; Zakharov et al., 2005). This zone is also recognized in the Zal section of NW Iran (H. Kozur's data), where *P. occidentale*, was discovered between the *Paratirolites* Limestone and Boundary Clay. This fauna seems to be contemporaneous to latest Dorashamian *Dushanoceras* fauna, known in North Caucasus (Zakharov et al., 2000; Kotlyar et al., 2004) and latest Changhsingian *Rotodiscoceras-Pseudotirolites-Pleuronodoceras* fauna of South China (Chao, 1965; Zhao et al., 1978; Yin et al., 1996; Zhao, 2005).

**Note 3.** No ammonoids were discovered just at the base of the Induan in Transcaucasia and Iran. Ammonoids found in the GSSP for the P/T boundary (Meishan) are pure preserved. Well preserved ammonoids from this level in the Tethys are known only in the Himalayas (*Otoceras* fauna) (Diener, 1897; Kummel, 1972). Early Induan *Lytosphericeras* fauna, found in the Dorasham II-3 section, is common for many sections in Transcaucasia, including the Karabaglar area, where it is represented by *Lytosphericeras medium* Griesbach (Kotlyar et al., 1983).

### Implications of the new data for P-T chronostratigraphy

We propose the aforementioned section (Zal in northwestern Iran (Kozur, 2007), Dorasham II-3 and Sovetashen (Fig. 2) in Transcaucasia), characterised by mostly open sea faunas (Kozur, 1994, 2004), to be auxiliary sections, because the GSSP the P/T boundary (Meishan section)

is characterized by shallower water fauna. Data from all auxiliary sections of the Iran-Transcaucasia area, classic area for Late Permian biostratigraphy, allow us to correlate to a closer approximation the main stages of ammonoid and conodont development during P/T boundary time.

### Acknowledgments

This work is a contribution to IGCP project 572 and was carried out the financial support of RFBR grants 08-05-00100-a and 09-05-98524-R\_vostok\_a, Russia.

### References

- Bando, Y. 1979. Upper Permian and Lower Triassic ammonoids from Abadeh, Central Iran. Mem. Fac. Educ., Kagawa Univ., Pt 2, 29 (2): 103-138.
- Chao Kingkoo. 1965. The Permian ammonoid-bearing formations of South China. Sci. Sinica, 14 (12): 1813-1826.
- Diener, C. 1897. Himalayan fossils. The Cephalopoda of the Lower Trias. Mem. Geol. Surv. India, Palaeont. Indica, Ser. 15, 2 (1): 1-191.
- Grigoryan, A.G. 1990a. Conodonts from Permian-Triassic boundary sediments of Armenia. PhD Thesis abstract, Moscow University, Moscow, 18 p. (in Russian).
- Grigoryan, A.G. 1990b. Conodonts from Permian-Triassic boundary sediments of Armenia. Dissertatsiya na soiskaniye uchenoi stepeni kandidata geologo-mineralogicheskikh nauk, Moscow University, Moscow, 210 p. (in Russian).
- Henderson, C. and Baud, A. 1997. Correlation of the Permian-Triassic boundary in Arctic Canada and comparison with Meishan, China. In: Naiwen, W. and Remane, J. (Eds.), Proceedings of the 30<sup>th</sup> International Geological Congress, 11: 143-152.
- Korte, Ch., Kozur, H.W., Joachimski, M.M., Strauss, H., and Veizer, J. 2004. Carbon, sulfur, oxygen and strontium isotope records, organic geochemistry and biostratigraphy across the Permian/Triassic boundary in Abadeh, Iran. Intern. J. Earth Sci., 93: 65-581.
- Kotlyar, G.V. 1991. Permian-Triassic boundary in Tethys and Pacific Belt and its correlation. In: Kotaka, T, Dickins, J (Eds.), Shallow Tethys 3. Saito Ho-on Kai Special Publication, 3: 387-391.
- Kotlyar, G.V., Zakharov, Y.D., Koczirkevich, B.V., Kropatcheva, G.S., Rostovtsev, K.O., Chedija, I.O., Vuks, G.P., and Guseva, E.A. 1983. Evolution of the Latest Permian biota. Dzhulfian and Dorashamian regional stages in the USSR. Nauka, Leningrad, 199 p. (in Russian).
- Kotlyar, G.V., Zakharov, Y.D., and Polubotko, I.V. 2004. Late Changhsingian fauna of the Northwestern Caucasus mountains, Russia. J. Paleontology, 78 (3): 513-527.
- Kozur, H. 1994. Permian pelagic and shallow-water conodont zonation. Permophiles, 24, 16-20.
- Kozur, H.W. 2004. Pelagic uppermost Permian and Permian-Triassic boundary conodonts of Iran. Part I: Taxonomy. Hallesches Jahrb. Geowiss., B, 18: 39-68.
- Kozur, H.W., 2007. Biostratigraphy and event stratigraphy

- in Iran around the Permian-Triassic boundary (PTB): implications for the causes of the PTB biotic crisis. *Glob. Planet. Changes*, 55, 155-176.
- Kozur, H., Leven, E.Y., Lozovsky, V.R., and Pyatakova, M.V. 1978. Subdivision of the Permian-Triassic boundary beds of Transcaucasia according to conodonts. *Byul. Mosk. Obsch. Ispyt. Prirody, Otd. Geol.*, 53 (5): 15-24 (in Russian).
- Kozur, H.W., Mostle, H., and Rahimi-Yazd, A. 1975. Beiträge zur Mikropaläontologie permotriadischer Schichtfolgen. Teil 2: Neue Conodonten aus dem Oberperm und der basalen Trias von Nord- und Zentraliran. *Geol. Paläont. Mitt. Innsbr.*, 5 (3): 1-23.
- Kozur, H. and Pjatokova, M. 1976. Die Conodontenart *Anchignathodus parvus* n. sp., eine wichtige Leitform der basalen Trias. *Kon. Ned. Akad. Wetensch.*, 79 (2): 123-128.
- Kummel, B. 1972. The Lower Triassic (Scythian) ammonoid *Otoceras*. *Bull. Mus. Comp. Zoology*, 143 (6): 365-417.
- Mei, Sh., Zhang, K., and Wardlaw, B.R. 1998. A refined succession of Changhsingian and Griesbachian neogondolellid conodonts from the Meishan section, candidate of the global stratotype section and point of the Permian-Triassic boundary. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 143: 213-226.
- Orchard, M.J. and Krystyn, L. 1998. Conodonts of the lowermost Triassic of Spiti, and new zonation based on *Neogondolella* succession. *Riv. It. Paleont. Stratigr.*, 10 (3): 341-368.
- Ruzhencev, V.E. 1962. Classification of the family Araxoceratidae. *Paleont. Zhurn.*, 4: 88-103 (in Russian).
- Ruzhencev, V.E. 1963. New data on the family Araxoceratidae. *Paleont. Zhurn.*, 3: 56-64 (in Russian).
- Shevyrev, A.A. 1965. Ammonoidea. In: Ruzhencev, V.E. and Sarycheva, T.G. (Eds.), *Development and the succession of marine organisms at the Palaeozoic/Mesozoic boundary*. *Trudy PIN AN SSSR*, 108: 166-182 (in Russian).
- Shevyrev, A.A. 1968. Triassic ammonoids of the southern USSR. *Trudy PIN AN SSSR*, 108: 1-272 (in Russian).
- Stoyanov, A.A. 1910. On the character of the boundary of the Palaeozoic and Mesozoic near Djulfa. *Zapiski Peterb. Miner. Obsch., Ser. 2*, 47 (1): 61-135.
- Sweet, W.C. 1973. In: Teichert, C., Kummel, B., and Sweet, W. *Permian-Triassic strata, Kuh-E-Ali Bashi, north-western Iran*. *Bull. Mus. Comp. Zool.*, 145 (8): 359-472.
- Taraz, H., Golshani, F., Nakazawa, K., Shimizu, D. et al. 1981. The Permian and Lower Triassic Systems in Abadeh region, Central Iran. *Mem. Fac. Sci., Kyoto Univ., Ser. Geol. Miner.*, 47 (2): 61-133.
- Teichert, C., Kummel, B., and Sweet, W. 1973. Permian-Triassic strata, Kuh-E-Ali Bashi, Northwest Iran. *Bull. Mus. Comp. Zool.*, 145 (8): 359-472.
- Yin, H., Wu, Sh., Ding, M., Zhang, K., Tong, J., Yang, F., and Lai, X. 1996. The Meishan section, candidate of the Global Stratotype Section and Point of Permian-Triassic boundary. In: Yin, H. (Ed.), *The Palaeozoic-Mesozoic Boundary Candidates of Global Stratotype Section and Point of the Permian-Triassic Boundary*. *China Univ. Geosci. Press, Wuhan*, p. 31-48.
- Zakharov, Y.D. 1985. On the type of the Permian-Triassic boundary. *Byul. Mosk. Obsch. Ispyt. Pri., Ser. Geol.*, 60 (5): 59-70 (in Russian).
- Zakharov, Y.D. 1986. Type and hypotype of the Permian-Triassic boundary. *Mem. Del. Soc. Geol. It.*, 34: 277-289.
- Zakharov, Y.D. 1992. The Permo-Triassic boundary in the southern and eastern USSR and its intercontinental correlation. In: Sweet, W.C., Yang Z., Dickins, J.M., and Yin H. (Eds.), *Permo-Triassic events in the Eastern Tethys. Stratigraphy, classification and relations with the Western Tethys. World and Regional Geology 2*. Cambridge, Cambridge University Press, p. 46-55.
- Zakharov, Y.D., Biakov, A.S., Baud, A., and Kozur, H. 2005. Significance of Caucasian sections for working out carbon-isotope standard for the Upper Permian and Lower Triassic (Induan) and their correlation with the Permian of North-Eastern Russia. *Journ. China Univ. Geosci.*, 16 (2): 141-151.
- Zakharov, Y.D., Mousavi Abnavi, N., Yazdi, M., and Ghaedi, M. (in press). New species of Dzhulfian (Late Permian) ammonoids from the Hambast Formation of Central Iran. *Paleont. Zhurn.* (in Russian).
- Zakharov, Y.D. and Rybalka, S.V. 1987. A standards for the Permian-Triassic in the Tethys. In: Zakharov, Y.D. and Onoprienko, Y.I. (Eds.), *Problems of the Permian and Triassic biostratigraphy of the East USSR*. *DVNC AN SSSR, Vladivostok*, p. 6-48 (in Russian).
- Zakharov, Y.D., Ukhaneva, N.G., Ignatyev, A.V., Afanasyeva, T.B., Buryi, G.I., Panasenkov, E.S., Popov, A.M., Punina, T.A., and Cherbadzhi, A.K. 2000. Latest Permian and Triassic carbonates of Russia: new palaeontological findings, stable isotopes, Ca-Mg ratio, and correlation. Yin, H., Dickins, J.M., Shi, G.R., and Tong, J. (Eds.), *Permian-Triassic evolution of Tethys and Western circum-Pacific*. Amsterdam: Elsevier, p. 141-171.
- Zhao, L. 2005. Permian-Triassic sequences in Meishan and Hushan, Lower Yangtze. Guide to the pre-Symposium field excursion of the International Symposium on the Triassic Chronostratigraphy and Biotic Recovery (23-25 May 2005, Chaohu, China). *Albertiana*, 33: 119-128.
- Zhao, J.K., Liang, X.L., and Sheng, Z.G. 1978. Late Permian cephalopods of South China. *Palaeont. Sinica, New Ser. B.*, 12, 1-194 (in Chinese with English abstract).

# Triassic Ammonoid Succession in South Primorye: 5. Stratigraphical position of the Olenekian Meekoceras fauna

Yuri D. Zakharov<sup>1</sup>, Olga P. Smyshlyaeva, Peter P. Safronov,  
Alexander M. Popov and Galina I. Buryi

<sup>1</sup> yurizakh@mail.ru

**Abstract** – A review of a new data on inner morphology of the Meekoceras shell and distribution of the Meekoceras fauna in different facies of the Lower Olenekian of South Primorye is given. Correlation of this fauna with those of western North America, the Himalayas and South China is established.

## Introduction

The original description of the genus *Meekoceras* was made by Hyatt (White, 1879). This is by far the best known ammonoid in western North America (Nevada, Idaho and California). *Meekoceras gracilitatis* White is by far the best known early Olenekian ammonoid in the mentioned region of North America and gives its name to the most fossiliferous Lower Olenekian zone, characterized by *Meekoceras* fauna (Hyatt and Smith, 1905; Smith, 1932; Kummel and Steele, 1962). Common ammonoid genera, associated with *Meekoceras gracilitatis* in Nevada, Idaho and California are *Pseudosageceras*, *Cordillerites*, *Pseudohedenstroemia*, *Flemingites*, *Euflemingites*, *Anaflemingites*, *Dieneroceras*, *Preflorianites*, *Inyoites*, *Owenites*, *Juvenites*, *Proshingitoides*, *Parussuria*, *Metussuria*, *Anakashmirites*, *Wyomingites*, *Arctoceras*, *Arctoprionites*, and *Anasibirites* (Kummel and Steele, 1962), most of which are known in the *Euflemingites prynadai* Beds (upper part of the “*Hedenstroemia bosphorensis* Zone”) of South Primorye. (Fig. 1). The figure conclusively illustrates the presence of the *Meekoceras* fauna in Russian Far East.

The main aim of this study is to show some new data on inner morphology of the *Meekoceras* shell from South Primorye and the evidence of geological age of the *Meekoceras* fauna in this region.

## *Meekoceras subcristatum* Kiparisova: external and inner shell morphology

Evidence on typical Early Olenekian *Meekoceras* species from South Primorye was firstly reported by Diener (1895) and Kiparisova (1961), who identified them as *Meekoceras boreale* Diener and *Meekoceras* nov. sp. ind. ex aff. *M. boreale* Diener (1895) and *Meekoceras subcristatum* Kiparisova (= *Meekoceras* nov. sp. ind. ex aff. *M. boreale* Diener (Kiparisova, 1961). The latter is most investigated in the Primorye region now. The resemblance in both suture (Fig. 2) and external morphology (Fig. 3) of it to *Meekoceras gracilitatis* White is indeed remarkable. According to Zakharov’s (1978) data, who investigated *Meekoceras subcristatum* from shallow water facies of the Ayax Bay (Russian Island) in detail, the inner structure of its shell is characterised by original type, named as *Meekoceras* type. Recently similar type was established for *Meekoceras subcristatis* from deeper facies of another locality in South Primorye (“SMID” quarry at the Artyom environs) (Table 1, Fig. 2). Information on the inner structure of the *Meekoceras*

*gracilitatis* White from Nevada (Fig. 3) has not been got because of bad preservation of its earliest stages.

## Facial response

There are two lower Olenekian (“*Hedenstroemia*” *bosphorensis* and *Anasibirites nevolini* zones) lithological facies in South Primorye: shallow-water sandy facies in its western part (Russian Island) and deeper silty-clayey facies in its eastern part (Golyj Cape, Abrek Bay, Artyomovka River, “SMID” quarry, and Smolyaninovo village). Intermediate type facies was discovered in the Tri Kamnya Cape section at the western Ussuri Gulf (Zakharov, 1996).

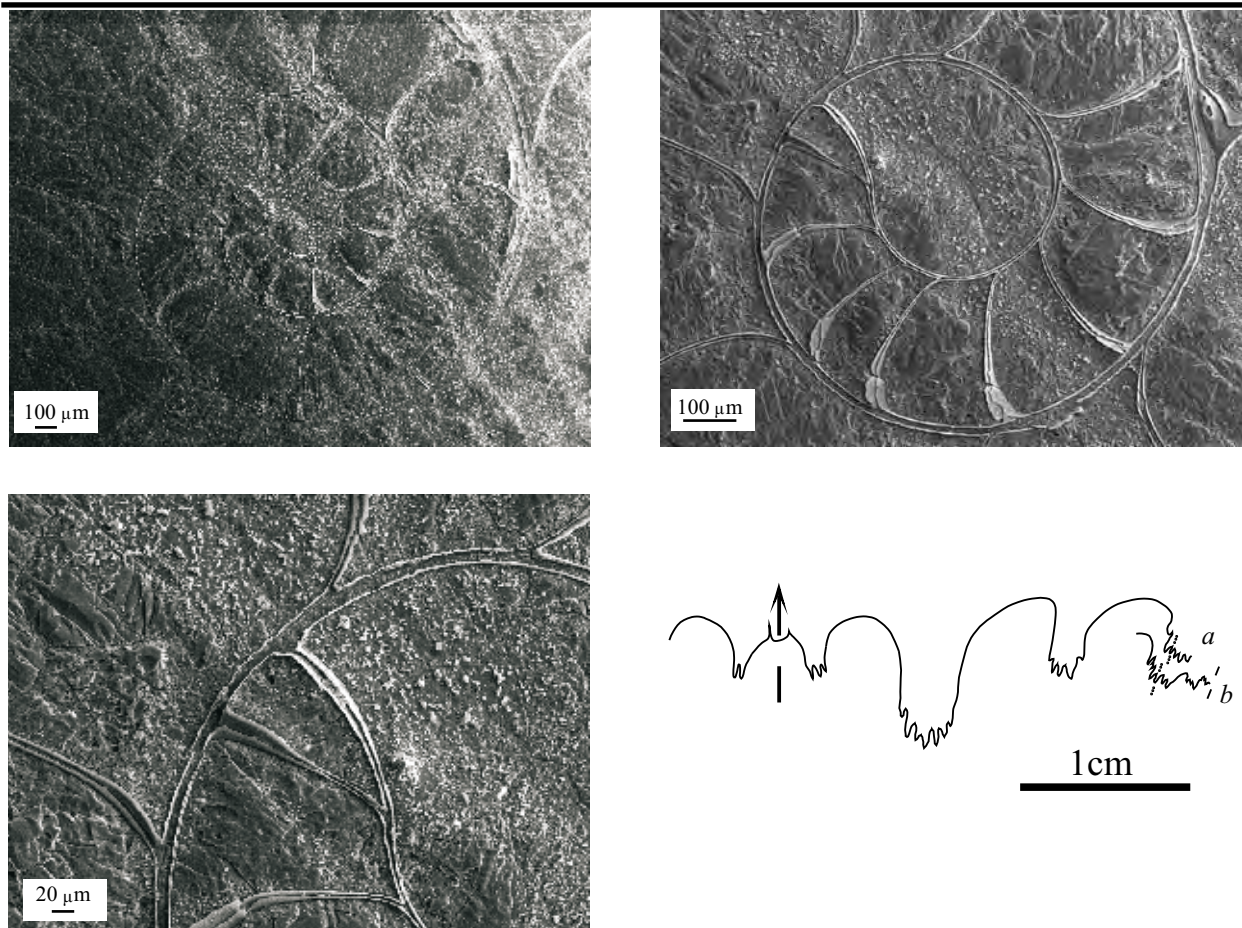
*Meekoceras subcristatum* Kiparisova is a dominant species in the shallow-water facies of the “*Hedenstroemia*” *bosphorensis* Zone (with exception of its basal beds) in Russian Island of the western part of South Primorye. It was found in the interval characterised by *Pseudosageceras longilobatum* Kiparisova, “*Hedenstroemia*” *bosphorensis* (Zakharov), *Epihedenstroemia ajaxensis* Zakharov, *Meekoceras boreale* Diener, *Dieneroceras chaoi* Kiparisova, *Preflorianites* sp., *Inyoites spicini* Zakharov, *Owenites koeneni* Hyatt and Smith, *Juvenites* sp., *Proshingitoides hexagonalis* (Zakharov), *Ussuria iwanowi* Diener, *Ussuria* aff. *iwanowi* Diener, *Arctoceras septentrionale* (Diener), *Arctoceras subhydaspis* (Kiparisova), and *Anaxenaspis orientalis* (Diener) there. Conodont assemblage yields *P. symmetrica* (Staesche), *H. raridenticulata* Müller, *H. adunca* Staesche, *H. triassica* Müller and *N. pakistanensis* Sweet ((Buryi, 1979).

In contrast, *Meekoceras subcristatum* is not so common (e.g. “SMID” quarry), very rare (e.g. Abrek Bay and possibly Tri Kamnya), or possibly absent (e.g. Golyj Cape) in deeper facies of the region, where a main body of the ammonoid assemblage was formed by *Arctoceras septentrionale* (Diener) and *Proshingitoides ovalis* Kiparisova (e.g. Golyj Cape and “SMID” quarry) or *Clypeoceras timorense* (Wanner) and *Arctoceras septentrionale* (Diener) (e.g. Abrek Bay). Ammonoids common for the *Euflemingites prynadai* Beds of the deeper silty-clayey facies of the eastern part of South Primorya are as follows: *Pseudosageceras multilobatum* Noetling, “*Hedenstroemia*” sp. nov. Zakharov and Smyshlyaeva (Fig. 4.1), *Parahedenstroemia kiparisovae* Shigeta and Zakharov, *Clypeoceras timorense* (Wanner), *Flemingites* aff. *trilobatum* Waagen (Fig. 5), *Euflemingites prynadai* (Kiparisova), *Balchaeceras balhaense* Shigeta and Zakharov, *Rohillites laevis* Shigeta and Zakharov,

Induan		Olenekian		Stage
<i>T. ussuriense</i>	<i>G. subdharm.</i>	<i>"Hedenstroemia" bosphorensis</i>		Zone
-	-	<i>Gyr. separatus</i>	<i>E. prynadai</i>	Beds
<p style="text-align: center;"><b>Ammonoid genera</b></p> <p style="text-align: center;">(Diener, 1895; Kiparissova, 1961; Zakharov, 1968; Maeda et al., 2009; Shigeta et al., 2009; Zakharov et al., 2009)</p>				
	<p><i>Tompophiceras</i></p> <p><i>Lytophiceras</i></p> <p><i>Pseudoproptychites</i></p> <p><i>Bukkenites?</i></p> <p><i>Pachyproptychites</i></p> <p><i>Ussuridiscus</i></p> <p><i>Gyronites</i></p> <p><i>Wordieoceras</i></p> <p>—?</p> <p><i>Preflorianites?</i></p> <p><i>"Hedenstroemia"</i></p> <p><i>Parahedenstroemia</i></p> <p><i>Dunedinites</i></p> <p><i>Radioprionites</i></p> <p>? — <i>Proharpoceras</i></p> <p><i>Juvenites</i></p> <p><i>Arctoceras</i></p> <p><i>Inyites</i></p> <p><i>Clypeoceras</i></p>	<p><i>Ambitoides</i></p> <p><i>Epihedenstroemia</i></p> <p><i>Pseudosageceras</i></p> <p><i>Cordillerites</i></p> <p><i>Gurleyites</i></p> <p><i>Kummelia</i></p> <p><i>Paranorites</i></p> <p><i>Rohillites</i></p> <p><i>Balhaeceras</i></p> <p><i>Euflemingites</i></p> <p><i>Flemingites</i></p> <p><i>Palaeokazakhstanites</i></p> <p><i>Eophyllites</i></p> <p><i>Parakymatoceras</i></p> <p><i>Meekoceras</i> - ?</p> <p><i>Owenites</i></p> <p><i>Prosphingitoides</i></p> <p><i>Abrekites</i></p> <p><i>Shamaraites</i></p> <p><i>Dieneroceras</i></p> <p><i>Ussuria</i></p> <p><i>Parussuria</i></p> <p><i>Metussuria</i></p> <p><i>Anaxenaspis</i></p> <p><i>Prionolobus</i></p> <p><i>Ambites</i></p>		

Figure 1. Vertical range of the Induan and early Olenekian ammonoid genera in South Primorye.





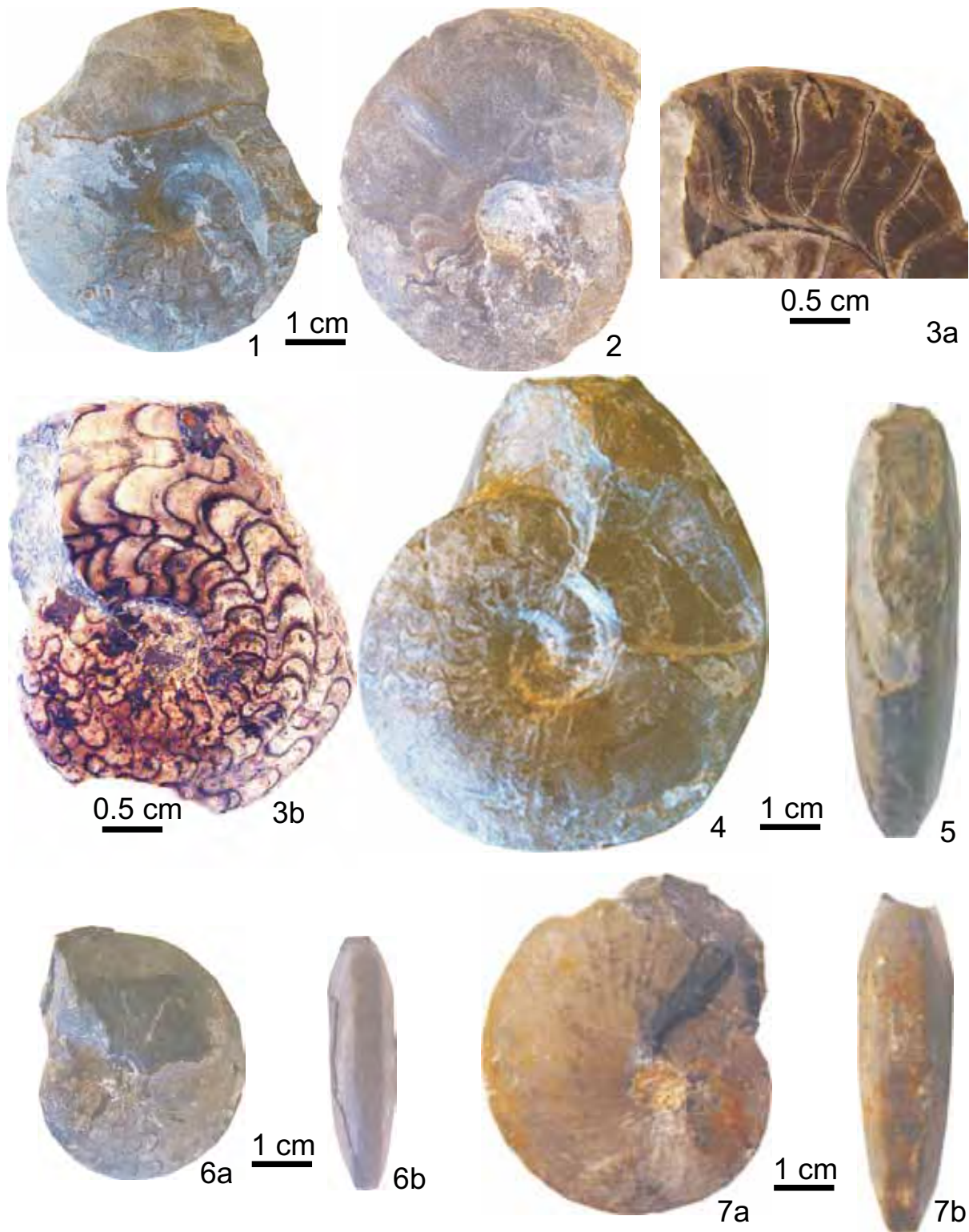
**Figure 2.** Inner structure of the *Meekoceras subcristatum* Kiparisova shell, showing protoconch, ammonitella, embryonic and early postembryonic septa, and its suture line at H=20 mm (a) and H=19.5 mm (b) (the coecum and prosiphon investigated earlier were lost during the later polishing). DVGI 5/888 (locality 741); suture was “*Hedenstroemia*” *bosphorensis* Zone; “SMID” quarry (Artyom), South Primorye.

*Palaeokazakhstanites ussuriensis* (Zakharov), *Abrekites editus* Shigeta and Zakharov, *Abrekites planus* Shigeta and Zakharov, *Radioprionites abrekensis* Shigeta and Zakharov, *Dieneroceras chaoi* Kiparisova, *Preflorianites* cf. *radians* Chao, *Inyoites spicini* Zakharov, *Inyoites* sp. nov. Zakharov and Smyshlyaeva (Fig. 4.2), *Owenites koeneni* Hyatt and Smith, *Prionolobus subevolvense* Zakharov, *Hemiprionites dunajensis* Zakharov, *Bandoites elegans* Zakharov, *Juvenites simplex* (Chao), Melagaticeratidae gen. and sp. nov. Zakharov and Smyshlyaeva, *Prospiringitoides hexagonalis* (Zakharov), *Prospiringitoides ovalis* Kiparisova, *Ussuria iwanowi* Diener, *Metussuria* cf. *bella* Zakharov, *Shamaraites shamarensis* (Zakharov), *Arctoceras septentrionale* (Diener), *Arctoceras subhydaspis* (Kiparisova), and *Anaxenaspis orientalis* (Diener). Conodont assemblage: *N. zharnikovae* Buryi, *Furnishius triserratus* Clark, *H. subsymmetrica* (Müller), *E. triassica* Müller, *E. cf. meissneri* (Tatge), *H. triassica* Müller, *H. nevadensis* Müller (Seryj Cape – Buryi, 1979), *N. concavus* Zhao and Orchard, *N. pakistanensis* Sweet, *N. aff. posterolongatus* Zhao and Orchard, *N. ex gr. waageni* Sweet, *E. costatus* Staesche, *F. gardinae* Staesche, *E. cf. peculiaris* (Sweet), *N. aff. novaehollandiae* McTavish, *N. spiciensis* Goel (Abrek Bay - Igo, 2009).

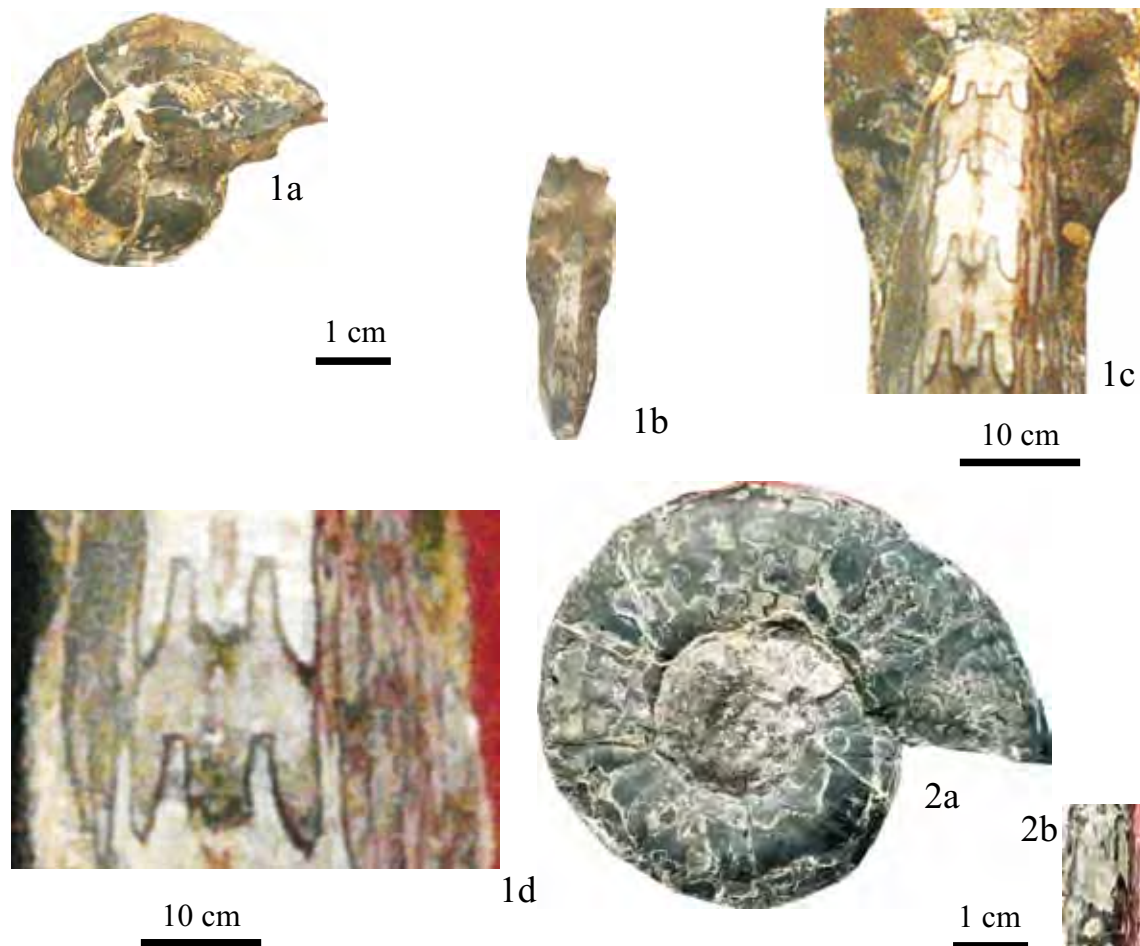
Ammonoids common for the *Euflemingites prynadai* Beds of intermediate type facies of the central part of South Primorya (Tri Kamnya Cape section) are as follows: *Pseu-*

*dosageceras multilobatum* Noetling, *Parahedenstroemia conspicienda* Zakharov, “*Meekoceras*” sp., *Clypeoceras timorensis* (Wanner), *Euflemingites prynadai* (Kiparisova), *Flemingites radius* Waagen, *Flemingites* aff. *glaber* Waagen, *Flemingites* sp., *Palaeokazakhstanites ussuriensis* (Zakharov), *Dieneroceras* sp., *Preflorianites* sp., *Prionolobus subevolvense* Zakharov, *Prospiringitoides ovalis* Kiparisova, *Ussuria iwanowi* Diener, *Shamaraites shamarensis* (Zakharov), *Shamaraites latiplicatus* (Diener), *Arctoceras septentrionale* (Diener), *Arctoceras subhydaspis* (Kiparisova), and *Anaxenaspis orientalis* (Diener). Conodont assemblage: very rare *Neospathodus* sp. indet., *N. dieneri* Sweet, *Diplodella* sp. indet. and *Lonchodina* cf. *triassica* Müller (Buryi, 1979).

According to Maeda and Shigeta’s (2009) version, the silty-clayey facies of Abrek Bay was formed at the deep anoxic basin environment and abundant well-preserved ammonoids found there were significantly transported along the slope from their original biotope. With regard to dependence of Olenekian ammonoids of South Primorye from facies (include even a change of ammonoid dominance in different facies), as was shown above, the role of process mentioned by Maeda and Shigeta (2009) seems to be at least somewhat exaggerated. Early Triassic conodont biofacies of Primorye have been discussed by Buryi (1979).



**Figure 3.** External morphology of *Meekoceras* shells: 3.1-3.6 - *Meekoceras subcristatum* Kiparisova; “*Hedenstroemia*” *bosphorensis* Zone; “SMID” quarry (Artyom), South Primorye: 3.1 – DVGI 6/888 (locality 743-3a-4), 3.2 - DVGI 7/888 (locality 743-3b), 3.3 – DVGI 5/888 (locality 741), 3-4 – DVGI 8/888 (locality 743-3a-3), 3.5 – DVGI 8/888 (locality 743-3a), 3.6 – DVGI 9/888 (locality 743-3a-2); 3.7 – *Meekoceras gracilitatis* White, DVGI 10/888; *Meekoceras gracilitatis* Zone; Critenden Springs, Nevada (K. Tanabe’s coll.).



**Figure 4.** Early Olenekian “*Hedenstroemia*” and *Inyoites* from the *Hedenstroemia*” *bosphorensis* Zone of the “SMID” quarry: 4.1 - “*Hedenstroemia*” sp. nov. Zakharov and Smyshlyaeva, DVGI 1/888 (locality AK-1); *Inyoites* sp. nov. Zakharov and Smyshlyaeva, DVGI 2/888 (locality OC-1).

#### Stratigraphical distribution of the *Meekoceras* fauna

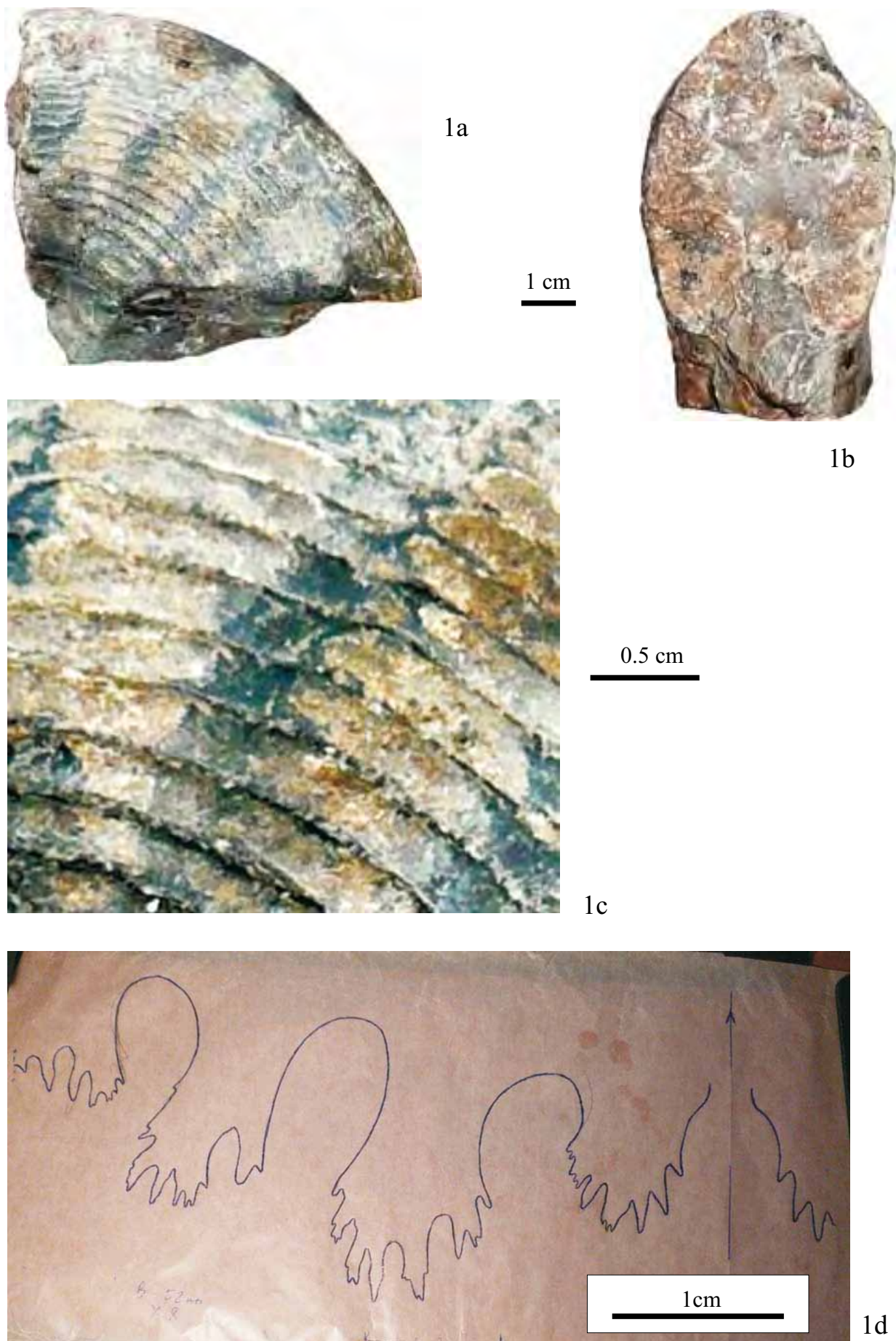
The shallow-water sandy facies of the western part of South Primorye and deeper silty-clayey facies of the eastern part of the mentioned area characterised by different stratigraphical distribution of the main elements of the *Meekoceras* fauna: the former contains them in both “*Hedenstroemia*” *bosphorensis* Zone (with exception its basal beds) and overlying *Anasibirites nevolini* Zone. In the latter their distribution is restricted apparently by the *Euflemingites prynadai* Beds of the “*Hedenstroemia*” *bosphorensis* Zone. In shallow-water sandy facies of South Primorye, as well as in shallow-water carbonate facies of western North America, the main elements of the *Meekoceras* fauna more likely existed longer than in deeper facies of eastern part of South Primorye, although rare its genera (e.g. *Owenites*) were also present in deeper facies.

In Russian Island of the western part of South Primorye the *Anasibirites nevolini* Zone, determined by presence of *Anasibirites* sp., *Wasatchites sikhotealinensis* Zakharov, *Wasatchites* sp., and *Hemiprionites* sp. Among elements of the *Meekoceras* fauna, discovered there, may be distinguished *Parahedenstroemia conspicienda* Zakharov, *Clypeoceras timorensis* (Wanner), *Meekoceras subcristatum* Kiparisova, *Owenites koeneni* Hyatt and Smith, *Prosphingitoides ovalis* Kiparisova, *Arctoceras septentrionale* (Diener), *Arctoceras*

*subhydaspis* (Kiparisova), and flemingitid *Guangxiceras tobisinsense* (Zakharov). The base of the *Anasibirites nevolini* Zone in South Primorye seems to be easier recognized in deeper silty-clayey facies, where its ammonoid assemblage is significantly more diverse than in facies of Russian Island: *Pseudosageceras* sp., *Parahedenstroemia nevolini* Burij and Zharnikova, *Paranannites minor* Kiparisova, *Owenites koeneni* Hyatt and Smith, *Arctoprionites maritimus* Burij and Zharnikova, *Hemiprionites dunajensis* Zakharov, *Hemiprionites contortus* Burij and Zharnikova, *Prionolobus involutus* Zakharov, “*Meekoceras*” sp., *Wasatchites vlasovi* Burij and Zharnikova, *Gurleyites maichensis* Burij and Zharnikova, *Preflorianites* sp., *Anasibirites nevolini* Burij and Zharnikova, *Anasibirites* sp., *Burijites skorochodi* (Burij and Zharnikova), *Subalbanites mirabilis* Zakharov, *Churkites syaskoi* Zakharov and Shigeta, etc. This ammonoid assemblage and its equivalents in South Primorye, as well as in other regions, including Spiti and Boreal realm, correspond to the conodont *N. milleri* Zone ((Buryi, 1979).

#### Lowest Olenekian layers (*Gyronites separatus* Beds)

The *Gyronites separatus* Beds underlying the *Euflemingites prynadai* Beds at the western Ussuri Gulf (Zakharov, 1997; Zakharov et al., 2009b), has been identified as the lower portion of the Lower Olenekian “*Hedenstroemia*”



**Figure 5.** *Flemingites* aff. *trilobatum* Waagen, DVGI 3/888 (locality OC-2), suture line at H=52 mm; “*Hedenstroemia*” bosphorensis Zone; “SMID” quarry (Artyom), South Primorye.



**Figure 6.** Ammonoid fossils, found at the base of the Olenekian (*Gyronites separatus* Beds) on the western coast of Ussuri Gulf: 6.1 – *Pseudosageceras* cf. *multilobatum* Noetling (=“*Hedenstroemia* cf. *bosphorensis*”), DVGI 948/801 (Kontaknyj Creek, locality 988-7, basal layer 401-8 of the “*Hedenstroemia*” *bosphorensis* Zone); 6.2 – *Parahedenstroemia* sp., DVGI 950/801 (Kontaknyj Creek, locality 988-7, basal layer 401-8 of the “*Hedenstroemia*” *bosphorensis* Zone); 6.3 – *Gyronites separatus* Kiparisova, DVGI 935/801 (Kontaknyj Creek, locality 988-7, basal layer 401-8 of the “*Hedenstroemia*” *bosphorensis* Zone); 6.4-6.6 – *Ambitoides* cf. *orientalis* Shigeta and Zakharov (Kontaknyj Creek, locality 988-7, basal layer 401-8 of the “*Hedenstroemia*” *bosphorensis* Zone): 6.4 – DVGI 946a/801, 6.5 – DVGI 946/801, 6.6 – DVGI 946b/801, suture line at H=6 mm; 6.7 – *Ambitoides*? sp. (= *Meekoceras* cf. *subcristatum*”), DVGI 4/888 (Oryel Cliff, basal layer 95-11 of the “*Hedenstroemia*” *bosphorensis* Zone).

Table 1. The inner structure of *Mesloceras* shells from the Olenekian "Hedenstroemia" bayherensis Zone (*Euflemingia pyramidi* Beds) of South

Primorye

Species	Facies	Locality	Type of the hydrostatic apparatus	Dimension of the protoconch, mm			Dimension of the saccus, mm		L <sub>90</sub> , mm	
				D <sup>1</sup> <sub>p</sub>	D <sup>2</sup> <sub>p</sub>	W <sub>p</sub>	D <sub>h</sub>	D <sup>1</sup> <sub>c</sub>		D <sup>2</sup> <sub>c</sub>
<i>M. subcrinitum</i> (original data)	Shallow-water sandy facies	"SMID" quarry	Mesloceras-type	0.40-0.49	0.38	-	0.9-0.92	0.13	0.09	0.14
<i>M. subcrinitum</i> (Zakharov, 1978)	Deeper silty-chayey facies	Ayas Bay	Mesloceras-type	0.43-0.45	0.31-0.39	0.50	-	0.13	0.09	0.14

Species	Facies	Locality	Position of the spherule within the whorls I-IV					Type of the septal necks						
			I	II	III	IV	V	I	II	III	IV	V		
<i>M. subcrinitum</i> (original data)	Shallow-water sandy facies	"SMID" quarry	V	V	V	V	-	-	-	-	R	R	R	R
<i>M. subcrinitum</i> (Zakharov, 1978)	Deeper silty-chayey facies	Ayas Bay	V	V	V	-	-	-	-	R	R	R	R	R-A

Designations: D<sup>1</sup><sub>p</sub> – biggest diameter of the protoconch, D<sup>2</sup><sub>p</sub> – least diameter of the protoconch, W<sub>p</sub> – width of the protoconch, D<sub>h</sub> – diameter of the saccus, D<sup>1</sup><sub>c</sub> – position of the septal neck construction (in degrees), D<sup>2</sup><sub>c</sub> – biggest diameter of the saccus, D<sup>1</sup><sub>s</sub> – least diameter of the saccus, L<sub>90</sub> – length of the pearly part, R – rostrochamber, A – axial chamber.

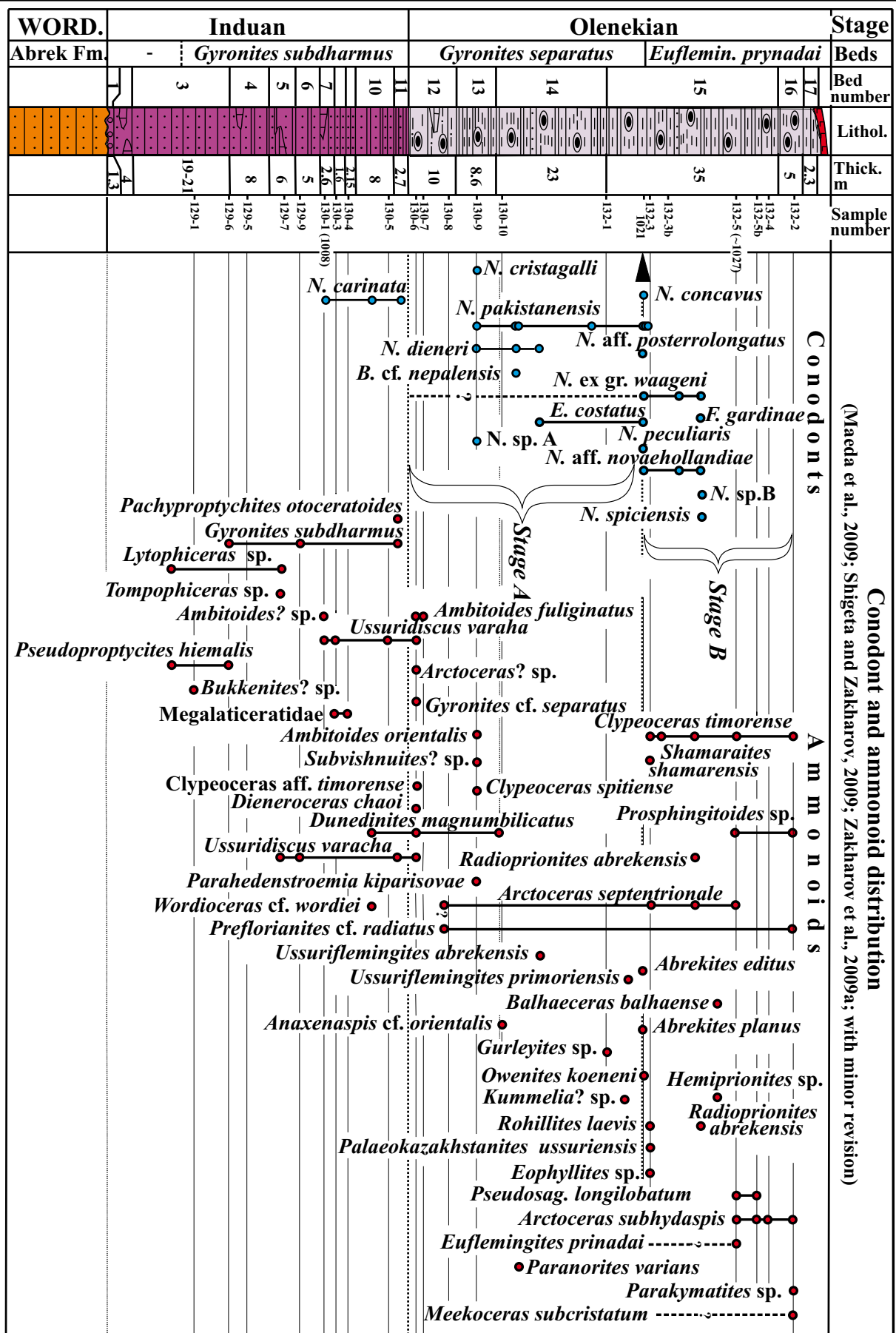


Figure 7. Vertical range and zonation of ammonoids in the IOB in Abrek Bay, South Primorye (new version).

*bosphorensis* because of finding there *Pseudosageceras* cf. *multilobatum* Noetling (Fig. 6.1), identified as *Hedenstroemia bosphorensis* (Zakharov, 1996) till now, *Parahedenstroemia* sp. (Fig. 6.2), *Gyronites separatus* Kiparisova (Fig. 6.3), *Ambitoides orientalis* Shigeta and Zakharov (Fig. 6.4-6.6) in the Kontaknyj Creek locality (401-8), Tri Kamnya Cape area, and *Ambitoides* ? sp. (= "Meekoceras") (Fig. 6.7) in the same level at the Oryel Cliff of the western Ussuri Gulf, locality 95-11. Basal beds of the Olenekian at the Ajax Bay in Russian Island yield flemingitid? ammonoids and *Proharpoceras carinatitabulatum* Chao (Zakharov et al., 2004). No conodonts were found in the mentioned layers.

More diverse and better preserved ammonoid assemblage was recently discovered in the lower portion of the Olenekian at the Abrek Bay section (Fig. 7), which corresponds, in our opinion, to the *Gyronites separatus* Beds at western Ussuri Gulf. It consists of *Gyronites* cf. *separatus* (= *Gyronites* sp.), *Ambitoides fuliginatus*, *Arctoceras*? sp., *Ambitoides orientalis*, *Subvishnuites*? sp. (= "Vishnuites" sp.), *Clypeoceras* aff. *timorense*, *Clypeoceras spitiense*, *Parahedenstroemia kiparisovae*, *Ussuriflemingites abrekenensis*, *Ussuriflemingites primoriensis*, *Anaxenaspis* cf. *orientalis*, *Gurleyites* sp., *Kummelia*? sp., *Paranorites varians* and some others. This ammonoid assemblage is not believed to be comparative to the *Meekoceras* fauna of western North America. Known conodonts associated are as following: *N.* cf. *cristagalli* (Huckriede), *N. pakistanensis* Sweet, *N. dieneri* Sweet, *B.* cf. *nepalensis* Kozur and Mostler, and *E. costatus* Staesche (Igo, 2009).

## Correlation

New information on Early Olenekian ammonoid assemblages from South Primorye seems to be useful for determination of the I/O boundary in the ammonitiferous beds of western North America, the Mud section at Pin Valley of the Himalayas, a main candidate GSSP for the base of the Olenekian Stage and northwestern Guangxi in South China. The *Euflemingites prynadai* Beds of South Primorye are believed to be synchronous with the lower part of the *Meekoceras gracilitatis* Zone in western North America (Kummel and Steele, 1962), *Rohillites rohilla*, *Flemingites-Euflemingites* and *Owenites* zones in Spiti (Krystyn et al., 2007) and *Flemingites rursiradiatus* and *Owenites koeneni* beds of Guangxi (Brayard and Bucher, 2008). The earliest Olenekian *Gyronites separatus* Beds of South Primorye seems to be equivalent to the "*Meekoceras*" *vercherei* Beds in the Himalayas (Krystyn et al., 2007), underlying the *Rohillites rohilla* Zone. It is characterised by ammonoid species "*Meekoceras*" *vercherei* (Waagen), assigned by us to *Ambitoides*, which is common mainly for the earliest Olenekian layers in South Primorye (Fig. 7). However, more research is needed to define the position of the Induan-Olenekian boundary in the Spiti region from data on ammonoids. The *Gyronites separatus* Beds in South Primorye and their equivalents cannot be contemporaneous with the zone of *Meekoceras gracilitatis*.

## Acknowledgments

We thank Dr. Vladimir T. S"edin for his help to collect well preserved ammonoids of the Zone of "*Hedenstroemia*" *bosphorensis* (upper part) from crushed stone recently taken from the "SMID" quarry (Artyom) and based along the road Artyom-Vladivostok. Prof. Kazushige. Tanabe is acknowledged for his accordance of collection material from the *Meekoceras gracilitatis* Zone in western North America. This work is a contribution to IGCP project 572 and was carried out the financial support of RFBR grant 09-05-98524-R\_vostok\_a and FEB grant 10-III-V-08-037, Russia.

## References

- Buryi, G.I. 1979. Lower Triassic conodonts in Southern Primorye. Nauka, Moscow. 144 p. (in Russian).
- Buryi, G.I. 1997. Early Triassic conodont biofacies of Primorye. In: Baud, A., Popova, I., Dickins, J.M., Lucas, S., and Zakharov, Y. (Eds.), Late Paleozoic and Early Mesozoic circum-Pacific events: biostratigraphy, tectonic and ore deposits of Primorye (Far East Russia). Mém. Géol. (Lausanne), 35-44.
- Diener, K. 1895. Tradische Cephalopoden-faunen der ostsibirischen Kustenprovinz. Mém. Com. Géol. St. Petersburg, 14, 1-59.
- Hyatt, A. and Smith, J.P. 1905. The Triassic Cephalopod Genera of America. U.S. Geol. Survey, Prof. Paper 40, 1-394.
- Igo, H. 2009. Conodonts. 181-196. In: Shigeta, Y., Zakharov, Y.D., Maeda, H., Popov, A.M. (Eds.), The Lower Triassic system in the Abrek bay area, South Primorye, Russia. National Museum of Nature and Science, Tokyo, 36-38.
- Kiparisova, L.D. 1961. Palaeontological basis of Triassic stratigraphy of Primorye region. I. Cephalopods. Trudy VSEGEI, "Gosgeoltekhizdat", Leningrad, new ser. 48, 1-278.
- Krystyn, L., Bhargava, O.N. and Richoz, S. 2007. A candidate GSSP for the base of the Olenekian Stage: Mud at Pin Valley; district Lahul and Spiti, Himachal Pradesh (Western Himalaya), India. *Albertiana*, 35: 5-29.
- Kummel, B. and Steele, G. 1962. Ammonites from the *Meekoceras gracilitatis* Zone at Cretenden Spring, Elko County, Nevada. *J. Paleont.*, 36: 638-703.
- Maeda, H. and Shigeta, Y. 2009. Ammonoid mode of occurrence. In: Shigeta, Y., Zakharov, Y.D., Maeda, H., Popov, A.M. (Eds.), The Lower Triassic system in the Abrek bay area, South Primorye, Russia. National Museum of Nature and Science, Tokyo, p. 36-38.
- Maeda, H., Shigeta, Y., Tsujino, Y., and Kumagai, T. 2009. Stratigraphy. In: Shigeta, Y., Zakharov, Y.D., Maeda, H., Popov, A.M. (Eds.), The Lower Triassic system in the Abrek bay area, South Primorye, Russia. National Museum of Nature and Science, Tokyo, p. 4-24.
- Shigeta, Y. and Zakharov, Y.D. 2009. Cephalopods. In: Shigeta, Y., Zakharov, Y.D., Maeda, H., Popov, A.M.



- (Eds.), The Lower Triassic system in the Abrek bay area, South Primorye, Russia. National Museum of Nature and Science, Tokyo, p. 44-140.
- Smith, J.P. 1932. Lower Triassic ammonoids of North America. U.S. Geol. Surv. Prof. Pap., 167: 1-199.
- White, C.A. 1879. Fossils of the Jura-Trias of southeastern Idaho. U.S. Geol. Geog. Survey Terr. Bull. 5, 105-117.
- Zakharov, Y.D. 1978. Early Triassic ammonoids of East USSR. Nauka, Moscow, 224 pp. (in Russian).
- Zakharov, Y.D. 1996. The Induan-Olenekian boundary in the Tethys and Boreal realm. *Annali dei Musei Civici di Revereto, Sezione Archeologia, Storia e Scienze Naturali*, 11: 133-156.
- Zakharov, Y.D. 1997. Recent view on the Induan, Olenekian and Anisian ammonoid taxa and zonal assemblages of South Primorye. *Albertiana*, 19, 25-35.
- Zakharov, Y.D., Popov, A.M., and Konovalova, I.V. 2004. Ayaks Bay- Akhlestyshv Cape. In: Markevich, P.V. and Zakharov, Y.D. (Eds.), *Triassic and Jurassic of the Sikhote-Alin. Book I. Terrigenous assemblage*. Dalnauka, Vladivostok, 18-35. (in Russian).
- Zakharov, Y.D., Shigeta, Y. and Igo, Y. 2009a. Correlation of the Induan-Olenekian boundary beds in the Tethys and Boreal realm: evidence from conodont and ammonoid fossils. *Albertiana*, 37, 20-27.
- Zakharov, Y.D., 2009b. Triassic ammonoid succession in South Primorye: 4. Stratigraphical and palaeobiogeographical significance of flemingitids. *Albertiana*, 37, 28-35.

---

# Stratigraphic potential of the Upper Triassic benthic foraminifers

S. Rigaud<sup>1</sup>, R. Martini<sup>1</sup>, R. Rettori<sup>2</sup> and G. D. Stanley Jr.<sup>3</sup>

<sup>1</sup>Department of Geology & Paleontology, University of Geneva, Switzerland

<sup>2</sup>Earth Science Department, University of Perugia, Italy

<sup>3</sup>The University of Montana Paleontology Center, Missoula, Montana, USA

**Abstract** - A succession of unusually rich, well-preserved and diversified Carnian-Norian benthic foraminiferal assemblages has been found in an isolated limestone remnant of the Panthalassa Ocean (Black Marble Quarry, Wallowa terrane, Oregon). Foraminifers, including about 75% of well-known Tethyan species, show there a comparable stratigraphic distribution with Tethyan localities. The apparent synchronous occurrence of similar forms on both sides of the Panthalassa Ocean highlights the strong potential of foraminifers as stratigraphic tools for the Upper Triassic global correlations.

Keywords: Upper Triassic, benthic foraminifers, Panthalassa, Wallowa terrane.

## Introduction

Upper Triassic high-resolution biochronological data are generally based on ammonites, conodonts, radiolarians or *Halobia* bivalves. Nevertheless, these fossils, normally abundant in slope and basins facies are rare to absent in most shallow-water deposits of isolated, epeiric and “rimmed” carbonate platforms. In such deposits, palynomorphs and foraminifers are, at a fewer level of resolution, good substitutes. However, commonly, like in our study area, Upper Triassic rocks are too altered by metamorphism to yield valuable palynological data and foraminifers represent the only fossils having the ability to provide a reliable stratigraphical resolution.

Foraminiferal studies on the Upper Triassic carbonate rocks of Tethys are numerous and have led to the construction of consistent stratigraphic and systematic frameworks. In contrast, foraminiferal investigations on coeval carbonate rocks of the wide Panthalassa Ocean are scarce, hampering biostratigraphic correlations between Tethyan and Panthalassan faunal provinces. This paper is a preliminary report on our ongoing research regarding the Upper Triassic foraminifers from the Wallowa terrane, notably aiming at defining their potential as tools for global stratigraphic correlations.

## Geological overview and study area

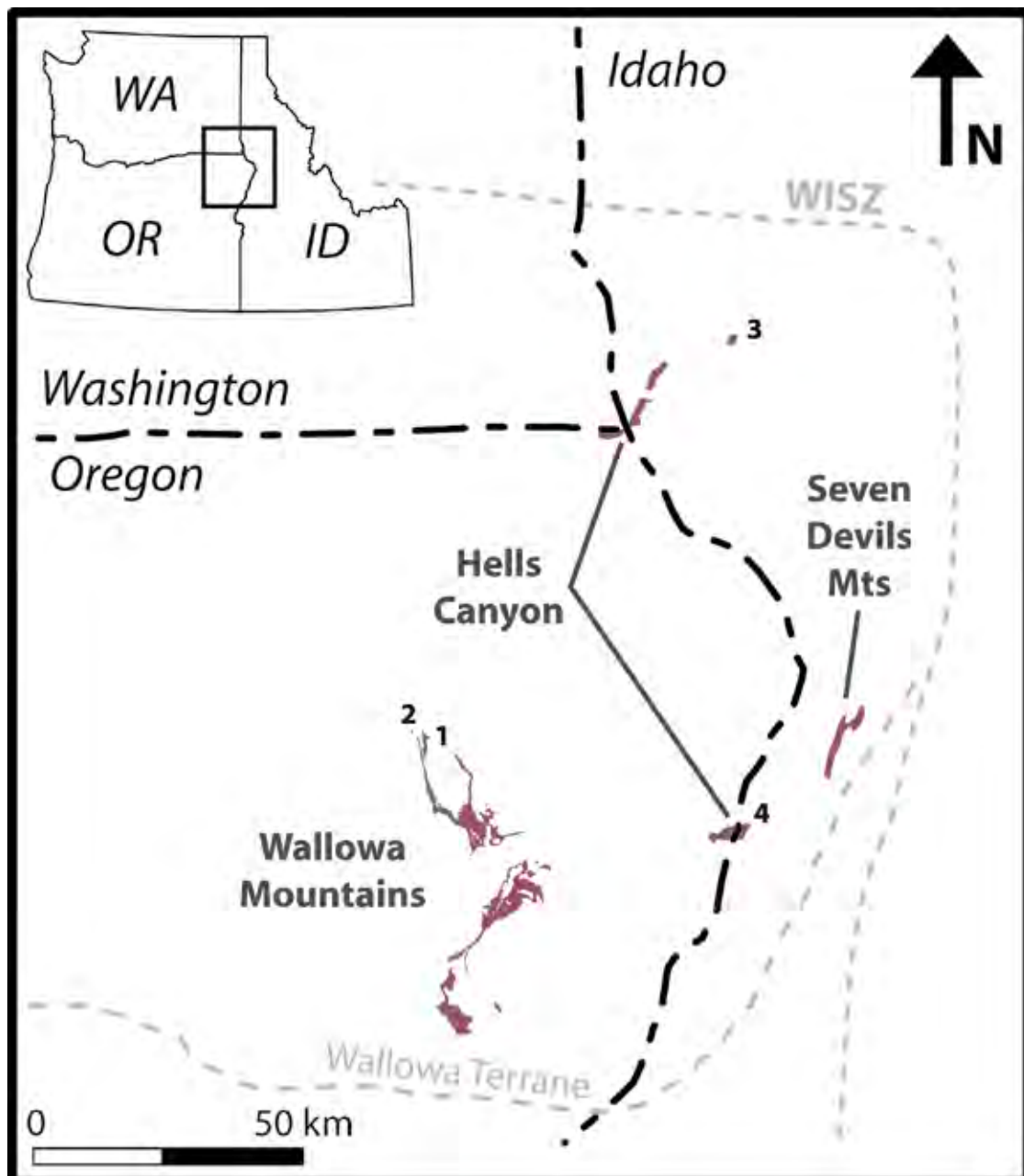
The North America Cordillera is made up of numerous displaced terranes originated in the Panthalassa and accreted to the American continental margin during Mesozoic and Early Cenozoic time (Coney *et al.*, 1980). The Wallowa terrane (Fig. 1), remain of a volcanic island-arc, is one of the four distinct tectonostratigraphic terranes structuring the Blue Mountains Province (Vallier *et al.*, 1977; Silberling *et al.*, 1984). It presents fossiliferous Upper Triassic carbonate deposits having close similarities with those from the Tethyan Realm (Stanley & Senowbary-Daryan, 1986; Stanley *et al.*, 2008). After a long volcanic, accretionary and tectonical history (Armstrong *et al.*, 1977; Brooks &

Vallier, 1978; Avé Lallemand *et al.*, 1985; Manduca *et al.*, 1993; Wyld & Wright, 2001; Gray & Oldow, 2005; Dorsey & LaMaskin, 2007; Dorsey & LaMaskin, 2008), the Early Permian to Late Jurassic, eight kilometer thick, Wallowa terrane stratigraphic succession is almost completely covered by the Mio-Pliocene Columbia River Basalt. Hence, the Wallowa terrane appears isolated or dismantled and crops out only in areas where tectonic, river incision or uplift and erosion of the basalt cover have exposed rocks (i.e., in the Wallowa Mountains, the Snake River Canyon and the Seven Devils Mountains).

The foraminiferal associations described below come from the Black Marble Quarry (BMQ), a lagoonal stratigraphic succession isolated in the Northern Wallowa Mountains (N 45°22'24", W 117°21'14") (Fig. 1 & 2). It is a thick-bedded, distinctive dark, bituminous-like micritic limestone regarded as the most fossiliferous locality in the entire region. The different levels include in situ colonial corals, chambered demosponges, hemispherical, chaetetid-like “stromatoporoid” sponges *Heptastylis*, branching hydrozoans *Spongiomorpha*, spiriferid brachiopods and diverse mollusks, bryozoans, ostracods and echinoderms (e.g., Stanley, 1979). According to the literature, ammonites (Smith & Allen, 1941), reef-builders organisms (Stanley, 1979; Follo, 1986), foraminifers (Kristan-Tollmann & Tollmann, 1983; Stanley *et al.*, 2008) and Wallowaconchid bivalves, that are only known in Norian age deposits (Yancey *et al.*, 2005), point to a Carnian to Norian age for the whole sedimentary sequence. An upper Middle Norian age was assigned according to a preliminary report of *Heterastridium conglobatum* Reuss uncovered during preparation of a wallowaconchid bivalve (Yancey & Stanley, 1999). We here clarify this erroneous assignment based upon subsequent study which failed to confirm the identification.

## Material and methods

Field work was conducted during summer of 2007, 2008



**Figure 1:** General map of the Wallowa terrane. Gray patches indicate the main Upper Triassic limestone outcrops and numbers, the localities mentioned in the text (1: Black Marble Quarry; 2: Lostine River; 3: Mission Creek Quarry; 4: Kinney Creek).

and 2009. Additionally to the collected material, we include some samples from Stuart Ashbaugh (BSc, University of Montana). Our study is based on an analysis of more than 500 thin sections from the Wallowa terrane, including about 200 thin sections from the BMQ. The extreme maturation of the organic matter has prevented any palynological preservation and attempt to extract conodonts failed.

#### Foraminiferal assemblages and inferred age

Kristan-Tollmann & Tollmann (1983) first illustrated foraminifers from the BMQ. They only mentioned “*Angulodiscus eomesozoicus*” and “*Diplotremina?* sp.”, considering the quarry to be Carnian in age. Our study of the BMQ shows that foraminifers are there far more abundant and diversified. In fact, including 28 genera from 18 families and about 25% of new species, the BMQ holds the most

complete and best preserved Upper Triassic Tethyan-type assemblage ever found in America (study in progress).

Foraminifers only occur within the firsts 44 meters of the BMQ succession (see Fig. 2). Along this portion, the foraminiferal assemblages are dominated by abundant aragonitic foraminifers, Textularioidea, rich Ammodiscidae, Duostominidae, Polymorphinidae, Oberhauserellidae and common Lagenidae. Above, the depositional setting, more energetic, seems hostile to most foraminifers and only Duostominids persist.

Although there are no lithological changes within the firsts 44 meters of the BMQ, a rapid succession of foraminiferal assemblages occur. In the lowermost part of the quarry, the association of *Lamelliconus multispinus* (Oberhauser), *L. cucullatus* di Bari & Laghi, *L. depressus* di Bari & Laghi,



**Figure 2:** Panorama of the Black Marble Quarry outcrop. The white dotted line represents the top of the first 44 meters of the succession.

*Aulotortus* ex gr. *sinuosus* (Weynschenk) and *A. praegaschei* (Koehn-Zaninetti) with reliable Tethyan Carnian guide fossils such as *Glomospira kuthani* (Salaj), *Gsollbergella spiroloculiformis* (Oravec-Scheffer), *Semimeandrosira* ex gr. *karnica-planispira* (Oravec-Scheffer) and *Piallina bronnimanni* Martini, Rettori, Urošević & Zaninetti clearly attests a Carnian age (Salaj *et al.*, 1983; Rettori, 1995; Rettori *et al.*, 1998). At the top of the first 15 meters of the succession, these typical Carnian foraminifers, less and less diversified, suddenly disappear giving way to Norian forms. Indeed, within this interval, together with the appearance of *Wallowaconchid* bivalves, the foraminiferal assemblages evolve bed by bed and record the appearance of “*Triasina oberhauseri*” Koehn-Zaninetti & Brönnimann, *Trocholina acuta* Oberhauser, *T. umbo* Frentzen, *Gandinella apenninica* Ciarapica & Zaninetti and *Aulotortus tumidus* (Kristan-Tollmann). In the middle and upper part of the succession, the assemblages are characterized by a high diversification in Aulotortidae represented by *Aulotortus communis* (Kristan), *A. impressus* (Kristan-Tollmann), *A. tenuis* (Kristan), *A. friedli* (Kristan-Tollmann), *A. minutus* (Koehn-Zaninetti) and ?*Auloconus permodiscoïdes* (Oberhauser), species known to be major constituent of Norian foraminiferal assemblages of Tethys (see Koehn-Zaninetti, 1969; Piller, 1978; Zaninetti *et al.*, 1992; Velić, 2007). This interval of few meters, where the trend gradually reverses with a notable diversification of Aulotortidae that completely replace Lamelliconinae, most likely comprises the Carnian-Norian boundary (Rigaud *et al.*, in prep.).

According to Tethyan data, it is noteworthy that in the BMQ, Norian forms such as *Trocholines* and “*Triasina oberhauseri*” Koehn-Zaninetti & Brönnimann are also encountered concurrently with Carnian guide foraminifers. The co-occurrence of Carnian and Norian forms observed in the BMQ has never been mentioned in any Upper Triassic deposits. We draw attention to the stratigraphic range of such forms that seems to span the Carnian-Norian boundary interval in the Panthalassa Ocean. Based on this observation, we demonstrate that some stratigraphic disparities could exist between Tethys and Panthalassa. In

spite of that, the succession of foraminiferal assemblages observed in the BMQ remains stratigraphically coherent with the foraminiferal stratigraphy known in Tethys.

### Upper Triassic foraminifers: a potential tool for global stratigraphic correlations?

In North America, Triassic foraminifers have been described in the Lower Triassic (Schell & Clark, 1960; Schroeder, 1968), in the Middle Triassic (Tappan, 1951; Gaździcki & Stanley, 1983) and in the Upper Triassic (Gaździcki & Reid, 1983; Kristan-Tollmann & Tollmann, 1983; Igo & Adachi, 1992). Foraminifers are reported from accreted terranes of Alaska, Yukon, Washington and Oregon as well as along the American paleomargin of Idaho, Wyoming and Nevada. As Kristan-Tollmann & Tollmann (1983) and Kristan-Tollmann (1988) first discussed, North American Triassic foraminifers reveal strong similarities with those of the Tethys. Furthermore, as for the BMQ, these foraminifers, the majority of which are well-calibrated by ammonites and/or conodonts, show compatible stratigraphic distribution with their Tethyan counterparts. It is here important to be noticed that the Norian foraminiferal assemblages found in the BMQ present some resemblances with the foraminiferal assemblage of Lime Peak, Yukon (Gaździcki & Reid, 1983).

Up to now, in contrast with Tethyan localities, foraminifers were thought to be rare in the terranes of North America (Gaździcki & Reid, 1983). Our preliminary study, however, evidences that foraminifers were common and well-distributed, at least throughout the Wallowa terrane carbonate platform. Foraminifers are currently assumed to be facies dependant in both modern and ancient carbonate platforms (Piller, 1978; Martini *et al.*, 2004; Gischler & Möder, 2009). Accordingly, in the Wallowa terrane, the foraminiferal assemblages of the BMQ are partly encountered in others Upper Carnian to Norian lagoonal sedimentary successions: at the Lostine River (Oregon), Kinney Creek (Idaho) and the Mission Creek Quarry (Idaho) (see Fig. 1). At the scale of the Wallowa terrane, the wide distribution of these Carnian to Norian assemblages gets them into position of tools for further local

biostratigraphic correlations.

In Tethys, calibrated, more or less reliable stratigraphic subdivisions of the foraminiferal distribution exist (Salaj, 1969; Salaj, 1977; Trifonova, 1978; Salaj *et al.*, 1983; Trifonova, 1984; Oravec-Scheffer, 1987; Salaj *et al.*, 1988; He Yan & Norling, 1991; Kamoun *et al.*, 1997). However, since most accurate works on Carnian-Norian stratigraphy lack a foraminiferal control, the foraminifer stratigraphic value has not been fully evaluated yet. According to the literature, the Upper Triassic foraminiferal radiation was a rapid evolutionary process that led to the diversification of several, stratigraphically significant foraminifers. As far as concerned the suborder Involutinina, the major constituent of the BMQ assemblage, a rapid radiation took place from the Late Ladinian, and especially during the Carnian, represented by the explosion of Lamelliconinae, and then, along the Norian, characterized by the diversification of Aulotortidae (Zaninetti, 1976). This two-step diversification is recorded along the BMQ sedimentary series and help to corroborate the Carnian to Norian age of the succession.

Rich in the BMQ, the Carnian and Norian foraminiferal assemblages record from the quarry are common and well distributed in coeval deposits of the Western and the Eastern Tethyan domain (Salaj, 1969; Brönnimann *et al.*, 1970; Zaninetti, 1976; Piller, 1978; Salaj *et al.*, 1983; He Yan and Wang Lijun, 1990; Zaninetti *et al.*, 1992; di Bari & Laghi, 1994; Rettori *et al.*, 1998), demonstrating their widespread and probably global distribution in the Upper Triassic seas. For example, the BMQ Carnian foraminiferal assemblages show strong similarities with those found in the type locality of the Calcare del Predil, Northeastern Italy (Rettori *et al.*, 1998) and are closed to those from the Global Stratotype Section and Point (GSSP) Ladinian-Carnian boundary candidate Prati di Stuoeres/Stuoeres Wiesen section of Northern Italy (Broglia Loriga *et al.*, 1998; Broglia Loriga *et al.*, 1999; Mietto *et al.*, 2007).

As a consequence: 1) since the foraminiferal associations found in the BMQ are rich, easily recognizable, most probably worldwide distributed, and 2) taking into account the strong similitude of stratigraphic distributions between Tethys and America, we postulate that the BMQ foraminiferal assemblages, well-calibrated in the Tethys domain, might be use in global correlations as indicator of the Carnian and Norian stages and may help to define the Carnian-Norian boundary.

## Conclusion

Ammonites, conodonts, radiolarians and *Halobia* bivalves are markers for Late Triassic stratigraphical subdivisions. The only drawback is that shallow-water carbonates, in which these organisms are generally sporadic, are frequent in outcrops of this age. As a consequence, it is essential to erect another global biostratigraphic marker, common in shallow-water deposit.

Similar Carnian and Norian foraminiferal assemblages are recognized in distant areas all over the Tethys and Panthalassa where they mostly lived in tropical shallow-water environments as a major component of the carbon-

ate platforms. Even if world foraminiferal distribution and stratigraphic repartition must be clarified, since these foraminiferal associations are common, widely distributed and well identifiable, they must be considered as relevant biostratigraphic tools.

Considering the whole Triassic, the Carnian-Norian shallow-water carbonates of Panthalassa are the most significant in term of their richness and diversity in foraminifers (i.e., in America: Rigaud *et al.*, in prep.; and in Japan: Chablais *et al.*, in prep.), offering good opportunities for future prospects.

## Acknowledgements

We wish to thank Jérôme Chablais and Elias Samankasou (University of Geneva) for reviewing early drafts of the manuscript. Thanks to Adeline Bergamini and Megan Rosenblatt for their field assistance. The present report is part of an international collaboration aiming at comparing the Wallowa terrane with other regions of the Tethys and Panthalassa (research funded by: the National Swiss Science Foundation grants 200021-113816 and 200020-124402 to R. M.; an Augustin Lombard grant from the SPHN Society of Geneva to S. R.; and a grant NSF-EAR962450 to G. S.).

## References

- Armstrong, R. L., Taubeneck, W. H., & Hales, P. O., 1977. Rb-Sr and K-Ar geochronometry of Mesozoic granitic rocks and their Sr isotopic composition, Oregon, Washington, and Idaho. *Geological Society of America Bulletin*, 88: 397–411.
- Avé Lallemant, H. G., Schmidt, W. J., & Kraft, J. L., 1985. Major Late-Triassic strike-slip displacement in the Seven Devils Terrane, Oregon and Idaho: a result of left-oblique plate convergence. *Tectonophysics*, 119: 299–328.
- Broglia Loriga, C., Cirilli, S., De Zanche, V., Di Bari, D., Gianolla, P., Laghi, G. F., Lowrie, W., Manfrin, S., Mastandrea, A., Mietto, P., Muttoni, G., Neri, C., Posenato, R., Rechichi, M., Rettori, R., & Roghi, G., 1998. A GSSP candidate for the Ladinian/Carnian boundary: the Prati Di Stuoeres/Stuoeres Wiesen Section (Dolomites, Italy). *Albertiana*, 21: 2–18.
- Broglia Loriga, C., Cirilli, S., De Zanche, V., Di Bari, D., Gianolla, P., Laghi, G. F., Lowrie, W., Manfrin, S., Mastandrea, A., Mietto, P., Muttoni, G., Neri, C., Posenato, R., Rechichi, M., Rettori, R., & Roghi, G., 1999. The Prati Di Stuoeres/Stuoeres Wiesen Section (Dolomites, Italy): a candidate Global Stratotype Section and Point for the base of the Carnian stage. *Rivista Italiana di Paleontologia e Stratigrafia*, 105 (1): 37–78.
- Brönnimann, P., Poisson, A., Zaninetti, L., 1970. L'unité du Domuz Dag (Taurus Lycien – Turquie). *Microfaciès et foraminifères du Trias et du Lias*. *Rivista Italiana di Paleontologia e Stratigrafia*, 76 (1): 1–36.
- Brooks, H. C., & Vallier, T. L., 1978. Mesozoic rocks and tectonic evolution of eastern Oregon and western Idaho. In Howell, D. G., and McDougall, K. A.,

- editors, Mesozoic Paleogeography of the western United States. Society of Economic Palaeontologists and Mineralogists, Pacific Section, Paleogeography Symposium 2: 133–145.
- Coney, P. J., Jones, D. L., & Monger, J. W. H., 1980. Cordilleran suspect terranes. *Nature*, 288: 329–333.
- Di Bari, D., & Laghi, G. F., 1994. Involutinidae Butschli (Foraminifera) in the Carnian of the Northeastern Dolomites (Italy). *Memorie di Scienze Geologiche*, 46: 93–118.
- Dorsey, R. J., & LaMaskin, T. A., 2007. Stratigraphic record of Triassic-Jurassic collisional tectonics in the Blue Mountains Province, northeastern Oregon. *American Journal of Science*, 307: 167–193.
- Dorsey, R. J., & LaMaskin, T. A., 2008. Mesozoic collision and accretion of oceanic terranes in the Blue Mountains Province of northeastern Oregon: New Insights from the stratigraphic record. In Spencer, J. E., & Titley, S. R., editors, *Circum-Pacific Tectonics, Geologic Evolution, and Ore Deposits*: Tucson, Arizona Geological Society, Digest 22: 325–332.
- Follo, M. F., 1986. Sedimentology of the Wallowa Terrane, Northeastern Oregon. Cambridge, Massachusetts, Harvard University, Ph. D. Thesis: 292 p.
- Gaździcki, A., & Reid, P., 1983. Upper Triassic Involutinidae (Foraminifera) of Lime Peak in Yukon, Canada. *Acta Geologica Polonica*, Warszawa, 33 (1-4): 99–106.
- Gaździcki, A., & Stanley, G. D., 1983. First report of Involutinidae (Foraminifera) in marine Triassic rocks of North America. *Neues Jahrbuch für Geologie und Paläontologie Monatshefte*, Stuttgart, 2: 80–90.
- Gischler, E., & Möder, A., 2009. Modern benthic foraminifera on Banco Chinchorro, Quintana Roo, Mexico. *Facies*, 55: 27–35.
- Gray, K. D., & Oldow, J. S., 2005. Contrasting structural histories of the Salmon River belt and Wallowa terrane: Implications for terrane accretion in northeastern Oregon and west-central Idaho. *Geological Society of America Bulletin*, 117: 687–706.
- He Yan, & Wang Lijun, 1990. Triassic Foraminifera from Yushu Region, Qinghai. From Devonian-Triassic stratigraphy and palaeontology from Yushu Region of Qinghai, China. Nanjing University Press, Part 1: 59–96.
- He Yan, & Norling, E., 1991. Upper Triassic Foraminifera and stratigraphy of Mianzhu, Sichuan province, China. *Sveriges Geologiska Undersökning. Avhandlingar Och Uppsatser*, 76: 1–47.
- Igo, H., & Adachi, S., 1992. Triassic Foraminifera from the San Juan Islands, Washington, U.S.A. In Takayanagy, Y., Saito, T., editors, *Studies in Benthic Foraminifera BENTHOS '90*, Sendai, 1990, Tokai University Press: 313–321.
- Kamoun, F., Peybernès, B., Martini, R., Zaninetti, L., Vila, J.-M., Trigui, A., & Rigane, A., 1997. Associations de foraminifères benthiques dans les séquences de dépôt du Trias moyen ?-supérieur de l'Atlas Tunisien central et méridional. *Geobios*, 31 (6): 703–714.
- Koehn-Zaninetti, L., 1969. Les Foraminifères du Trias de la région de l'Almtal (Haute-Autriche). *Jahrbuch der Geologischen Bundesanstalt*, 14: 1–155.
- Kristan-Tollmann, E., 1988. A comparison of Late Triassic agglutinated foraminifera of Western and Eastern Tethys. *Abhandlungen der Geologischen Bundesanstalt*, 41: 245–253.
- Kristan-Tollmann, E., & Tollmann, A., 1983. Tethys-Faunenelemente in der Trias der USA. *Mitteilungen der Österreichischen Geologischen Gesellschaft*, 76: 213–272.
- Manduca, C. A., Kuntz, M. A., & Silver, L. T., 1993. Emplacement and deformation history of the western margin of the Idaho batholith near McCall, Idaho: influence of a major terrane boundary. *Geological Society of America Bulletin*, 105: 749–765.
- Martini, R., Zaninetti, L., Lathuilière, S., Cirilli, S., Cornée, J.-J., & Villeneuve, M., 2004. Upper Triassic carbonate deposits of Seram (Indonesia): palaeogeographic and geodynamic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 206: 75–102.
- Mietto, P., Andretta, R., Broglio Loriga, C., Buratti, N., Cirilli, S., De Zanche, V., Furin, S., Gianolla, P., Manfrin, S., Muttoni, G., Neri, C., Nicora, A., Posenato, R., Preto, N., Roghi, G., & Spötl, C., 2007. A GSSP candidate for the Ladinian/Carnian Boundary: the Prati Di Stuares/Stuares Wiesen Section (Dolomites, Italy). *Albertiana*, 36: 78–97.
- Oravec-Scheffer, A., 1987. Triassic foraminifera of the Transdanubian Central Range. *Geologica Hungarica, Series Palaeontologica*, 50: 1–331.
- Piller, W., 1978. Involutinacea (Foraminifera) der Trias und des Lias. *Beiträge zur Paläontologie Österreich*, 5:1–164.
- Rettori, R., 1995. Le associazioni a foraminiferi nel Carnico. *Annali Università di Ferrara*, 5: 101–110.
- Rettori, R., Loriga, C., & Neri, C., 1998. Lower Carnian foraminifera from the type locality of the Calcare del Predil (Raibl Group, North-eastern Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 104(3): 369–380.
- Salaj, J., 1969. Essai de zonations dans le Trias des Carpathes occidentales d'après les foraminifères. *Geologické práce*, 48: 123–132.
- Salaj, J., 1977. Contribution à la microbiostratigraphie du Trias des Carpathes Occidentales Tchecoslovaques. *Annales des Mines et de la Géologie, Actes du VI<sup>e</sup> Colloque Africain de Micropaléontologie, Tunis 1974*, 28: 103–127.
- Salaj, J., Borza, K., & Samuel, O., 1983. Triassic Foraminifera of the West Carpathians. *Geologický Ústav Dionýza Štúra*, 213 pp.
- Salaj, J., Trifonova, E., Gheorghian, D., & Coroneou, V., 1988. The Triassic foraminifera microbiostratigraphy of the Carpatian-Balkan and Hellenic Realm. *Mineralia slovenia*, 20(5): 387–415.
- Schell, W. W., Clark, D. L., 1960. Lower Triassic foraminifera from Nevada. *Micropaleontology*, 6(3): 291–296.
- Schroeder, M. L., 1968. Lower Triassic foraminifera from the Thaynes Formation in southeastern Idaho and western Wyoming. *Micropaleontology*, 14 (1): 73–82.
- Silberling, N. J., Jones, D. L., Blake, M. C., Jr., & Howell,

- 
- D. G., 1984. Lithotectonic terrane map of the western conterminous United States. U.S. Geological Survey, Open File Report 84: 1–43.
- Smith, D. W., & Allen, J. E., 1941. Geology and Physiography of the northern Willowa Mountains, Oregon. Bulletin of the Oregon Department of Geology and Mineral Resources, 12: 1–75.
- Stanley, G. D., Jr., 1979. Paleogeology, structure, and distribution of Triassic coral build-ups in western North America. The University of Kansas paleontological Contributions, Article 6: 1–58.
- Stanley, G. D., Jr., & Senowbari-Daryan, B., 1986. Upper Triassic, Dachstein-type, reef limestone from the Willowa Mountains, Oregon: First reported occurrence in the United States. *Palaios*, 1: 172–177.
- Stanley G. D., Jr., McRoberts, C. A., & Whalen, M. T., 2008. Stratigraphy of the Triassic Martin Bridge Formation, Willowa terrane: Stratigraphy and depositional setting. In Blodgett, R. B., & Stanley, G. D., editors, *The terrane puzzle: New perspectives on paleontology and stratigraphy from the North American Cordillera*. Geological Society of America Special Paper, 442: 227–250.
- Tappan, H., 1951. Foraminifera from the Arctic Slope of Alaska. I. Triassic Foraminifera. Geological Survey Professional Paper, 236 (A): 1–20.
- Trifonova, E., 1978. Foraminifera Zones and Subzones of the Triassic in Bulgaria. II. Ladinian and Carnian. *Geologia Balcanica*, Sofia, 8 (4): 49–64.
- Trifonova, E., 1984. Correlation of Triassic foraminifers from Bulgaria and some localities in Europe, Caucasus, and Turkey. *Geologica Balcanica*. 13 (6): 3–24.
- Vallier, T. L., Brooks, H. C., & Thayer, T. P., 1977. Paleozoic rocks of eastern Oregon and western Idaho. In Stewart, J. H., Stevens, C. H., & Fritsche, A. E., editors, *Paleozoic paleogeography of the western United States*. Society of Economic Paleontologists and Mineralogists, Pacific Section: Pacific Coast paleogeography symposium 1: 455–466.
- Velić, I., 2007. Stratigraphy and Palaeobiogeography of Mesozoic Benthic Foraminifera of the Karst Dinarides (SE Europe). *Geologica Croatica*, 60 (1): 1–113.
- Wyld, S. J., & Wright, J. E., 2001. New evidence for Cretaceous strike-slip faulting in the United States Cordillera and implications for terrane-displacement, deformation patterns, and plutonism. *American Journal of Science*, 301: 150–181.
- Yancey, T. E., & Stanley, G. D. (1999). Giant alatoform bivalves in the Upper Triassic of western North America. *Palaentology*, 42: 1–23.
- Yancey, T. E., Stanley, G. D., Piller, W. E., & Woods, M. A., 2005. Biogeography of the Late Triassic wallawaconchid megalodontoid bivalves. *Lethaia* 38: 351–365.
- Zaninetti, L., 1976. Les Foraminifères du Trias. Essai de synthèse et corrélation entre les domaines mésogéens européen et asiatique. *Rivista Italiana di Paleontologia e Stratigrafia*, 82 (1): 1–258.
- Zaninetti, L., Martini, R., & Dumont, T., 1992. Triassic foraminifers from sites 761 and 764, Wombat Plateau, Northwest Australia. 122: 427–436.
-

---

# Re-evaluating the correlation between Late Triassic terrestrial vertebrate biostratigraphy and the GSSP-defined marine stages

Randall B. Irmis<sup>1,2</sup>, Jeffrey W. Martz<sup>3</sup>, William G. Parker<sup>3,4</sup>,  
Sterling J. Nesbitt<sup>4</sup>

<sup>1</sup>Utah Museum of Natural History, 1390 E. Presidents Circle, Salt Lake City, UT 84112-0050, U.S.A., e-mail: irmis@umh.utah.edu

<sup>2</sup>Department of Geology & Geophysics, University of Utah, Salt Lake City, UT 84112, U.S.A.

<sup>3</sup>Division of Resource Management, Petrified Forest National Park, P.O. Box 2217, Petrified Forest, AZ 86028, U.S.A.

<sup>4</sup>Jackson School of Geosciences, The University of Texas at Austin, TX 78712, U.S.A.

**Abstract** – One of the main methods for correlating Late Triassic terrestrial strata is through the use of land-vertebrate faunachrons (LVFs). Use of LVFs is widespread because of their supposed global application and ability to be correlated with the marine stages of the timescale. New magnetostratigraphic and radioisotopic data indicate that the traditional correlation of Late Triassic LVFs requires revision, although some authors maintain that these original correlations are sound, and that the new correlations of the marine stages to the numerical timescale are in error. Here, we examine the available evidence for cross-correlation of Late Triassic LVFs with the marine stages and numerical timescale. We conclude that the biostratigraphic links between the LVFs and marine stages are not robust; they are based on non-diagnostic specimens and/or taxonomically controversial specimens, endemic taxa, and/or ambiguously correlated assemblage zones. Given the available data, new correlations of the LVFs, marine stages, and the numerical timescale using magnetostratigraphy and radioisotopic ages that support a “long Norian” are preferential to those using largely vertebrate biostratigraphy that support a “long Tuvolian.” We also outline a framework for improving the accuracy and relevance of Late Triassic vertebrate biostratigraphy going forward in the near future.

## Introduction

Correlation of marine and terrestrial strata is an outstanding problem in the study of Earth history events. Because the sub-divisions of the geologic timescale are defined using Global Boundary Stratotype Sections and Points (GSSP) in marine stratigraphic sections, and are diagnosed using the First Appearance Datum (FAD) of fossil marine organisms, it can be difficult to reliably correlate these marine biotic events to terrestrial strata. This general problem is particularly acute for the Late Triassic, where the lack of ratified GSSPs has hampered the recognition of common definitions for constituent timescale boundaries (as of writing, only the end-Triassic and Carnian GSSPs have been agreed upon), and few data exist for global marine-terrestrial cross correlation.

Building on previous work (e.g., Colbert and Gregory, 1957 in Reeside et al., 1957; Gregory, 1957; Long and Padian, 1986; Lucas and Hunt, 1993a), Lucas (1998a) proposed that a system of “Land Vertebrate Faunachrons” (LVFs) were ideal for global cross-correlation of Triassic strata, because specimens of key land vertebrate index taxa had been found in marine strata that also contained biostratigraphically important marine invertebrates and microfossils. Lucas (1998a) described these key marine tie points, and further elaborated on them in a subsequent publication (Lucas and Heckert, 2000). Lucas’s (1998a) correlations utilized further support from existing palynomorph biostratigraphic correlations (e.g., Litwin et al., 1991; Cornet, 1993). Not

only have these vertebrate and pollen-based correlations been widely used to correlate within terrestrial strata, but they remain one of the main methods to correlate Triassic terrestrial strata to marine units (Ogg, 2005), and thus to the stages of the timescale.

A curious feature of the Triassic LVF framework is that the boundaries of biochronologic units often match precisely with the boundaries of the marine stages of the Triassic timescale (Lucas and Hunt, 1993; Lucas 1998a: fig. 14; Lucas et al., 2007a: fig. 1). For example, the Adamanian/Revueltian LVF boundary corresponds to the Carnian/Norian boundary. Presumably, the restriction of these biochrons to particular stages reflects the lack of any evidence of LVF index taxa occurring in the preceding or following marine stage. This is not surprising given the rarity of biostratigraphically relevant terrestrial vertebrates in Triassic marine strata, although authors have never made clear why the boundaries should line up so neatly.

Some recent authors have questioned the robustness of the underlying data for Late Triassic LVFs and their correlations across terrestrial strata (Langer, 2005; Parker and Irmis, 2005; Parker, 2006; Rayfield et al., 2005, 2009; Schultz, 2005), but these criticisms have generally been met with the response that they merely reflect individual taxonomic opinion, and that the overall usefulness of the scheme is not compromised (Lucas et al., 2007a; Spielmann et al., 2009).



New magnetostratigraphic and radioisotopic data from marine strata indicate that the Carnian-Norian boundary falls at about 228 Ma, and consequently that the duration of the Norian stage was extremely long (~20 Ma) (Muttoni et al., 2004; Furin et al., 2006). This led some workers to suspect that some of the type and referred LVF assemblages from terrestrial strata in North America may not correlate to the marine stages as originally proposed (Fig. 1). In particular, it became clear that most or all of the Late Triassic terrestrial strata in the western United States, including the Adamanian LVF type assemblage, could be Norian in age (Parker, 2006; Parker and Barton 2008; Parker et al., 2008), thus moving the Adamanian/Revueltian boundary well into the Norian. These suspicions were strongly supported by the report of new high-precision U-Pb ages from the Upper Triassic Chinle Formation, which demonstrated that most of the formation post-dated 220 Ma (Irmis and Mundil, 2008; Mundil et al., 2008), and thus was at least eight million years younger than the re-dated Carnian/Norian boundary (Muttoni et al., 2004; Furin et al., 2006). Because the type assemblage for the Adamanian LVF overlies the stratum producing this new age, it would also be Norian or younger in age.

In contrast, Lucas and colleagues (Lucas et al., 2007a; Lucas, 2009; Heckert et al., 2009) have maintained the correspondence between the Adamanian/Revueltian and Carnian/Norian boundaries, argued against a long Norian, and suggested instead that the Tuvallian (latest Carnian) was upwards of 15 million years long (Fig. 1). Here, we re-examine evidence for correlating Late Triassic LVFs to the marine stages of the Triassic timescale, and its relevance to the “long Norian” and Lucas’s alternate “long Tuvallian” hypothesis. Our goal is to examine which hypothesis best fits the available data, and to explicate the limits of interpretation for global correlation of Late Triassic strata using land vertebrate fossils.

### Correlation of Terrestrial and Marine Strata

In the original proposal of the global LVF scheme, Lucas (1998a) used two main sets of data to correlate each LVF with Late Triassic marine stages. The first was a set of occurrences of terrestrial vertebrates found in biostratigraphically-dated marine strata from Europe. The second source of evidence was correlation of palynomorph biostratigraphy from terrestrial strata in the western U.S. (which also contained type and referred LVF assemblages) to similar palynomorph assemblages from the Newark Supergroup of eastern North America and marine strata in the Germanic Basin. Below, we reconsider the degree to which these two sets of data support proposed correlations of Late Triassic LVFs to marine stages.

#### Vertebrates

One of the main difficulties with using marine occurrences of terrestrial vertebrate fossils for cross-correlation is that these occurrences are rare, and often consist of taxa endemic only to one depositional basin. This is particularly apparent in the list published by Lucas and Heckert (2000); of the over 30 terrestrial vertebrate taxa found in Triassic marine strata, 21 taxa are endemic to the marine

basins they are found in, so they are not biostratigraphically useful in globally correlating terrestrial and marine strata. The elimination of these endemic taxa leaves only four occurrences tying Late Triassic LVFs to biostratigraphically dated marine strata: *Metoposaurus* and *Paleorhinus* correlating the Otischalkian with the Carnian; no links for the Adamanian and Carnian; *Mystriosuchus* and *Aetosaurus* correlating the Revueltian with the Norian, and no links for the Apachean (Lucas, 1998a; Lucas and Heckert, 2000). Unfortunately, these terrestrial-marine links are not robust, and the occurrences are subject to severe taxonomic disagreement among Triassic vertebrate workers. In particular, it is not clear whether the marine records are diagnostic specimens, and whether their referral to the index taxon of interest is justified.

Even prior to the formal establishment of the LVF framework, Hunt and Lucas (1991) and Lucas and Hunt (1993a) identified the phytosaur taxon *Paleorhinus* as an index taxon that could globally correlate Late Triassic terrestrial strata to the Carnian marine stage. Lucas (1998a) later formalized the FAD of *Paleorhinus* as the definition of the Otischalkian LVF, designating the vertebrate assemblage of the Otis Chalk quarries in the Dockum Group of western Texas, U.S.A. as the type assemblage. Lucas (1998a; Lucas and Heckert, 2000) originally considered the Otischalkian to be early Carnian in age, but later correlated it to the middle Carnian (Lucas et al. 2007a) because he referred the Schilfsandstein in Germany to the Otischalkian and considered it to be late Julian, and other Otischalkian assemblages to be early Tuvallian. However, there is no clearly diagnostic phytosaur material in the Schilfsandstein (Hungerbühler, 2001b), and *Paleorhinus* is reported only in the younger Blasensandstein (Hassberge Formation) (Hunt and Lucas, 1991). So by Lucas’s (1998a) boundary definition, the Schilfsandstein is pre-Otischalkian in age.

A single phytosaur specimen is known from the Tuvallian aged Opponitzer Schichten of Austria (Hunt and Lucas, 1991; Lucas, 1998a; Lucas and Heckert, 2000). This specimen was originally described by von Huene (1939) as cf. *Francosuchus trauthi*, and consists of partial premaxillae and nasals, broken posteriorly across the external nares (von Huene, 1939: fig. 1; Westphal, 1976: fig. 7). Westphal (1976) referred this specimen to *Paleorhinus* as *P. trauthi* without comment. Hunt and Lucas (1991) referred this specimen to *Paleorhinus* sp. based on a single character: openings for the external nares that are anterior to the antorbital fenestra. These authors used this specimen to correlate *Paleorhinus*-bearing strata worldwide to the Tuvallian, a correlation accepted by all subsequent papers (e.g., Lucas, 1998a; Lucas and Heckert, 2000; and Lucas et al., 2007a).

*Paleorhinus* (= *Parasuchus* in the usage of Lucas et al. 2007a,b; see Chatterjee, 2001 and ICZN, 2003) is a problematic taxon. It is diagnosed partly based on characters shared with other archosauriforms (plesiomorphies), specifically the following two character states: external nares anterior to the antorbital fenestra and supratemporal fenestrae level with the skull roof (Hunt and Lucas, 1991; Long and Murry, 1995). The referral of all basal phytosaurs

to a single taxon is not universally endorsed. The paraphyly of these basal phytosaurs has long been suspected (Padian, 1994; Fara and Hungerbühler, 2000; Hungerbühler, 2001a; Irmis, 2005; Rayfield et al., 2005, 2009), and has recently been demonstrated in a comprehensive phylogenetic analysis that showed that different species-level taxa of *Paleorhinus* form a grade along the backbone of the phytosaur evolutionary tree (Stocker, 2008, in press). Monophyly is essential when using supraspecific taxa for biostratigraphy (e.g., Angielczyk and Kurkin, 2003); the recognition of *Paleorhinus* as a paraphyletic grade places its utility as a global index taxon in doubt.

Even if we diagnose *Paleorhinus/Parasuchus* as a valid taxon possessing a combination of plesiomorphic and derived characters, the *F. trauthi* specimen is still not diagnostic. Of the four character states listed in the diagnosis of *Paleorhinus/Parasuchus* (Hunt and Lucas, 1991; Long and Murry, 1995; Lucas et al., 2007a). *F. trauthi* is only known to possess one of these characters: external nares anterior to the antorbital fenestra. As this particular character is plesiomorphic, it is therefore shared with a variety of non-phytosaurian archosaurs, as well as any phytosaurs more basal than *Paleorhinus*. Accepting that evolution is a reality and that *Paleorhinus* was descended from more primitive phytosaurs, *F. trauthi* can only be considered an indeterminate basal phytosaur (Rayfield et al., 2009). It is therefore not a robust occurrence for correlating the Otischalkian LVF and Tuvanian.

The second and only other vertebrate to correlate the Otischalkian LVF to the Carnian is the presence of the temnospondyl amphibian *Metoposaurus santaecrucis* in the Julian (lower Carnian) Raibler Schichten of Austria (Lucas and Heckert, 2000). Lucas and Heckert (2000) considered this specimen to be unequivocally assignable to the metoposaurid genus *Metoposaurus*, which is a secondary index taxon for the Otischalkian (Lucas, 1998a), but did not adequately justify this taxonomic referral. The taxonomic status of this specimen is poorly understood. Hunt (1993) considered *M. santaecrucis* to be an indeterminate metoposaurid (?Metoposauridae indet.), Schoch and Milner (2000) listed it as a valid species without comment, and Sulej (2002) listed it as a *nomen dubium* (indeterminate metoposaurid). A reasonable approach given the incompleteness of the specimen and the absence of any clear character states shared exclusively with *Metoposaurus* would consider *M. santaecrucis* to be an indeterminate metoposaurid until demonstrated otherwise. The available evidence indicates that the specimen is clearly not a well-supported occurrence of *Metoposaurus* until a comprehensive re-study of the specimen is undertaken.

If *M. santaecrucis* is a valid occurrence of *Metoposaurus*, the genus is still not a robust index taxon for the Otischalkian LVF. In the Germanic Basin, the youngest occurrences of *Metoposaurus* are in strata that are regarded by Milner and Schoch (2004; Rayfield et al., 2009; Schoch, pers. comm.; contra Lucas et al., 2007a) as correlative with the younger Revueltian LVF. Even if these alleged young occurrences are in error and European *Metoposaurus* is a robust index taxon for the Otischalkian,

there is also disagreement about the alpha taxonomy of North American occurrences. Sulej (2002, 2007) recently argued persuasively that North American occurrences of *Metoposaurus* are actually assignable to the genus *Buettneria* (now *Koskinonodon*; Mueller, 2007). This would remove any North American occurrences of *Metoposaurus*. Moreover, both Sulej (2002, 2007) and Milner and Schoch (2004) noted that the type species of *Metoposaurus* and Adamanian specimens of “*Buettneria*” in North America share a critical diagnostic character (the lacrimal contacting the orbit) that had previously been used to separate “*Buettneria*” from *Metoposaurus* (e.g., Hunt, 1994) (contra Lucas et al., 2007a). These points severely weaken the use of *Metoposaurus* as a global Late Triassic index taxon for the Otischalkian.

The vertebrate-bearing levels of the Calcare di Zorzino are hypothesized to be middle Norian to early late Norian in age based on multiple marine invertebrate and microfossil biostratigraphic constraints (Wild, 1989; Renesto, 2006). Two specimens assignable to *Mystriosuchus planirostris* have been described from the Calcare di Zorzino (Renesto and Paganoni, 1998; Renesto and Lombardo, 1999; Renesto et al., 1999; Gozzi and Renesto, 2003). Buffetaut (1993) also briefly mentioned and figured a skull of *Mystriosuchus* from the Norian Dachsteinkalk of Austria. *Mystriosuchus* is otherwise only known from the middle Stubensandstein (Löwenstein Formation) of the Germanic Basin (Schoch and Wild, 1999; Seegis, 2005). Thus, correlation to the type Revueltian LVF assemblage in western North America is difficult, because there no known specimens of *Mystriosuchus* from any Triassic deposits in North America. To relate the marine records of *Mystriosuchus* to the type Revueltian, one either has to correlate at a higher taxonomic level, using the phytosaur group Pseudopalatinae (e.g., Hungerbühler, 2002), or correlate first to the Germanic Basin, and then make a secondary correlation from the Germanic Basin to western North America using other vertebrate taxa. Correlating at higher taxonomic levels is problematic because the Pseudopalatinae includes a taxon that defines the overlying Apachean LVF (*Redondasaurus*; Lucas and Hunt, 1993a; Lucas, 1998a; Lucas et al., 2007a).

Wild (1989) described an articulated segment of osteoderms of the aetosaur *Aetosaurus* from the Calcare di Zorzino, which Lucas (1998a, Lucas et al., 1998) used to correlate the Norian to the lower and middle Stubensandstein (Löwenstein Formation) of the Germanic Basin (Schoch and Wild, 1999; Schoch, 2007; Seegis, 2005) with part of the Newark Supergroup in eastern North America, the Chinle Formation of western Colorado (Small, 1998) and the type Revueltian assemblage in eastern New Mexico (Heckert and Lucas 1998). The elimination of reliable marine occurrences of *Paleorhinus* and *Metoposaurus*, the geographic limitations of *Mystriosuchus*, and the lack of any known Adamanian or Apachean index taxa in marine strata, leaves *Aetosaurus* as the sole Late Triassic terrestrial index taxon with a marine occurrence that might have utility for intercontinental correlation, but even the assignment of the North American material to *Aetosaurus* is controversial (e.g., Sues et al., 2003).

A final point worth noting is that if the tie points of marine occurrences of terrestrial vertebrate connecting the Revueltian to the Norian are taken at face value, the age of the Revueltian LVF is middle to upper Norian. Unless there is a large biochronologic gap in between the Adamanian and Revueltian, and many workers suggest that there is not (e.g., Hunt et al., 2005; Parker, 2006; Woody, 2006; Lucas et al., 2007a; Martz, 2008), this would imply that at least part of the Adamanian LVF is lower to middle Norian in age, in agreement with new precise U-Pb ages for the type Adamanian assemblage in the Chinle Formation (Irmis and Mundil, 2008), and in stark contrast to the late Carnian age favored by Lucas and colleagues (Lucas, 1998a; Lucas and Heckert, 2000; Lucas et al., 2007a; Lucas, 2009; Heckert et al., 2009).

To summarize, the terrestrial vertebrate specimens that are used to tie Late Triassic LVFs to marine strata suffer from three main problems: 1) the specimens are non-diagnostic; 2) taxonomically controversial; or 3) are difficult to directly correlate to the type assemblages of the LVFs in question. They do not represent robust data points with which to correlate non-marine LVFs to the marine stages of the Late Triassic timescale.

#### *Palynomorphs*

The second major method for correlating Late Triassic LVFs to marine stages uses palynomorph assemblages shared by vertebrate-bearing terrestrial sequences and marine strata. The Chinle Formation and Dockum Group of western North America (type areas of the LVFs) were correlated by Litwin et al. (1991) and Cornet (1993) to the palynomorph record of the Newark Supergroup in eastern North America, and to marine strata in Europe. These palynomorph correlations were used by Lucas (1998a) to support his LVF to marine stage correlations.

No palynomorphs have been published from the type area of the Otischalkian LVF in west Texas, so this biochronologic unit is not directly constrained by palynostratigraphy. The type assemblage of the Adamanian LVF in northern Arizona as well as referred assemblages from New Mexico and Texas all yield palynomorphs diagnostic of Zone II of Litwin et al. (1991). Litwin et al. (1991) and Cornet (1993) considered this zone to be late Carnian in age, based on correlation to the New Oxford-Lockatong Palynofloral Zone of the Newark Supergroup in eastern North America and Carnian marine strata in Europe. However, recent magnetostratigraphic correlation of the Newark to Tethyan marine sections (Muttoni et al., 2004; Furin et al., 2006) demonstrates that the New Oxford-Lockatong Palynofloral Zone in the Newark Supergroup is early Norian in age. This casts doubt on a Carnian age for this same pollen assemblage occurring with Adamanian assemblages in western North America, and is again consistent with new radioisotopic ages indicating the Adamanian is Norian (e.g., Irmis and Mundil, 2008). In fact, Channell et al. (2003: p. 94) have already noted that several index taxa of the New Oxford-Lockatong assemblage, such as *Camerosporites verrucosus* and *Kyrtomispuris laevigatus*, have an undisputed Norian range in western North

America (Zone III of Litwin et al., 1991). Moreover, at least one of Litwin et al.'s (1991) index taxa for Zone II, *Cycadopites stonei*, is a characteristically Norian taxon in Late Triassic strata of Australia (Backhouse et al., 2002). It is also worth highlighting that Litwin et al. (1991: fig. 4) interpreted uncontroversially Carnian palynomorph assemblages from Italy and the Germanic Basin as being older than any assemblages from the Chinle or Dockum of western North America.

No palynomorphs have been published from the type Revueltian LVF assemblage of the Bull Canyon Formation (Dockum Group) in eastern New Mexico (cf. Dunay and Fisher 1979), but palynomorphs from Revueltian assemblages in Arizona and northern New Mexico are assignable to Litwin et al.'s (1991) Zone III. Litwin et al. (1991) considered this zone to be lower Norian based on correlation with the Lower Passaic-Heidlersburg Palynofloral Zone of the Newark Supergroup. With the magnetostratigraphic re-calibration of the Newark palynostratigraphy (Muttoni et al., 2004), this palynofloral zone and the western North American Revueltian assemblages become upper Norian in age, consistent with available radioisotopic ages (Riggs et al., 2003).

As with most of the Late Triassic LVFs, there are no published palynomorph assemblages from the type Apachean LVF assemblage. Palynomorphs from the referred Apachean assemblage of the "siltstone member" of the Chinle Formation in northern New Mexico are part of Zone III of Litwin et al. (1991), indicating an upper Norian age (see above). Litwin et al. (1991: p. 280) specifically mentioned that the "siltstone member" palynomorph assemblages appeared to be older than Rhaetian, which at that time was interpreted to be quite short. However, the Rhaetian is now thought to be 6-8 million years long, and to contain the entire Balls Bluff-Upper Passaic Palynofloral Zone of the Newark Supergroup (Muttoni et al., 2004; Muttoni et al., in press), previously considered upper Norian in age (Cornet, 1993). Therefore, there are no palynomorph data excluding a Rhaetian age for some of the Zone III assemblages (such as the "siltstone member" in northern New Mexico).

To summarize, re-calibration of the Newark palynostratigraphy using magnetostratigraphic and radioisotopic data tied directly to European marine sections (Muttoni et al., 2004, in press; Furin et al., 2006) revises the correlation of Litwin et al.'s (1991) Zones II and III to both be Norian in age. It is also possible that the Zone III assemblages might be partially or wholly Rhaetian, but this requires further radioisotopic ages from strata containing Zone III assemblages. These data are consistent with a Norian age for both the Adamanian and Revueltian LVFs.

Irrespective of the re-calibration of the Newark palynomorph record, how robust are the correlations of the LVFs to the marine stages using palynomorphs? The major difficulty in answering this question is that Late Triassic palynomorph assemblages from terrestrial strata in western North America require long-distance intercontinental correlation to be related to marine stages. Regionally adjacent

marine strata in western North America (i.e., Nevada) are nearly barren of palynomorphs; samples have recovered only a few fungal spores and acritarchs (Gottesfeld, 1975, 1980). Precise intercontinental correlation of palynomorph assemblages is notoriously difficult, because plants track climate and form distinct biogeographic provinces, and both processes limit global correlation and create diachronous ranges. For example, even palynomorph assemblages associated with the K-T extinction, a sudden global event, show latitudinally-influenced diachronous ranges for individual taxa (Nichols and Johnson, 2008). Similarly, Lindström and McLoughlin (2007) documented diachronous FADs across Pangea for individual taxa during the Early Triassic. Consequently, palynomorph assemblages may not be the most robust data for intercontinental correlations.

### Assumptions in Correlation

With the rare exception of two sections with multiple high-precision radioisotopic ages, it will always be difficult to correlate vertebrate-bearing terrestrial strata (type or referred LVF assemblage) directly to marine GSSPs. In most cases, these correlations must be indirect, with intermediate steps (Fig. 2).

Initial formulations of the LVF concept tied Late Triassic faunachrons to type assemblages (e.g., Lucas and Hunt, 1993a). However, Lucas (1998a) subsequently revised his biochronologic philosophy and defined each LVF based on the FAD of a single taxon, with LVFs diagnosed by the presence of additional index taxa present in type or referred assemblages. Lucas (1998a) did not specify if these defining FADs were global (that is, based on the earliest first appearance anywhere), or allowed for diachronous ranges by recognizing the observed FAD in each local section.

By defining each LVF using a single taxon FAD, this theoretically allows correlation of vertebrate-bearing terrestrial strata directly to marine strata if there are marine occurrences of the defining taxon. However, there are two main problems with such a correlation. First, it assumes that the ranges in the two sections are equivalent without independent non-biostratigraphic verification of relative age. This is doubly difficult when most of the specimens found in marine strata are single occurrences (see below). Determining if the local FAD (or LAD for that matter) in the terrestrial section is the same as that of the marine section requires independent non-biostratigraphic evidence (e.g., magnetostratigraphy or radioisotopic ages). Nonetheless, only one LVF-defining taxon has a marine occurrence (*Paleorhinus/Parasuchus*), and this specimen is taxonomically controversial (see above).

Thus, in practice, there must be some sort of intermediate correlation, which introduces additional assumptions. Setting aside any taxonomic issues, correlation using the other marine occurrences (i.e., *Metoposaurus*, *Aetosaurus*, or *Mystriosuchus*) requires an intermediate correlation through an assemblage that contains both the marine-occurring taxon and the LVF-defining taxon. For *Metoposaurus*, this requires correlating through the Hassberge Formation of the Germanic Basin, where the ranges of *Me-*

*toposaurus* and *Paleorhinus/Parasuchus* overlap (Seegis, 2005). Correlations become even more convoluted for the Revueltian, because the LVF is defined by the FAD of the phytosaur *Pseudopalatus* (Lucas, 1998a: pg. 370), which is unknown from outside of western North America. To relate a terrestrial assemblage to the marine occurrence of *Aetosaurus* thus requires correlation through western North American terrestrial strata (specifically eastern New Mexico), because that is the only place where *Aetosaurus* co-occurs with *Pseudopalatus* (e.g., Lucas, 1998). Correlation to marine strata using *Mystriosuchus* presents a similar problem, because *Mystriosuchus* is not known outside of Europe (Hungerbühler, 2002). *Mystriosuchus* must first be correlated to *Aetosaurus* (they co-occur in the Calcare di Zorzino of Italy and Stubensandstein of Germany), and then to western North America where *Aetosaurus* co-occurs with *Pseudopalatus*. The introduction of these secondary taxa for correlation assumes that both the LVF-defining taxon and secondary taxon have the same FAD. In most cases, this assumption remains untested because sample sizes are low and the specimens have not been placed in a precise stratigraphic framework (see below). These assumptions are also implicit for correlations using palynomorphs, because the correlation must utilize a section where the palynomorphs co-occur with the defining FAD of the LVF.

Of the taxa whose FADs define Late Triassic LVFs, only one, *Paleorhinus/Parasuchus* (FAD of the Otischalkian), includes putative occurrences outside of North America. This means that all correlations of possible Adamanian, Revueltian, and Apachean assemblages must go through North American terrestrial strata that preserve the FAD of the phytosaurs *Rutiodon*, *Pseudopalatus*, and/or *Redondasaurus*. In effect, this requires long distance biostratigraphic correlations that often introduce additional assumptions about the equivalence of the FADs of secondary taxa with those of the LVF definitions.

In contrast to such long distance biostratigraphic correlations, we propose that where possible, these intercontinental correlations should be made using independent non-biostratigraphic methods (Fig. 2), with the numerical timescale as the ultimate tie point. We are not so naïve as to expect that there are no assumptions in magnetostratigraphic or radioisotopic correlation. However, in the correlation scheme we propose (Fig. 2), each step can and has been independently verified. The correlation between marine sections, if made using magnetostratigraphy, is independently verified by invertebrate biostratigraphy (e.g., Furin et al., 2006), the calibration of the magnetostratigraphic record to the numerical timescale using radioisotopic ages is validated by cyclostratigraphy (Muttoni et al., 2004), etc. These independent checks are not available when biostratigraphy is assumed to be the only way to correlate the LVFs to the marine stages, independent of any radioisotopic or magnetostratigraphic data. Finally, if we are interested in the evolution of these terrestrial vertebrates, then using them to tell time leads to inherent circularity. By using independent methods to age these assemblages and relate them to the timescale, we can test hypotheses

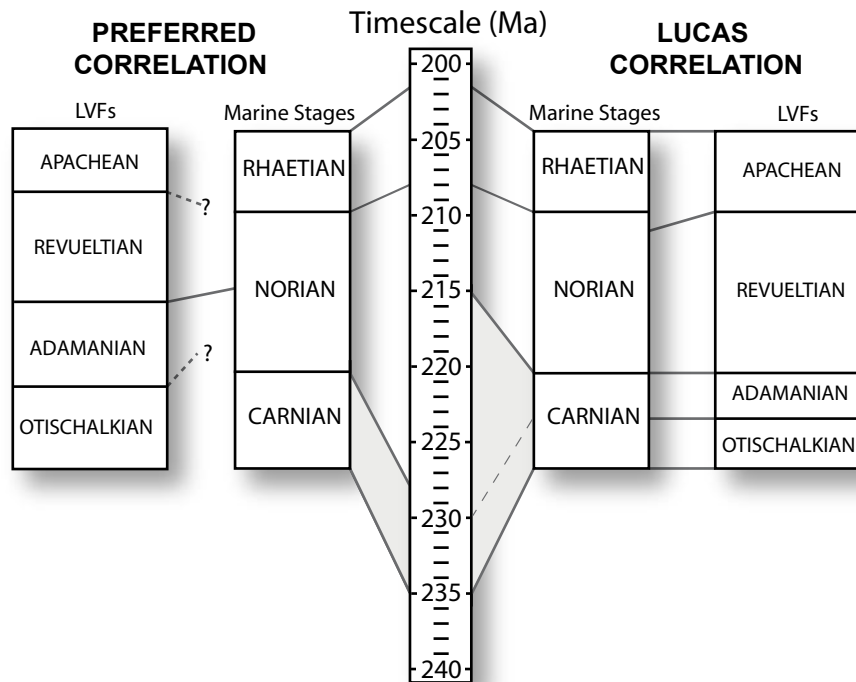


Figure 1. Alternative hypotheses for correlating Late Triassic land-vertebrate faunachrons (LVFs) to the marine stages and numerical timescale. Correlation on the right follows Lucas et al. (2007), Lucas (2009), and Heckert et al. (2009).

about diachronous distributions, biogeographic provinces, and tempo of evolution.

#### *Single Occurrences Are Not Ranges*

One striking feature of how Lucas and his colleagues use marine occurrences of vertebrate taxa (e.g. Lucas, 1998; Lucas and Heckert, 2000) is to assume that individual occurrences of a taxon represent the total chronostratigraphic range of the taxon. In other words, if a single specimen can be shown to belong to a particular stage or substage, then all individuals of that taxon must be confined to the same stage or sub-stage.

This is an extraordinary assumption. Individual animals represent only a single geologic instance in the total time range that a taxon existed, and there is absolutely no reason to assume that taxa were “afraid” or unable to cross chronostratigraphic boundaries. For example, even if we accept that a particular specimen of *Paleorhinus* existed during the Tuvanian because of its presence in Tuvanian marine strata (Hunt and Lucas, 1991), this does not mean the range of the taxon did not extend into the Norian or back into the Middle Triassic.

This is an especially relevant point given that most proposed vertebrate index taxa are genera or higher taxa, with different species occurring on different continents. Examples include *Metoposaurus diagnosticus* and *Aetosaurus ferratus* from Europe, versus “*Metoposaurus*” *bakeri* and *Aetosaurus arcuatus* from western North America (Hunt, 1993; Heckert and Lucas, 1998). Moreover, most workers on Upper Triassic vertebrates recognize more local taxonomic variation between continents than do Lucas and his colleagues (see below). For example, some

workers remain unconvinced that all specimens from around the world assigned by Lucas and his colleagues to *Paleorhinus/Parasuchus* are a single species, or even a single genus (e.g. Long and Murry, 1995; Hungerbühler, 2001a; Stocker, 2008, in press). The lack of shared species found worldwide has important implications for potential precision of vertebrate biochronology. Individual species may be shown to have relatively short ranges, providing that they can be well-calibrated by radioisotopic and magnetostratigraphic data (e.g. Woodburne, 1996; 2006; Lindsay, 2003). However, genera and higher order taxa, which encompass multiple species, may well have much longer ranges, because each species of a genus may have a separate, overlapping but different stratigraphic range. Compiling these separate ranges together thus will logically result in a longer stratigraphic range for the genus. Thus, this emergent property for higher level taxa limits possible resolution in any biochronologic scheme because of the longer stratigraphic ranges involved. In most cases, a higher-level group (e.g., “family”) or genus will have a longer stratigraphic range than each of its constituent species.

#### **Implications for the Late Triassic Timescale**

Despite the revised correlations of Late Triassic terrestrial strata based on new magnetostratigraphic and radioisotopic data, Lucas and colleagues (Lucas et al., 2007a; Lucas, 2009; Heckert et al., 2009) continue to assert that their vertebrate and pollen-based correlations are correct. In doing so, they must infer that the new radioisotopic ages from the Chinle Formation (e.g., Irmis and Mundil, 2008; Mundil et al., 2008) come from late Carnian strata. Because the early Tuvanian has been dated to 231 Ma (Furin et al., 2006),

and Lucas and colleagues infer a Carnian-Norian boundary age of ~218-217 Ma in the Chinle Formation (Lucas, 2009; Heckert et al., 2009; Spielmann et al., 2009), they conclude that the Tuvalian (upper Carnian) is in excess of 15 Ma (Fig. 1).

We argue this is not the most reasonable interpretation of the available evidence. To accept a “long Tuvalian” encompassing the New Oxford-Lockatong pollen assemblage requires that many magnetochrons present in the Newark Supergroup record are missing from the available record at all three main Tethyan marine sections (Silická Brezová, Channell et al., 2003; Pizzo Mondello, Muttoni et al., 2004; and Pignola, Furin et al., 2006). This seems extremely unlikely given that the magnetostratigraphic and marine invertebrate biostratigraphic correlations between these sections cross-validate each other. In addition, the unconformities at Pizzo Mondello are well-documented (e.g., Muttoni et al., 2004: fig. 3), and all lie *above* the biostratigraphically-defined Carnian-Norian boundary. Furthermore, the correlation of these Tethyan sections to the Newark Geo-Polarity Timescale (NGPTS) is also cross-validated by astronomically calibrated cyclostratigraphy (Kent and Olsen, 1999; Muttoni et al., 2004).

We have demonstrated that the proposed correlations based on vertebrates and pollen are not based on robust evidence, and make more assumptions than those using magnetostratigraphy and radioisotopic ages that support a “long Norian hypothesis.” For these reasons, we support the idea of a long Norian (~20 Ma) that includes most if not all of the Otischalkian, Adamanian, and Revueltian LVFs (Fig. 1).

## Future Considerations for Correlating Upper Triassic Terrestrial Strata

We wish to make several recommendations for improving the detail and accuracy of Triassic vertebrate biostratigraphy and biochronology in their use for both regional and global chronostratigraphic correlation. These recommendations recognize the importance of detailed biostratigraphic data on the local level, and its limitations on the global scale. Supplementing non-biostratigraphic methods as the primary means of global chronostratigraphic correlation we hope will (perhaps counter-intuitively) improve our understanding of vertebrate evolution.

### *Recognizing Regional Variation in Alpha Taxonomy*

One of the most striking contrasts in comparing the methodologies of Lucas and his colleagues with those of other workers is their treatment of vertebrate alpha taxonomy. Lucas and his colleagues often confidently identify material on different continents as belonging to the same taxon with little justification (e.g., Hunt and Lucas, 1991; Lucas and Hunt, 1993b; Lucas, 1998b; Heckert and Lucas, 2002; Heckert et al., 2002; Lucas et al., 2007a-c); this opinion is not shared as frequently by other taxonomists, who often consider these specimens to be non-diagnostic or taxonomically distinct from material on other continents (e.g., Long and Murry, 1995: p. 200; Sulej, 2002, 2007; Langer, 2005; Hungerbühler, 2001; Milner and Schoch, 2004;

Irmis, 2005: p. 78; Rayfield et al., 2009). The fact that uniting vertebrate specimens in different parts of the world happens to smooth the way for biochronologic correlation can hardly be ignored, but biochronologic convenience should not come at the expense of recognizing patterns of regional variation.

Certain vertebrate groups have highly uneven distributions across the Pangaeian supercontinent during Late Triassic time (e.g., Benton, 1983; Fraser, 2006; Irmis et al., 2007; Olsen, 2009), suggesting the existence of one or more types of barriers (e.g., physiographic and/or climatic) to dispersal of vertebrate groups into particular regions. Such barriers could be expected to encourage the development of endemic taxa, and this seems to be the case for many groups of Late Triassic terrestrial vertebrates. For example, although it was once a common practice to assign derived North American phytosaurs to the German genus *Nicrosaurus* (or “*Phytosaurus*”) (e.g., Gregory, 1962; Westphal, 1976; Chatterjee, 1986; Hunt, 1994), the current consensus is to assign North American forms to distinct endemic genera (e.g., Camp, 1930; Ballew, 1989; Long and Murry, 1995; Lucas, 1998a; Parker and Irmis, 2006; Stocker, 2008, in press), an important consideration given the part that phytosaurs play in the definition and diagnosis of the Late Triassic LVFs in western North America (Lucas and Hunt, 1993a; Lucas, 1998a; Lucas et al., 2007a). It is clearly counterproductive to our understanding of vertebrate evolution and paleobiogeography to ignore regional taxonomic variation, or to extend the geographic ranges of taxa based on dubious material, simply because it improves apparent biostratigraphic correlations.

### *Importance of Detailed Provincial Biostratigraphic Data*

Examination of the system of biochronology developed for Cenozoic mammals, particularly in North America, aids in outlining possible improvements to Late Triassic vertebrate biochronology. The North American Land Mammal Ages (NALMAs) represent the most sophisticated system of terrestrial vertebrate biochronology available, having undergone extensive development and revision over the almost seventy years since their formulation. Moreover, there have been numerous papers devoted to discussing exactly what the NALMAs represent and what methodological approaches should be taken to further refine them (e.g., Tedford, 1970; Savage, 1977; Flynn et al., 1984; Walsh, 1998, 2000; Lindsay, 2003; Woodburne, 1977, 2004, 2006). Two methods used to improve the precision and accuracy of the NALMAs are particularly worth considering, specifically the plotting of detailed biostratigraphic data, and the detailed calibration of this data using magnetostratigraphy and radioisotopic dates.

As biochrons are necessarily derived from biostratigraphic data tied to the rock record (e.g., Berggren and Van Couvering, 1974: p. 7), they can only be as detailed and accurate as the stratigraphic data allows. Plotting detailed and accurate biostratigraphic data on equally detailed and accurate lithostratigraphic columns allows the stratigraphic range of a vertebrate taxon to be compared as precisely as possible to the ranges of other taxa, as well as to lithologic

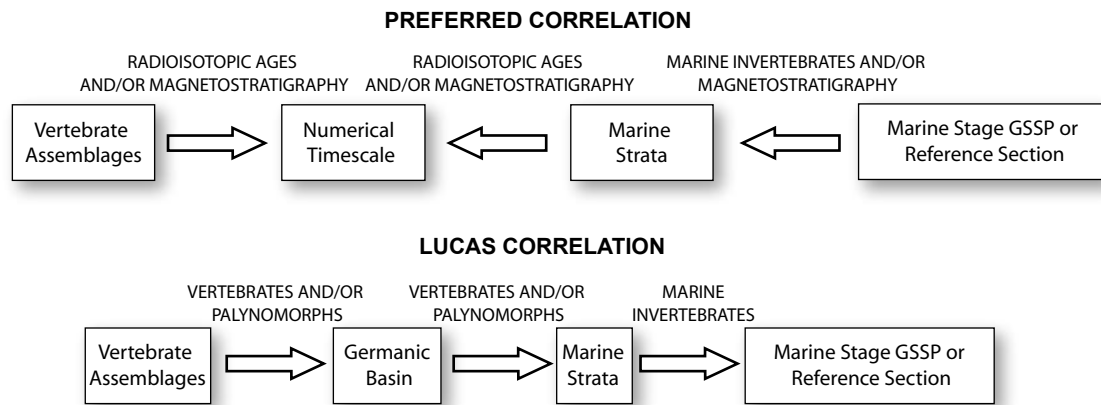


Figure 2. Number of steps and types of data used in correlations for the two hypotheses in Fig. 1.

changes, magnetic polarity changes, and radioisotopic ages (e.g., Tedford, 1970; Woodburne, 1977; 1987; 2004, 2006; Prothero, 1990; Case, 1996; Lofgren et al., 2004). Such detailed data also discourages the misleading practice of treating biostratigraphic, lithostratigraphic, and chronostratigraphic boundaries (and therefore their chronologic equivalents) as equivalent. As noted by Prothero (1990: p. 240): “Too often an index fossil is equated with the formation, and no attempt is made to document the actual range of the fossil within the formation. This results in a loss of resolution of the data. The stratigraphic range of the fossil is often reported to be the same as the total thickness of the formation, which may artificially extend the range.” If the boundaries of biochrons (and/or biozones) are defined by the FADs of vertebrate taxa (Woodburne, 1977; 2006), then they clearly cannot be pinpointed without knowing the exact stratigraphic position of these first appearances, which may or may not coincide with lithostratigraphic and chronostratigraphic boundaries.

Although Lucas (1998a: p. 349) advised the same caution when approaching Late Triassic biochronology, with few exceptions (e.g., Camp, 1930; Rogers et al., 1993: fig. 2; Parker, 2006; Martz, 2008), detailed stratigraphic data is very rarely provided for analyses of Late Triassic faunal change. As a result, the artificial equation of biostratigraphic and lithostratigraphic boundaries is common, and the FAD-based LVF definitions of Lucas (1998a) are rarely applied properly. For example, Lucas (1993: figs. 3, 5) presented the boundaries of the ranges of nearly all biochronologically important Late Triassic vertebrate taxa as precisely equating with LVF boundaries, which he then precisely equated in turn with the boundaries of many lithostratigraphic and chronostratigraphic units, including the marine stages. A more recent paper by Hunt et al. (2005: fig. 5), although recognizing that the ranges of taxa need not be precisely equivalent, nonetheless continued to precisely equate the boundaries of lithostratigraphic and biochronologic units. Moreover, this same figure presented a composite of range data from two distinct areas of the western United States, making the separate comparison of taxon ranges for each of these regions difficult.

In contrast, Parker (2006) plotted the exact lithostratigraphic horizons of vertebrate localities within the Chinle Formation of Petrified Forest National Park, and was so

able to demonstrate that the boundary between the Adamanian and Revueltian LVFs fell within the Jim Camp Wash beds of the Sonsela Member rather than precisely at one of its boundaries. Moreover, recent radioisotopic data suggests that this transition occurred well within the Norian, rather than at the Carnian-Norian boundary (Irmis and Mundil, 2008). Ongoing research in Petrified Forest National Park is increasing the resolution of both lithostratigraphic and biostratigraphic data, and has not only clarified the stratigraphic position and timing of the Adamanian-Revueltian faunal transition, but allowed it to be plotted to a resolution of within a few meters (Parker and Martz, 2009; Martz and Parker, in review). This allows appraisal of the precise relationship of this transition to a growing body of information from magnetostratigraphy, radioisotopic ages, and paleoenvironmental change within the Chinle Formation.

#### *Incorporation of Non-Biochronologic Methods of Correlation*

Another crucial refinement of North American mammalian biochronology was the incorporation of abundant non-biostratigraphic information (radioisotopic ages and magnetostratigraphic zonation) to calibrate the detailed biostratigraphic data. In the case of the North American Cenozoic mammal record, the incorporation of abundant radioisotopic ages and densely sampled magnetic polarity data has allowed the detailed calibration of the biostratigraphic record (e.g., Woodburne, 2004, 2006). This allows faunal events to be dated with a high degree of precision. The accumulation of such data from other parts of the world has allowed the timing of faunal events in different regions of the globe, and the rate of dispersal of taxa, to be precisely established (e.g., Woodburne, 1989, 1996). It is important to emphasize that this calibration allows the isochroneity of taxon dispersal to be rigorously tested, rather than merely assumed (e.g., Woodburne, 1996, 2006; Lindsay, 2003). Without such independent means of dating, it is extremely difficult, if not impossible, for putative isochronous distributions of vertebrate taxa to be tested without the risk of circular reasoning (e.g. Rayfield et al., 2009: p. 85).

It is clear that methods of geochronologic correlation completely independent of vertebrate biochronology are

required to test intercontinental correlations of strata bearing putative Late Triassic LVF assemblages. Already, radioisotopic dates suggest that the Ischigualasto Formation, alleged to be Adamanian by Lucas and colleagues (Lucas, 1998a; Lucas et al., 2007a) may in fact be older than the type Adamanian fauna in the Blue Mesa Member of the Chinle Formation in western North America (Furin et al., 2006; Irmis and Mundil, 2008). Such revised ages for terrestrial vertebrate-bearing strata have already resulted in major changes in our understanding of Late Triassic biotas. For example, in combination with recent reviews of the North American record of putative dinosaurs (Nesbitt et al., 2007), the new ages indicate that global dinosaur distributions were both more disparate and more diachronous than previously appreciated (Irmis et al., 2007). Not only are the earliest known North American dinosaurs younger than those of the Ischigualasto Formation, but sauropodomorphs and ornithischians, although present in parts of Gondwana and Europe (in the case of sauropodomorphs) during the Late Triassic, may not have appeared in North America until the Early Jurassic (Nesbitt et al., 2007). Moreover, basal dinosauriforms and dinosauromorphs, which were present in Middle Triassic faunas of Argentina but are unknown from the Upper Triassic Ischigualasto Formation, are present in the younger Upper Triassic faunas of North America (Irmis et al., 2007). Understanding the evolution and biogeography of Late Triassic vertebrates, requires an accurate appraisal of their stratigraphic range and age. This is clearly difficult to obtain if the isochronous distribution of vertebrate taxa is an *a priori* assumption, as is mandated by biostratigraphic correlation that is unsupported by rigorous non-biochronologic calibration.

## Conclusions

We acknowledge that the new concept of a “long Norian” spanning over 20 Ma, encompassing virtually all western North American Upper Triassic terrestrial vertebrate-bearing strata, is preliminary and requires further corroboration. The Furin et al. (2006) date for the Carnian-Norian boundary requires confirmation from further radioisotopic dating of other marine boundary sections. This could be supported by additional radioisotopic calibration of the Newark Basin section, where the only available precise ages are from near the top of the sequence (Schoene et al., 2006; Blackburn et al., 2009). We do not argue that the “long Norian” is unimpeachable, but it is much better supported by the data than the “long Tuvolian” hypothesis, because the correlations of the Late Triassic LVFs to the late Carnian are ambiguous.

However, an important point is that confirmation or rejection of the Furin et al. (2006) date for the Carnian-Norian boundary, the magnetostratigraphic correlations of the Newark Supergroup and Chinle Formation sections containing “Carnian” palynofloras to Norian marine rocks, and the possible diachroneity of vertebrate taxa and palynofloras, can only be settled by one type of evidence: additional radioisotopic dates from marine and terrestrial sections. Even if palynology and vertebrate biochronology are ultimately demonstrated to be reliable methods of Late Triassic intercontinental chronostratigraphic correlation,

their vindication is reliant on independent correlation using non-biochronologic methods. The evidence for the long Norian is based on the sort of methods and types of data to which Late Triassic continental geochronology workers must turn.

It is clear to us that the veracity of vertebrate biochronology as a means of correlating Upper Triassic strata has reached the present limits of its resolution, and has been compromised by controversial taxonomic practices and circular reasoning. Our understanding of Late Triassic faunal change, and the geochronologic correlation of these faunas, must develop along different lines. Detailed lithostratigraphic and biostratigraphic frameworks must be constructed for particular regions, with chronostratigraphic correlation between these regions being based primarily on non-biostratigraphic methods, specifically precise radioisotopic ages augmented by magnetostratigraphy. It then becomes possible not only for geochronologic correlations to achieve a far greater level of precision, but to recognize potentially diachronous patterns of vertebrate dispersal. Moreover, by relieving the pressure to downplay taxonomic variation in different parts of the world for the sake of biochronology, it becomes possible to see patterns of regional variation un-blurred by biochronologically-convenient synonymies. To advance, Late Triassic vertebrate biochronology, which has assumed an importance in chronostratigraphic correlation far in excess of its actual substance, must yield to other methods for understanding of Late Triassic vertebrate faunal change.

## Acknowledgments

Funding for this work was provided by the University of Utah, Petrified Forest National Park, and Texas Tech University. We thank Paul Barrett, Sofie Lindström, Rainer Schoch, and Michelle Stocker for thoughtful discussions. This is Petrified Forest National Park Paleontological Contribution no. 27.

## References

- Angielczyk, K. D. and Kurkin, A. A. 2003. Has the utility of *Dicynodon* for Late Permian terrestrial biostratigraphy been overstated? *Geology*, 31 (4): 363-366.
- Backhouse, J., Balme, B. E., Helby, R., Marshall, N. G. and Morgan, R. 2002. Palynological zonation and correlation of the latest Triassic, northern Carnarvon Basin. In: Keep, M and Moss, S. J. (editors): *Sedimentary Basins of Western Australia 3*. Petroleum Exploration Society of Australia, Perth: 179-201.
- Ballew, K. L. 1989. A phylogenetic analysis of Phytosauria from the Late Triassic of the western United States. In: Lucas, S.G., and Hunt, A.P., (editors): *Dawn of the Age of Dinosaurs in the American Southwest*. New Mexico Museum of Natural History, Albuquerque: 309-339.
- Benton, M. J. 1983. Dinosaur success in the Triassic; a noncompetitive ecological model. *The Quarterly Review of Biology*, 58 (1): 29-55.
- Berggren, W. A., and Van Couvering, J. A. 1974. The late Neogene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 16: 1-16.



- Blackburn, T., Bowring, S., Olsen, P., Kent, D., Rasbury, T., and McHone, J. G. 2009. New high-precision U-Pb zircon dating of Central Atlantic Magmatic Province: implications for the Triassic-Jurassic extinction and the astrochronological timescale. *Geological Society of America Abstracts with Programs*, 41 (7): 421.
- Buffetaut, E. 1993. Phytosaurs in time and space. *Paleontologia Lombarda, Nuova Serie*, 2: 39-44.
- Camp, C. L. 1930. A study of the phytosaurs with description of new material from western North America. *Memoirs of the University of California*, 10: 1-160.
- Case, J.A. 1996. The importance of fine-scaled biostratigraphic data in addressing questions of vertebrate paleoecology and evolution. *PaleoBios*, 17 (2-4): 59-69.
- Channell, J. E. T., Kozur, H. W., Sievers, T., Mock, R., Aubrecht, R., and Sykora, M. 2003. Carnian-Norian biomagnetostratigraphy at Silická Brezová (Slovakia): correlation to other Tethyan sections and to the Newark Basin. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 191: 65-109.
- Chatterjee, S. 1986. The Late Triassic Dockum vertebrates: their stratigraphic and paleobiogeographic significance. In: Padian, K. (editor): *The Beginning of the Age of Dinosaurs: Faunal Changes Across the Triassic-Jurassic Boundary*. Cambridge University Press, Cambridge: 161-169.
- Chatterjee, S. 2001. Case 3165: *Parasuchus hislopi* Lydekker, 1885 (Reptilia, Archosauria): proposed replacement of the lectotype by a neotype. *Bulletin of Zoological Nomenclature*, 58 (1): 34-36.
- Colbert, E. H. and Gregory, J. T. 1957. Correlation of continental Triassic sediments by vertebrate fossils. *Geological Society of America Bulletin*, 68: 1456-1467.
- Cornet, B. 1993. Applications and limitations of palynology in age, climatic, and paleoenvironmental analyzes of Triassic sequences in North America. *New Mexico Museum of Natural History and Science Bulletin*, 3: 75-93.
- Dunay, R. E. and Fisher, M. J. 1979. Palynology of the Dockum Group (Upper Triassic), Texas, U.S.A. *Review of Palaeobotany and Palynology*, 28: 61-92.
- Fara, E. and Hungerbühler, A. 2000. *Paleorhinus magnoculus* from the Upper Triassic of Morocco: a juvenile primitive phytosaur (Archosauria). *Comptes Rendus de l'Académie des Sciences, Sciences de la Terre et des Planètes*, 331: 831-836.
- Flynn, J. J., MacFadden, B. J., and McKenna, M. C. 1984. Land-mammal ages, faunal heterochrony, and temporal resolution in Cenozoic terrestrial sequences. *Journal of Geology*, 92: 687-705.
- Fraser, N. 2006. *Dawn of the Dinosaurs: Life in the Triassic*. Indiana University Press, Bloomington, 307 pp.
- Furin, S., Preto, N., Rigo, M., Roghi, G., Gianolla, P., Crowley, J. L., and Bowring, S. A. 2006. High-precision U-Pb zircon age from the Triassic of Italy: implications for the Triassic time scale and the Carnian origin of calcareous nannoplankton and dinosaurs. *Geology*, 34 (12): 1009-1012.
- Gottesfeld, A. S. 1975. Upper Triassic palynology of the southwestern United States. Ph.D. dissertation, University of California, Berkeley, CA, 219 pp.
- Gottesfeld, A. S., 1980. Upper Triassic palynofloras of the western United States. *Proceedings of the IV International Palynological Conference, Lucknow*, 2: 295-308.
- Gozzi, E. and Renesto, S. 2003. A complete specimen of *Mystriosuchus* (Reptilia, Phytosauria) from the Norian (Late Triassic) of Lombardy (northern Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 109 (3): 475-498.
- Gregory, J. T. 1957. Significance of fossil vertebrates for correlation of Late Triassic continental deposits of North America. In: XX Congreso Geológico Internacional, Sección II - El Mesozoico del Hemisferio Occidental y sus Correlaciones Mundiales. International Geological Congress, Mexico City: 7-25.
- Gregory, J. T. 1962. The genera of phytosaurs. *American Journal of Science*, 260: 652-690.
- Heckert, A. B. and Lucas, S. G. 1998. First occurrence of *Aetosaurus* (Reptilia: Archosauria) in the Upper Triassic Chinle Group (USA) and its biochronological significance. *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte*, 1998 (10): 604-612.
- Heckert, A. B., and Lucas, S. G. 2002. South American occurrences of the Adamanian (Late Triassic: latest Carnian) index taxon *Stagonolepis* (Archosauria: Aetosauria) and their biochronological significance. *Journal of Paleontology*, 76 (5): 852-863.
- Heckert, A. B., Lucas, S. G. and Krzyzanowski, S. E. 2002. The rauisuchian archosaur *Saurosuchus* from the Upper Triassic Chinle Group, southwestern U.S.A., and its biochronological significance. *New Mexico Museum of Natural History and Science Bulletin*, 21: 241-244.
- Heckert, A. B., Lucas, S. G., Dickinson, W. R. and Mortensen, J. K. 2009. New ID-TIMS U-Pb ages for Chinle Group strata (Upper Triassic) in New Mexico and Arizona, correlation to the Newark Supergroup, and implications for the "long Norian". *Geological Society of America Abstracts with Programs*, 41 (7): 123.
- von Huene, F. F. 1939. Ein primitiver phytosaurier in der jüngeren nordostalpinen Trias. *Zentralblatt für Mineralogie, Geologie, und Paläontologie*, 1939 (4): 139-144.
- Hungerbühler, A. 2001a. Comment on the proposed designation of a neotype for *Parasuchus hislopi* Lydekker, 1885 (Reptilia, Archosauria). *Bulletin of Zoological Nomenclature*, 58 (3): 34-36.
- Hungerbühler, A. 2001b. The status and phylogenetic relationships of "*Zanclodon*" *arenaceus*: the earliest known phytosaur? *Paläontologische Zeitschrift*, 75: 97-112.
- Hungerbühler, A. 2002. The late Triassic phytosaur *Mystriosuchus westphali*, with a revision of the genus. *Palaeontology*, 45 (2): 377-418.
- Hunt, A. P. 1993. Revision of the Metoposauridae (Amphibia: Temnospondyli) and description of a new genus from western North America. *Museum of Northern Arizona Bulletin*, 59: 67-97.

- Hunt, A. P. 1994. Vertebrate paleontology and biostratigraphy of the Bull Canyon Formation (Chinle Group, Upper Triassic), east-central New Mexico with revisions of the families Metoposauridae (Amphibia: Temnospondyli) and Parasuchidae (Reptilia: Archosauria). PhD dissertation. University of New Mexico, Albuquerque, NM, 404 pp.
- Hunt, A. P. and Lucas, S. G. 1991. The *Paleorhinus* biochron and the correlation of the non-marine Upper Triassic of Pangaea. *Palaeontology*, 34 (2): 487-501.
- Hunt, A. P., Lucas, S. G., and Heckert, A. B. 2005. Definition and correlation of the Lamyian: a new biochronological unit for the nonmarine late Carnian (Late Triassic). *New Mexico Geological Society Guidebook*, 56: 357-366.
- ICZN. 2003. Opinion 2045: *Parasuchus hislopi* Lydekker, 1885 (Reptilia, Archosauria): lectotype replaced by a neotype. *Bulletin of Zoological Nomenclature*, 60 (2).
- Irmis, R. B. 2005. The vertebrate fauna of the Upper Triassic Chinle Formation in northern Arizona. *Mesa Southwest Museum Bulletin*, 9: 63-88.
- Irmis, R. and Mundil, R. 2008. New age constraints from the Chinle Formation revise global comparisons of Late Triassic vertebrate assemblages. *Journal of Vertebrate Paleontology*, 28 (3 Supplement): 95A.
- Irmis, R. B., Nesbitt, S. J., Padian, K., Smith, N. D., Turner, A. H., Woody, D., and Downs, A. 2007. A Late Triassic dinosauromorph assemblage from New Mexico and the rise of dinosaurs. *Science*, 317: 358-361.
- Kent, D. V. and Olsen, P. E. 1999. Astronomically tuned geomagnetic polarity timescale for the Late Triassic. *Journal of Geophysical Research B*, 104 (B6): 12831-12841.
- Langer, M. C. 2005. Studies on continental Late Triassic tetrapod biochronology. II. The Ischigualastian and a Carnian global correlation. *Journal of South American Earth Sciences*, 19: 219-239.
- Lindsay, E. 2003. Chronostratigraphy, biochronology, datum events, land mammal ages, stage of evolution, and appearance event ordination. *Bulletin of the American Museum of Natural History*, 279: 212-230.
- Lindström, S. and McLaughlin, S. 2007. Synchronous palynofloristic extinction and recovery after the end-Permian event in the Prince Charles Mountains, Antarctica: implications for palynofloristic turnover across Gondwana. *Review of Palaeobotany and Palynology*, 145: 89-122.
- Litwin, R. J., Traverse, A. and Ash, S. R. 1991. Preliminary palynological zonation of the Chinle Formation, southwestern U.S.A., and its correlation to the Newark Supergroup (eastern U.S.A.). *Review of Palaeobotany and Palynology*, 68: 269-287.
- Lofgren, D. L., Lillegraven, J. A., Clemens, W. A., Gingerich, P. D., and Williamson, T. E. 2004. Paleocene biochronology: the Puercan through Clarkfordian Land Mammal Ages. In: Woodburne, M. O. (ed.): *Late Cretaceous and Cenozoic Mammals of North America*. Columbia University Press, New York: 43-105.
- Long, R. A. and Murry, P. A. 1995. Late Triassic (Carnian and Norian) tetrapods from the southwestern United States. *New Mexico Museum of Natural History and Science Bulletin*, 4: 1-254.
- Long, R. A. and Padian, K. 1986. Vertebrate biostratigraphy of the Late Triassic Chinle Formation, Petrified Forest National Park, Arizona: preliminary results. In: Padian, K. (editor): *The Beginning of the Age of Dinosaurs: Faunal Changes Across the Triassic-Jurassic Boundary*. Cambridge University Press, Cambridge: 161-169.
- Lucas, S. G. 1993. The Chinle Group: revised stratigraphy and biochronology of Upper Triassic nonmarine strata in the western United States. *Museum of Northern Arizona Bulletin*, 59: 27-50.
- Lucas, S. G. 1998a. Global Triassic tetrapod biostratigraphy and biochronology. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 143: 347-384.
- Lucas, S. G. 1998b. The aetosaur *Longosuchus* from the Triassic of Morocco and its biochronological significance. *Comptes Rendus de l'Académie des Sciences, Sciences de la Terre et des Planètes*, 326: 589-594.
- Lucas, S. G. 2009. A Triassic timescale 2009. *Geological Society of America Abstracts with Programs*, 41 (7): 107.
- Lucas, S. G. and Heckert, A. B. 2000. Biochronological significance of Triassic nonmarine tetrapod records from marine strata. *Albertiana*, 24: 30-36.
- Lucas, S. G. and Hunt, A. P. 1993a. Tetrapod biochronology of the Chinle Group (Upper Triassic), western United States. *New Mexico Museum of Natural History and Science Bulletin*, 3: 327-329.
- Lucas, S. G., and Hunt, A. P. 1993b. A dicynodont from the Upper Triassic of New Mexico and its biochronological significance. *New Mexico Museum of Natural History and Science Bulletin*, 3: 321-326.
- Lucas, S. G., Heckert, A. B. and Huber, P. 1998. *Aetosaurus* (Archosauromorpha) from the Upper Triassic of the Newark Supergroup, eastern United States, and its biochronological significance. *Palaeontology*, 41 (6): 1215-1230.
- Lucas, S. G., Hunt, A. P., Heckert, A. B. and Spielmann, J. A. 2007a. Global Triassic tetrapod biostratigraphy and biochronology: 2007 status. *New Mexico Museum of Natural History and Science Bulletin*, 41: 229-240.
- Lucas, S. G., Heckert, A. B., and Rinehart, L. 2007b. A giant skull, ontogenetic variation, and taxonomic validity of the Late Triassic phytosaur *Parasuchus*. *New Mexico Museum of Natural History and Science Bulletin*, 41: 222-228.
- Lucas, S. G., Spielmann, J. A., and Hunt, A. P. 2007c. Biochronological significance of Late Triassic tetrapods from Krasiejów, Poland. *New Mexico Museum of Natural History and Science Bulletin*, 41: 248-258.
- Martz, J. W. 2008. Lithostratigraphy, chemostratigraphy, and vertebrate biostratigraphy of the Dockum Group

- (Upper Triassic), of southern Garza County, west Texas. PhD dissertation, Texas Tech University, Lubbock, TX, 504 pp.
- Martz, J. W. and Parker, W. G. In review. Revised lithostratigraphy of the Sonsela Member (Chinle Member, Upper Triassic) of Petrified Forest National Park, Arizona. PLoS One.
- Milner, A. R. and Schoch, R. R. 2004. The latest metoposaurid amphibians from Europe. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 232 (2/3): 231-252.
- Mundil, R., Gehrels, G., Deino, A. L. and Irmis, R. B. 2008. Zircon U-Pb analyses by TIMS and LA-ICPMS on the same material. *Eos Transactions AGU*, 89 (53, Fall Meeting Supplement): abstract V13A-2108.
- Mueller, B. 2007. *Koskinonodon* Branson and Mehl, 1928, a replacement name for the preoccupied temnospondyl *Buettneria* Case, 1922. *Journal of Vertebrate Paleontology*, 27 (1): 225.
- Muttoni, G., Kent, D. V., Jadoul, F., Olsen, P. E., Rigo, M., Galli, M. T., and Nicora, A. in press. Rhaetian magneto-biostratigraphy from the southern Alps (Italy): constraints on Triassic chronology. *Palaeogeography, Palaeoclimatology, Palaeoecology*.
- Muttoni, G., Kent, D. V., Olsen, P. E., Di Stefano, P., Lowrie, W., Bernasconi, S. M., and Hernandez, F. M. 2004. Tethyan magnetostratigraphy from Pizzo Mondello (Sicily) and correlation to the Late Triassic Newark astrochronological polarity time scale. *Geological Society of America Bulletin*, 116 (9-10): 1043-1058.
- Nesbitt, S. J., Irmis, R. B. and Parker, W. G. 2007. A critical re-evaluation of the Late Triassic dinosaur taxa of North America. *Journal of Systematic Palaeontology*, 5 (2): 209-243.
- Nichols, D. J. and Johnson, K. R. 2008. *Plants and the K-T boundary*. Cambridge University Press, Cambridge, 280 pp.
- Ogg, J.G. 2005. The Triassic Period. In: Gradstein, F. M., Ogg, J. G., and Smith, A. G. (editors): *A Geologic Time Scale 2004*. Cambridge University Press, Cambridge: 271-306.
- Olsen, P. 2009. Implications of Newark Basin astrochronology and geomagnetic polarity time scale (NBAGPTS) for the tempo and mode of early diversification of the Dinosauria. *Journal of Vertebrate Paleontology*, 29 (3 Supplement): 158A.
- Padian, K. 1994. What were the tempo and mode of evolutionary change in the Late Triassic to Middle Jurassic? In: Fraser, N. C., and Sues, H.-D., (editors): *In the Shadow of the Dinosaurs: Early Mesozoic Tetrapods*. Cambridge University Press, Cambridge: 401-407.
- Parker, W. G. 2006. The stratigraphic distribution of major fossil localities in Petrified Forest National Park, Arizona. *Museum of Northern Arizona Bulletin*, 62: 46-61.
- Parker, W. G. and Barton, B. J. 2008. New information on the Upper Triassic archosauriform *Vancleavea campi* based on new material from the Chinle Formation of Arizona. *Palaeontologia Electronica*, 11 (3): 14A, 1-20.
- Parker, W. G. and Irmis, R. B. 2005. Advances in Late Triassic vertebrate paleontology based on new material from Petrified Forest National Park, Arizona. *New Mexico Museum of Natural History and Science Bulletin*, 29: 45-58.
- Parker, W. G. and Irmis, R. B. 2006. A new species of the Late Triassic phytosaur *Pseudopalatus* (Archosauria: Pseudosuchia) from Petrified Forest National Park, Arizona. *Museum of Northern Arizona Bulletin*, 62: 126-143.
- Parker, W., and Martz, J. 2009. Constraining the stratigraphic position of the Late Triassic (Norian) Adamani-an-Revueltian faunal transition in the Chinle Formation of Petrified Forest National Park, Arizona. *Journal of Vertebrate Paleontology*, 29 (3 Supplement): 162A.
- Parker, W. G., Stocker, M. R. and Irmis, R. B. 2008. A new desmatosuchine archosaur (Archosauria: Pseudosuchia) from the Upper Triassic Tecovas Formation (Dockum Group) of Texas. *Journal of Vertebrate Paleontology*, 28 (3): 692-701.
- Prothero, D. R. 1990. *Interpreting the Stratigraphic Record*. W.H. Freeman & Co., New York, 410 pp.
- Rayfield, E. J., Barrett, P. M., McDonnell, R. A. and Willis, K. J. 2005. A Geographical Information System (GIS) study of Triassic vertebrate biochronology. *Geological Magazine*, 142 (4): 327-354.
- Rayfield, E. J., Barrett, P. M. and Milner, A. R. 2009. Utility and validity of Middle and Late Triassic 'land vertebrate faunachrons'. *Journal of Vertebrate Paleontology*, 29 (1): 80-87.
- Reeside, J. B., Jr., Jr., Applin, P. L., Colbert, E. H., Gregory, J. T., Hadley, H. D., Kummel, B., Lewis, P. J., Love, J. D., Maldonado-Koerdell, M., McKee, E. D., McLaughlin, D. B., Muller, S. W., Reinemund, J. A., Rodgers, J., Sanders, J., Silberling, N. J., and Waagé, K. 1957. Correlation of the Triassic formations of North America exclusive of Canada. *Geological Society of America Bulletin*, 68: 1451-1514.
- Renesto, S. 2006. A reappraisal of the diversity and biogeographic significance of the Norian (Late Triassic) reptiles from the Calcare di Zorzino. *New Mexico Museum of Natural History and Science Bulletin*, 37: 445-456.
- Renesto, S. and Lombardo, C. 1999. Structure of the tail of a phytosaur (Reptilia, Archosauria) from the Norian (Late Triassic of Lombardy (northern Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 105 (1): 135-144.
- Renesto, S. and Paganoni, A. 1998. A phytosaur skull from the Norian (Late Triassic) of Lombardy (northern Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 104 (1): 115-122.
- Renesto, S., Tintori, A., Lombardo, C. and Marazzi, B. 1999. A complete phytosaur (Reptilia, Archosauria) from the Norian (Late Triassic) of Lombardy (northern Italy). *Rivista del Museo Civico di Scienze Naturali "E. Caffi" Bergamo*, 20: 127-130.
- Riggs, N. R., Ash, S. R., Barth, A. P., Gehrels, G. E. and Wooden, J. L. 2003. Isotopic age of the Black For-

- est Bed, Petrified Forest Member, Chinle Formation, Arizona: an example of dating a continental sandstone. Geological Society of America Bulletin, 115 (11): 1315-1323.
- Rogers, R. R., Swisher, C. C., III, Sereno, P. C., Monetta, A. M., Forster, C. A., and Martínez, R. N. 1993. The Ischigualasto tetrapod assemblage (Late Triassic, Argentina) and  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of dinosaur origins. Science, 260 (5109): 794-797.
- Savage, D. E. 1977. Aspects of vertebrate paleontological stratigraphy and geochronology. In: Kauffman, E. G., and Hazel, J. E. (editors): Concepts and Methods of Biostratigraphy. Dowden, Hutchinson, and Ross, Stroudsburg: 427-442.
- Schoch, R. R. 2007. Osteology of the small archosaur *Aetosaurus* from the Upper Triassic of Germany. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 246 (1): 1-35.
- Schoch, R. R. and Milner, A. R. 2000. Stereospondyli. Handbuch der Paläoherpetologie, 3B: 1-203.
- Schoch, R. and Wild, R. 1999. Die wirbeltier-fauna im Keuper von Süddeutschland. In: Hauschke, N., and Wilde, V., (editors): Trias eine ganz andere welt: Mitteleuropa im frühen erdmittelalter. Verlag Dr. Friedrich Pfeil, München: 395-408.
- Schoene, B., Crowley, J. L., Condon, D. J., Schmitz, M. D. and Bowring, S. A., 2006. Reassessing the uranium decay constants for geochronology using ID-TIMS U-Pb data. Geochimica et Cosmochimica Acta, 70: 426-445.
- Schultz, C. L. 2005. Biostratigraphy of the non-marine Triassic: is a global correlation based on tetrapod faunas possible? In: Koutsoukos, E. A. M. (editor), Applied Stratigraphy. Springer, Dordrecht: 123-145.
- Seegis, D. 2005. Tetrapoden. In: Beutler, G., Hauschke, N., Nitsch, E., and Vath, U. (editors), Stratigraphie von Deutschland IV: Keuper. Courier Forschungsinstitut Senckenberg, 253: 50-54.
- Small, B. J. 1998. The occurrence of *Aetosaurus* in the Chinle Formation (Late Triassic: USA) and its biostratigraphic significance. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 1998: 285-296.
- Spielmann, J., Lucas, S. G., Heckert, A. B., Sullivan, R. and Jasinski, S. 2009. Land-vertebrate faunachrons, GIS and cladotaxonomy: towards a global Triassic tetrapod biochronology. Geological Society of America Abstracts with Programs, 41 (7): 107.
- Stocker, M. R. 2008. The relationships of the phytosaur *Leptosuchus* Case 1922 with descriptions of new material from Petrified Forest National Park, Arizona. M.S. thesis, University of Iowa, Iowa City, 220 pp.
- Stocker, M. R. in press. A new taxon of phytosaur (Archosauria: Pseudosuchia) from the Late Triassic (Norian) Sonsela Member (Chinle Formation) in Arizona, and a critical reevaluation of *Leptosuchus* Case 1922. Palaeontology.
- Sues, H.-D., Olsen, P. E., Carter, J. G. and Scott, D. M. 2003. A new crocodylomorph archosaur from the Upper Triassic of North Carolina. Journal of Vertebrate Paleontology, 23 (2): 329-343.
- Sulej, T. 2002. Species discrimination of the Late Triassic temnospondyl amphibian *Metoposaurus diagnosticus*. Acta Palaeontologica Polonica, 47 (3): 535-546.
- Sulej, T. 2007. Osteology, variability and evolution of *Metoposaurus*, a temnospondyl from the Late Triassic of Poland. Palaeontologia Polonica, 64: 29-139.
- Tedford, R. H. 1970. Principles and practices of mammalian geochronology in North America. Proceedings of the North American Paleontological Convention, Part F: 666-703.
- Walsh, S. L. 1998. Fossil datum and paleobiological event terms, paleostratigraphy, chronostratigraphy, and the definition of land mammal "age" boundaries. Journal of Vertebrate Paleontology, 18 (1): 150-179.
- Walsh, S. L. 2000. Eubiostratigraphic units, quasibiostratigraphic units, and "assemblage zones." Journal of Vertebrate Paleontology, 20 (4): 761-775.
- Westphal, F. 1976. Phytosauria. Handbuch der Paläoherpetologie, 13: 99-120.
- Wild, R. 1989. *Aetosaurus* (Reptilia: Thecodontia) from the Upper Triassic (Norian) of Cene near Bergamo, Italy, with a revision of the genus. Rivista del Museo Civico di Scienze Naturali "E. Caffi" Bergamo, 14: 1-24.
- Woodburne, M. O. 1977. Definition and characterization in mammalian chronostratigraphy. Journal of Paleontology, 51 (2): 220-234.
- Woodburne, M. O. 1987. Mammal ages, stages, and zones. In: Woodburne, M. O. (editor): Cenozoic Mammals of North America: Geochronology and Biostratigraphy. University of California Press, Berkeley: 18-23.
- Woodburne, M. O. 1989. Hipparion horses: A pattern of endemic evolution and intercontinental dispersal. In: Prothero, D. R., and Schoch, R. M. (editors): The Evolution of Perissodactyls. Oxford University Press, New York: 197-233.
- Woodburne, M. O. 1996. Precision and resolution in mammalian chronostratigraphy: principles, practices, examples. Journal of Vertebrate Paleontology, 16 (3): 531-555.
- Woodburne, M. O. (editor). 2004. Late Cretaceous and Cenozoic mammals of North America: biostratigraphy and geochronology. Columbia University Press, New York, 400 pp.
- Woodburne, M. O. 2006. Mammal ages. Stratigraphy, 3 (4): 229-261.
- Woody, D. T. 2006. Revised stratigraphy of the lower Chinle Formation (Upper Triassic) of Petrified Forest National Park, Arizona. Museum of Northern Arizona Bulletin, 62: 17-45.

or correlating Late Triassic land-vertebrate faunachrons (LVFs) to the marine stages and numerical timescale. Correlation on the right follows Lucas et al. (2007), Lucas (2009), and Heckert et al. (2009).

## New Triassic Literature

### Triassic Bibliography

Contributed by G. Warrington

*Honorary Visiting Fellow, Department of Geology, The University of Leicester, U.K. (e-mail: gw47@le.ac.uk). Address for ordinary mail: 3, Lamcote Gardens, Radcliffe on Trent, Nottingham NG12 2BS, U.K.*

Updated until 16<sup>h</sup> of November 2009

- Abdala, F. & Smith, R. M. H. 2009. A Middle Triassic cynodont fauna from Namibia and its implications for the biogeography of Gondwana. *Journal of Vertebrate Paleontology*, 29 (3): 837-851.
- Abohajar, A., Krooss, B. M., Harouda, M. & Littke, R. 2009. Maturity and source-rock potential of Mesozoic and Palaeozoic sediments, Jifarah Basin, NW Libya. *Journal of Petroleum Geology*, 32 (4): 327-341.
- Adams, C. J., Cluzel, D. & Griffin, W. L. 2009. Detrital-zircon ages and geochemistry of sedimentary rocks in basement Mesozoic terranes and their cover rocks in New Caledonia, and provenances at the eastern Gondwanaland margin. *Australian Journal of Earth Sciences*, 56 (8): 1023 – 1047.
- Adams, C. J., Mortimer, N., Campbell, H. J. & Griffin, W. L. 2009. Age and isotopic characterisation of metasedimentary rocks from the Torlesse Supergroup and Wai-papa Group in the central North Island, New Zealand. *New Zealand Journal of Geology and Geophysics*, 52 (2): 149-170.
- Adams, T. L. 2009. Deposition and taphonomy of the Hound Island Late Triassic vertebrate fauna: Fossil preservation within subaqueous gravity flows. *Palaiois*, 24 (9): 603-615.
- Ai-yang Ma. 2009. 40Ar-39Ar dating of muscovite in mylonite of Shanggangkundi Fault – new evidence for the main stage of Xar Moron River fault zone. *Xinjiang Geology*, 27 (2): 170 –175.
- Aldinucci, M., Pandeli, E. & Sandrelli, F. 2008. Tectono-sedimentary evolution of the Late Palaeozoic-Early Mesozoic metasediments of the Monticiano-Roccastrada Ridge (southern Tuscany, Northern Apennines, Italy). *Bolletino della Società Geologica Italiana*, 127 (3): 567-579.
- Al-Ameri, T. K., Al-Dolaimy, O. H. & Al-Khafaji, A. J. 2009. Palynofacies and hydrocarbon generation potential of the upper Triassic Kurrachine Formation and lower part of the Baluti Formation, Mosul Block, northwestern Iraq. *Arabian Journal of Earth Sciences*, 2 (3): 273-283.
- Al-Husseini, M. 2009. Update to Late Triassic – Jurassic stratigraphy of Saudi Arabia for the Middle East Geological Time Scale. *GeoArabia*, 14 (2): 145-186.
- Al-Juboury, A. 2007. Petrography and major element geochemistry of Late Triassic Carpathian Keuper sandstones : implications for provenance. *Bulletin de l' Institut Scientifique de l'Université Mohammed V Agdal, Rabat : Section Sciences de la Terre*, 29: 1-14.
- Arias, C. & Whatley, R. C. 2009. Multivariate hierarchical analyses of Early Jurassic Ostracoda assemblages. *Lethaia*, 42 (4): 495-510.
- Aristov, D. S., Wappler, T. & Rasnitsyn, A. P. 2009. New and little-known grylloblattids of the family Geinitziidae (Insecta: Grylloblattida) from the Triassic and Jurassic of Europe, Asia, and South Africa. *Paleontological Journal*, 43 (4): 418-424.
- Avanzini, M. & Cavin, L. 2009. A new Isochirotherium trackway from the Triassic of Vieux Emosson, SW Switzerland: stratigraphic implications. *Swiss Journal of Geosciences*, 102 (3): 353-361.
- Balini, M., Nicora, A., Berra, F., Garzanti, E., Levera, M., Mattei, M., Muttoni, G., Zanchi, A., Bollati, I., Larghi, C., Zanchetta, S., Salamati, R. & Mossavvari, F. 2009. The Triassic stratigraphic succession of Nakhlak (central Iran), a record from an active margin. *Geological Society, London, Special Publications*, 312: 287-321.
- Baouche, R., A. Nedjari, A., El Aadj, S. & Chaouchi, R. 2009. Facies analysis of Triassic formations of the Hassi r'Mel in southern Algeria using well logs: recognition of paleosols using log analysis. *The Open Geology Journal*, 3: 39-57.
- Bao-zhong Yang, Kun-guang Yang & Wen-chen Xia. 2007. Storm deposits of the Daye Formation of Lower Triassic of Huangshi area of eastern Hubei Province. *Journal of Palaeogeography*, 9 (4): 379-386.
- Bardola, T. P., Schmidt, I. D., Sommer, M. G. & Leandro, C. 2009. Ginkgophyta wood in petrified forest of the Upper Triassic from Rio Grande do Sul, Brazil. *Revista Brasileira de Paleontologia*, 12 (2): 139-148.
- Bardzinski, W., Surmik, D. & Lewandowski, M. 2008. Middle Triassic vertebrate locality near Zyglin in Upper Silesia, Poland. *Przegląd Geologiczny*, 56 (7): 532-536.
- Basilone, L. 2009. Sequence stratigraphy of a Mesozoic carbonate platform-to-basin system in Western Sicily. *Central European Journal of Geosciences*, 1 (3): 251-273.
- Bartdorff, O., Wallmann, K., Latif, M. & Semenov, V. 2008. Phanerozoic evolution of atmospheric methane. *Global Biogeochemical Cycles*, 22, GB1008, doi:10.1029/2007GB002985
- Beatty, B. L. & Heckert, A. B. 2009. A large archosauriform tooth with multiple supernumerary carinae from the Upper Triassic of New Mexico (USA), with comments on carina development and anomalies in the Archosauria. *Historical Biology*, 21 (1-2): 57 – 65.
- Beerling, D., Berner, R. A., Mackenzie, F. T., Harfoot, M. B. & Pyle, J. A. 2009. Methane and the CH<sub>4</sub> related greenhouse effect over the past 400 million years. *American Journal of Science*, 309 (2): 97-113.

- Benton, M. J. 2008. Presidential Address 2007: The end-Permian mass extinction – events on land in Russia. *Proceedings of the Geologists' Association*, 119 (2): 119-136.
- Ben-zhong Xian, Huai-bao Xu, Zhen-kui Jin, Chun-sheng Wang, Yang Lu & Li-liang Huang. 2008. Sequence stratigraphy and subtle reservoir exploration of Triassic system in northwestern margin of Junggar Basin. *Geological Journal of China Universities*, 14 (2): 139-146.
- Berner, R. A. 2009. Phanerozoic atmospheric oxygen: new results using the GEOCARBSULF model. *American Journal of Science*, 309 (7): 603-606.
- Berra, F., Galli, M. T., Reghellin, F., Torricelli, S. & Fantoni, R. 2009. Stratigraphic evolution of the Triassic–Jurassic succession in the western Southern Alps (Italy): the record of the two-stage rifting on the distal passive margin of Adria. *Basin Research*, 21 (3): 335-353.
- Béthoux, O., de la Horra, R., Benito, M. I., Barrenechea, J. F., Galán, A. B. & López-Gómez, J. 2009. A new triadotomorph insect from the Anisian (Middle Triassic), Buntsandstein facies, Spain. *Journal of Iberian Geology*, 35 (2): 179-184.
- Bin Chen, Wei Tian & An-kun Liu. 2008. Petrogenesis of the Xiaozhangjiakou mafic-ultramafic complex, north Hebei: constraints from petrological, geochemical and Nd-Sr isotopic data. *Geological Journal of China Universities*, 14 (3): 295-303.
- Bin Tang, Wei-cheng Hao & Zuo-yu San. 2007. Factor analyses and environmental evolution implications of element geochemistry data for the section bearing the Middle Triassic Panxian fauna in Guizhou Province. *Journal of Palaeogeography*, 9 (6): 651-659.
- Blakey, R. C. 2008. Pennsylvanian–Jurassic sedimentary basins of the Colorado Plateau and the southern Rocky Mountains. *Sedimentary Basins of the World*, 5: 245-296.
- Blazejowski, B. 2004. Shark teeth from the Lower Triassic of Spitsbergen and their histology. *Polish Polar Research*, 25 (2): 153-167.
- Bo Xu & Wei Sun. 2008. Pore type and diagenesis in the Chang 4+5 sandstone reservoirs of the Jiyuan oilfield. *Journal of Jilin University (Earth Science edition)*, 38 (6): 953-958.
- Bo Yu, Zhi-lin Cui, Xue-gang Liu, Li-dan Qian, Chang-e Bai & Tao Zhu. 2008. The diagenesis of Chang-8 reservoir sandstone and its effect on porosity in Xifeng oilfield. *Journal of Jilin University (Earth Science edition)*, 38 (3): 405-410.
- Bonis, N. R., Kürschner, W. M. & Krystyn, L. 2009. A detailed palynological study of the Triassic–Jurassic transition in key sections of the Eiberg Basin (Northern Calcareous Alps, Austria). *Review of Palaeobotany and Palynology*, 156 (3-4): 376-400.
- Boonchai, N., Grote, P. J. & Jintasakul, P. 2009. Paleontological parks and museums and prominent fossil sites in Thailand and their importance in the conservation of fossils. *Carnets de Géologie*, Book 2009/3: 75-95.
- Brakel, A. T., Totterdell, J. M., Wells, A. T. & Nicoll, M. G. 2009. Sequence stratigraphy and fill history of the Bowen Basin, Queensland. *Australian Journal of Earth Sciences*, 56 (3): 401-432.
- Brayard, A. & Bucher, H. 2008. Smithian (Early Triassic) ammonoid faunas from northwestern Guangxi (South China): taxonomy and biochronology. *Fossils and Strata*, 55: 179pp.
- Brayard, A., Escarguel, G., Bucher, H. & Brühwiler, T. 2009. Smithian and Spathian (Early Triassic) ammonoid assemblages from terranes: paleoceanographic and paleogeographic implications. *Journal of Asian Earth Sciences*, 36 (6): 420-433.
- Brogi, A. 2008. The Triassic and Palaeozoic successions drilled in the Bagnore geothermal field and Poggio Nibbio area (Monte Amiata, Northern Apennines, Italy). *Bolletino della Società Geologica Italiana*, 127 (3): 599-613.
- Brusatte, S. L., Benton, M. J., Ruta, M. & Lloyd, G. T. 2008. Superiority, competition, and opportunism in the evolutionary radiation of dinosaurs. *Science*, 321 (5895): 1485-1488.
- Brusatte, S. L., Butler, R. J., Sulej, T. & Niedzwiedzki, G. 2009. The taxonomy and anatomy of raiusuchian archosaurs from the Late Triassic of Germany and Poland. *Acta Palaeontologica Polonica* 54 (2): 221-230.
- Buckovic, D. 2008. Characteristics of a Triassic regional unconformity between the second and third shallow-marine depositional megasequences of the Karst Dinarides (Croatia). *Central European Geology*, 51 (2): 113-132.
- Burgess, P. M. 2008. Phanerozoic evolution of the sedimentary cover of the North American craton. *Sedimentary Basins of the World*, 5: 31-63.
- Burov, B. V. 2005. Boundary between the Permian and Triassic rocks in the Moscow Syncline reconstructed from the rock sequence exposed in the Kichmenga River basin. *Russian Journal of Earth Sciences*, 7 (2).
- Buser, S., Kolar-Jurkovsek, T. & Jurkovsek, B. 2008. The Slovenian Basin during the Triassic in the light of conodont data. *Bolletino della Società Geologica Italiana*, 127 (2): 257-263.
- Bussert, R. & Dawit, E. 2009. Unexpected diversity: new results on the stratigraphy and sedimentology of Palaeozoic and Mesozoic siliciclastic sediments in northern Ethiopia. *Zentralblatt für Geologie und Paläontologie*, Teil 1/2007 (3-4): 181-198.
- Butler, R. J., Smith, R. M. H. & Norman, D. B. 2007. A primitive ornithischian dinosaur from the Late Triassic of South Africa, and the early evolution and diversification of Ornithischia. *Proceedings of the Royal Society of London B*, 274 (1621): 2041-2046.
- Buzzi, L., Gaggero, L. & Oggiana, G. 2008. The Santa Giusta ignimbrite (NW Sardinia): a clue for the magmatic, structural and sedimentary evolution of a Variscan segment between Early Permian and Triassic. *Bolletino della Società Geologica Italiana*, 127 (3): 683-695.
- Cai Li, Qingguo Zhai, Yongsheng Dong, Shen Liu, Chaoming Xie & Yanwang Wu. 2009. High pressure eclogite-blueschist metamorphic belt and closure of paleo-Tethys

- Ocean in central Qiangtang, Qinghai-Tibet plateau. *Journal of Earth Science*, 20 (2): 209-218.
- Carrillat, A. & Martini, R. 2009. Paleoenvironmental reconstruction of the Mufara Formation (Upper Triassic, Sicily): high resolution sedimentology, biostratigraphy and sea-level changes. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 283 (1-2): 60-76.
- Cassinis, G., Cortesogno, L., Gaggero, L., Perotti, C. R. & Buzzi, L. 2008. Permian to Triassic geodynamic and magmatic evolution of the Brescian Prealps (eastern Lombardy, Italy). *Bolletino della Società Geologica Italiana*, 127 (3): 501-518.
- Cassinis, G., Decandia, F. A. & Tavarnelli, E. 2008. Pre-orogenic extensional deformations within Permian-Triassic rocks of Southern Tuscany: structural record of an episode of Early Mesozoic continental rifting? *Bolletino della Società Geologica Italiana*, 127 (3): 615-624.
- Centamore, E., Rossi, D. & Tavarnelli, E. 2009. Geometry and kinematics of Triassic –to-Recent structures in northern-central Apennines: a review and an original working hypothesis. *Italian Journal of Geosciences*, 128 (2): 419-432.
- Chang-qun Cao & Quan-feng Zheng. 2007. High-resolution lithostratigraphy of the Changhsingian Stage in Meishan Section D, Zhejiang. *Journal of Stratigraphy*, 31 (1): 14-22.
- Changqun Cao, Love, G. D., Hays, L. E., Wei Wang, Shuzhong Shen & Summons, R. E. 2009. Biogeochemical evidence for euxinic oceans and ecological disturbance presaging the end-Permian mass extinction event. *Earth & Planetary Science Letters*, 281 (3-4): 188-201.
- Changqun Cao & QuanFeng Zheng. 2009. Geological event sequences of the Permian-Triassic transition recorded in the microfacies in Meishan section. *Science in China Series D: Earth Sciences*, 52 (10): 1529-1536.
- Chang Yen-nien, Wu Xiao-chun & Tamaki, S. 2007. A new thalattosaurian (Reptilia: Diapsida) from the Upper Triassic of Guizhou, China. *Vertebrata Palasiatica*, 45 (3): 246-260.
- Chao Wang, Zhi-bin Huang & Ze-jin Tan. 2008. The classification and correlation of Triassic in Avati Depression, North Depression, Tarim Basin. *Xinjiang Geology*, 26 (2): 133-136.
- Chao Yang, Hong-bo Lu, Qing-hu Chen & Chang-xu Sun. 2008. *Chirotherium*-footprints of a primitive reptile from the Middle Triassic, Zhenfeng, Guizhou, southwest China. *Acta Palaeontologica Sinica*, 47 (2): 240-247.
- Charlton, T. R., Barber, A. J., McGowan, A. J., Nicoll, R. S., Roniewicz, E., Cook, S. E., Barkham, S. T. & Bird, P. R. 2009. The Triassic of Timor: lithostratigraphy, chronostratigraphy and palaeogeography. *Journal of Asian Earth Sciences*, 36 (4-5): 341-363.
- Chen-sheng Liu & Jian-hau Guo. 2008. Sequence stratigraphy of the Triassic Middle Oil-Member in the Akekule area, Xinjiang. *Journal of Stratigraphy*, 32 (1): 41-46.
- Chen, Z. Q., Twitchett, R. J. & Tong J. 2009. Permian-Triassic mass extinction and subsequent recovery: an update. 2009. *Australian Journal of Earth Sciences*, 56 (6): 741-744.
- Chen, Z. Q., Tong, J., Zhang, K., Yang, H., Liao, Z., Song, H. & Chen, J. 2009. Environmental and biotic turnover across the Permian-Triassic boundary on a shallow carbonate platform in western Zhejiang, South China. *Australian Journal of Earth Sciences*, 56 (6): 775-797.
- Cheng-dong Qi, Yu-jing Peng, Chang-jian Yin, Xiao-ping Lu & Xiao-dong Zhou. 2009. Relationship of granite type with basin evolution and its metallogenetic specialization of Jilin Province in Late Triassic-Early Cretaceous. *Global Geology (Changchun)*, 28 (2): 166-170.
- Cheng-li Zhang, Tao Wang & Xiao-xia Wang. 2008. Origin and tectonic setting of the early Mesozoic granitoids in Qinling Orogenic Belt. *Geological Journal of China Universities*, 14 (3): 304-316.
- Cheng-yao Guan, Guo-chun Zhao, Xiao-feng Li, Wen-juan Yu & Tian Zhao. 2009. Sedimentary microfacies study of Chang 3 Chang 4+5 of Triassic formation in Baibao oil field. *Xinjiang Geology*, 27 (1): 62-65.
- Chong-yong Wang, Rong-cai Zheng, Yong-lin Han, Hai-hong Wang, Xiao-wei Liang & Hong-gang Xin. 2009. High-resolution sequence stratigraphy and paleogeography of the Interval 6 of the Upper Triassic Yanchang Formation in the Jiyuan Region, Ordos Basin. *Journal of Stratigraphy*, 33 (3): 326-332.
- Chuan-shang Wang, Xiao-feng Wang, Hagdorn, H., Xiaohong Chen & Long Cheng. 2007. The first discovery of Triassic Roveacrinids in China and its significance. *Acta Palaeontologica Sinica*, 46 (3): 334-337.
- Ciarapica, G. & Passeri, L. 2008. Bahamian sedimentary models as constraint for the interpretation of Mesozoic isolated carbonate platforms of Apennines. *Bolletino della Società Geologica Italiana*, 127 (3): 467-475.
- Cirilli, S., Marzoli, A., Tanner, L., Bertrand, H., Buratti, N., Jourdan, F., Bellieni, G. Kontak, D. & Renne, P. R. 2009. Latest Triassic onset of the Central Atlantic Magmatic Province (CAMP) volcanism in the Fundy Basin (Nova Scotia): new stratigraphic constraints. *Earth & Planetary Science Letters*, 286 (3-4): 514-525.
- Cisneros, J.C., 2008. Taxonomic status of the reptile genus *Procolophon* from the Gondwanan Triassic. *Palaeontologia Africana*, 43 (1): 7-17.
- Clark, N. D. L. & Corrance, H. 2009. New discoveries of *Isochirotherium herculis* and a reassessment of chirotheriid footprints from the Triassic of the Isle of Arran, Scotland. *Scottish Journal of Geology*, 45 (1): 69-82.
- Costa da Silva, R., de Souza Carvalho, I., Fernandes, A. C. S. & Ferigolo, J. 2008. Pegadas teromorfoides do Triásico Superior (Formação Santa Maria) do Sul do Brasil. *Revista Brasileira de Geociências*, 38 (1): 98-113.
- Crisafulli, A. & Lutz, A. 2008. Un nuevo tallo permineralizado de Equisetales de la Formación Los Rastros (Triásico medio-superior), provincia de San Juan, Argentina. *Revista del Museo Argentino de Ciencias Naturales*, n.s.10 (1): 71-79.
- Dalla Vecchia, F. M. 2009. Anatomy and systematics of



- the pterosaur *Carniadactylus* gen. n. *rosenfeldi* (Dalla Vecchia, 1995). *Rivista Italiana di Paleontologia e Stratigrafia*, 115 (2): 159-188.
- Da-Rosa, A. A. S., Piñeiro, G., Dias-Da-Silva, S., Cisneros, J. C., Feltrin, F. F. & Neto, L. W. 2009. Bica São Tome, a new fossiliferous site for the early Triassic of southern Brazil. *Revista Brasileira de Paleontologia*, 12 (1): 67-76.
- Davis, G. A., Jiafeng Meng, Wenrong Cao & Xingqiang Du. 2009. Triassic and Jurassic tectonics in the Eastern Yanshan Belt, North China: insights from the controversial Dengzhangzi Formation and its neighboring units. *Earth Science Frontiers*, 16 (3): 69-86.
- Dawit, E. & Bussert, R. 2009. Stratigraphy and facies architecture of Adigrat Sandstone, Blue Nile Basin – Central Ethiopia. *Zentralblatt für Geologie und Paläontologie*, Teil 1/2007 (3-4): 217-232.
- Dayong Jiang, Motani, R., Weicheng Hao, Rieppel, O., Yuanlin Sun, Tintori, A., Zuoyu Sun & Schmitz, L. 2009. Biodiversity and sequence of the Middle Triassic Panxian marine reptile fauna, Guizhou Province, China. *Acta Geologica Sinica*, 83 (3): 451-459.
- De Amorim Arantes, B., Soares, M. B. & Schultz, C. L. 2009. *Clevosaurus brasiliensis* (Lepidosauria, Sphenodontia) from the Upper Triassic of Rio Grande do Sul: post-cranial anatomy and phylogenetic relationships. *Revista Brasileira de Paleontologia*, 12 (1): 43-54.
- De Jong, K., Kurimoto, C. & Ruffet, G. 2009. Triassic <sup>40</sup>Ar/<sup>39</sup>Ar ages from the Sakaigawa unit, Kii Peninsula, Japan: implications for possible merger of the Central Asian Orogenic Belt with large-scale tectonic systems of the East Asian margin. *International Journal of Earth Sciences*, 98 (6): 1529-1556.
- Decarlis, A. & Lualdi, A. 2009. A sequence stratigraphic approach to a Middle Triassic shelf-slope complex of the Ligurian Alps (Ligurian Briançonnais, Monte Carmo-Rialto unit, Italy). *Facies*, 55 (2): 267-290.
- De-ming Zeng, Xing-zhi Wang, Fan Zhang, Zhang-qing Song, Ruo-xiang Zhang, Yong-gang Zhu & Yue-gang Li. 2007. Study of reservoir of the Leikoupo Formation of the Middle Triassic in northwestern Sichuan Basin. *Journal of Palaeogeography*, 9 (3): 253-266.
- Dickinson, W. R. 2009. Anatomy and global context of the North American Cordillera. *Geological Society of America Memoirs*, 204: 1-29.
- Dickinson, W. R. & Gehrels, G. E. 2009. Use of U-Pb ages of detrital zircons to infer maximum depositional ages of strata: a test against a Colorado Plateau Mesozoic database. *Earth and Planetary Science Letters*, 288 (1-2): 115-125.
- Dilkes, D. & Sues, H.-D. 2009. Redescription and phylogenetic relationships of *Doswellia kaltenbachi* (Diapsida: Archosauriformes) from the Upper Triassic of Virginia. *Journal of Vertebrate Paleontology*, 29 (1): 58-79.
- Dill, H. G. & Sachsenhofer, R. F. (co-ordinators) and 10 others. 2008. Fossil fuels, ore and industrial minerals. Pp. 1341-1449 in McCann, T. (ed.) *The Geology of Central Europe*. Volume 2: Mesozoic and Cenozoic. Geological Society, London.
- Dittrich, D. 2008. Schertetonik im triassischen Deckgebirge der nordwestlichen Trierer Bucht. *Mainzer geowissenschaftliche Mitteilungen*, 36.
- Dixon, J. 2009. Triassic stratigraphy in the subsurface of the plains area of Dawson Creek (93P) and Charlie Lake (94A) map areas, northeast British Columbia. *Geological Survey of Canada, Bulletin 595: 78pp, 1 CD-ROM*.
- Doff, D. 2009. A clay mineralogy of Ireland. *Irish Journal of Earth Sciences*, 27: 11-14.
- Donnadieu, Y., Goddérès, Y. & Bouttes, N. 2009. Exploring the climatic impact of the continental vegetation on the Mesozoic atmospheric CO<sub>2</sub> and climate history. *Climate of the Past*, 5 (1): 85-96.
- Donofrio, D. A. 2008. Kurzmitteilung zu Conodonten, Echinodermen- und Fischresten aus dem Brenner-Mesozoikum (Kalkkögelgruppe SW Innsbruck, Tirol) und deren paläotemperaturen. *Geo.Alp*, 5: 83-95.
- Durand, M. 2008. Permian to Triassic continental successions in southern Provence (France): an overview. *Bolletino della Società Geologica Italiana*, 127 (3): 697-716.
- Edwards, R. A. 2008. *Geology of the Jurassic Coast: The Red Coast Revealed – Exmouth to Lyme Regis*. Wareham, Dorset, Coastal Publishing & Distribution, 128pp.
- Elezaj, Z. 2009. Geodynamic evolution of Kosovo during the Triassic and Jurassic. *Yerbilimleri*, 30 (2): 113-126.
- El-Ghali, M. A. K., Morad, S., Mansurbeg, H., Caja, M. A., Ajdanlijsky, G., Ogle, N., Al-Aasm, I. & Sirat, M. 2009. Distribution of diagenetic alterations within depositional facies and sequence stratigraphic framework of fluvial sandstones: evidence from the Petrohan Terrigenous Group, Lower Triassic, NW Bulgaria. *Marine and Petroleum Geology*, 26 (7): 1212-1227.
- Embry, A. & Beauchamp, B. 2008. Sverdrup Basin. *Sedimentary Basins of the World*, 5: 451-471.
- ErChie Wang & QingRen Meng. 2009. Mesozoic and Cenozoic tectonic evolution of the Longmenshan fault belt. *Science in China Series: Earth Sciences*, 52 (5): 579-592.
- Ettensohn, F. R. 2008. The Appalachian Foreland Basin in eastern United States. *Sedimentary Basins of the World*, 5: 105-179.
- Evans, K. 2008. The rise and fall of late Triassic sea level and its interaction with basinal brines. *OUGS Journal*, 29 (1): 24-27.
- Ezakai, Y. 2009. Secular fluctuations in Palaeozoic and Mesozoic reef-forming organisms during greenhouse periods: geobiological interrelations and consequences. *Paleontological Research*, 13 (1): 23-38.
- Fabuel-Perez, I., Hodgetts, D. & Redfern, J. 2009. A new approach for outcrop characterization and geostatistical analysis of a low-sinuosity fluvial-dominated succession using digital outcrop models: Upper Triassic Oukaimeden Sandstone Formation, central High Atlas, Morocco. *AAPG Bulletin*, 93 (6): 795-827.
- Fabuel-Perez, I., Redfern, J. & Hodgetts, D. 2009. Sedi-

- mentology of an intra-montane rift-controlled fluvial dominated succession: the Upper Triassic Oukaimeden Sandstone Formation, Central High Atlas, Morocco. *Sedimentary Geology*, 218 (1-4): 103-140.
- Farzipour-Saein, A., Yassaghi, A., Sherhati, S. & Koyi, H. 2009. Mechanical stratigraphy and folding style of the Laurestan region in the Zagros Fold-Thrust Belt, Iran. *Journal of the Geological Society, London*, 166 (6): 1101-1115.
- Feist-Burkhardt, S., Götz, A. E. & Szulc, J. (co-ordinators) and 14 others. 2008. Triassic. Pp. 749-821 in McCann, T. (ed.) *The Geology of Central Europe. Volume 2: Mesozoic and Cenozoic*. Geological Society, London.
- Feixiang Wu, Yuanlin Sun, Weicheng Hao, Dayong Jiang, Guanghui Xu, Zuoyu Sun & Tintori, A. 2009. New species of Saurichthys (Actinopterygii: Saurichthyidae) from Middle Triassic (Anisian) of Yunnan Province, China. *Acta Geologica Sinica*, 83 (3): 440-450.
- Feng-kui Zhang, Zhong-yi Zhang & Lin Zhang. 2008. New sequence stratigraphic observations of the Triassic Yanchang Formation in the Ordos Basin. *Journal of Stratigraphy*, 32 (1): 99-105.
- Fen-xiong Chen, Cheng-wei Wang & Li-yun Chen. 2008. Discuss on tectonic evolution to dominating process of sandstone type uranium deposits forming in Kumishi Basin. *Xinjiang Geology*, 26 (2): 176-179.
- Fildani, A., Weislogel, A., Drinkwater, N. J., McHargue, T., Tankard, A., Wooden, J., Hodgson, D. & Flint, S. 2009. U-Pb zircon ages from the southwestern Karoo Basin, South Africa—implications for the Permian-Triassic boundary. *Geology*, 37 (8): 719-722
- Fletcher, B. J., Brentnall, S. J., Anderson, C. W., Berner, R. A. & Beerling, D. J. 2008. Atmospheric carbon dioxide linked with Mesozoic and early Cenozoic climate change. *Nature Geoscience*, 1 (1): 43 – 48.
- Forel, M.-B., Crasquin, S., Kershaw, S., Feng, Q. L. & Collin, P.-Y. 2009. Ostracods (Crustacea) and water oxygenation in the earliest Triassic of South China: implications for oceanic events at the end-Permian mass extinction. *Australian Journal of Earth Sciences*, 56 (6): 815-823.
- Fraiser, M. L. & Bottjer, D. J. 2009. Opportunistic behaviour of invertebrate marine tracemakers during the Early Triassic aftermath of the end-Permian mass extinction. *Australian Journal of Earth Sciences*, 56 (6): 841-857.
- Franks, P. J. & Beerling, D. J. 2009. CO<sub>2</sub>-forced evolution of plant gas exchange capacity and water-use efficiency over the Phanerozoic. *Geobiology*, 7 (2): 227-236.
- Franks, P. J. & Beerling, D. J. 2009. Maximum leaf conductance driven by CO<sub>2</sub> effects on stomatal size and density over geologic time. *Proceedings of the National Academy of Science*, 106 (25): 10343-10347.
- Freudenberger, W. & Helmke, K. 2006. Der Buntsandstein in den Forschungsbohrungen Lindau 1 und Spitzeichen 1. *Geologica Bavarica*, 109: 49-61.
- Freudenberger, W., Herold, B. & Wagner, S. 2006. Bohrkernbeschreibung und stratigraphie der Forschungsbohrungen Lindau 1 und Spitzeichen 1. *Geologica Bavarica*, 109: 15-26.
- Frizon de Lamotte, D., Leturmy, P., Missenard, Y., Khomsi, S., Ruiz, G., Saddiqi, O., Guillocheau, F. & Michard, A. 2009. Mesozoic and Cenozoic vertical movements in the Atlas system (Algeria, Morocco, Tunisia): an overview. *Tectonophysics*, 475 (1): 9-28.
- Fröbisch, J. 2009. Composition and similarity of global anomodont-bearing tetrapod faunas. *Earth Science Reviews*, 95 (3-4): 119-157.
- Fu-ping Pei, Wen-liang Xu, Yang Yu, Quan-guo Zhao & De-bin Yang. 2008. Petrogenesis of the Late Triassic Mayihe pluton in southern Jilin Province: evidence from zircon U-Pb geochronology and geochemistry. *Journal of Jilin University (Earth Science edition)*, 38 (3): 351-362.
- Fürsich, F. T., Wilmsen, M., Seyed-Emami, K. & Majidifard, M. R. 2009. Lithostratigraphy of the Upper Triassic-Middle Jurassic Shemshak Group of northern Iran. Geological Society, London, Special Publications, 312: 129-160.
- Gaetani, G., Angiolini, L., Ueno, K., Nicora, A., Stephenson, M. H., Sciunnach, D., Rettori, R., Price, G. D. & Sabouri, J. 2009. Pennsylvanian-Early Triassic stratigraphy in the Alborz Mountains (Iran). Geological Society, London, Special Publications, 312: 79-128.
- Galeazzi, S., Point, O., Haddadi, N., Mather, J. & Druesne, D. 2010. Regional geology and petroleum systems of the Illizi-Berkine area of the Algerian Saharan Platform: an overview. *Marine and Petroleum Geology*, 27 (1): 143-178.
- Gallois, R. W. 2008. Landslip mechanisms in the Mercia Mudstone Group (Triassic) of the east Devon coast (Abstract). *Geoscience in south-west England*, 12 (1): 66.
- Garassino, A. & Rigo, R. 2008. Pseudopolydora friulana n. sp. (Decapoda, Astacidea, Mecoichiridae) from the Upper Triassic (Carnian) of Dogno (Udine, Friuli-Venezia Giulia, NE Italy). *Atti della Società italiana di Scienze naturali e del Museo Civico di Storia naturale di Milano*, 149 (1): 69-76.
- Gazdzicka, E., Gazdzicki, A., Filipczak, K. & Uchmann, A. 2009. Upper Sub-Tatric (Choc) Nappe between the Lejowa and Chocholowska valleys in the Tatra Mountains. *Przegląd Geologiczny*, 56 (1): 56-63.
- Gawlick, H.-J., Sudar, M., Suzuki, H., Derić, N., Missoni, S., Lein, R. & Jovanovic, D. 2009. Upper Triassic and Middle Jurassic radiolarians from the ophiolitic mélange of the Dinaridic Ophiolite Belt, SW Serbia. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 253 (2-3): 293-311.
- Geng Bin-He, Zhu Min & Jin Fan. 2009. A revision and phylogenetic analysis of Guizhoucoelacanthus (Sarcopterygii, Actinistia) from the Triassic of China. *Vertebrata Palasiatica*, 47 (3): 165-177.
- Gen-ming Luo, Ke-xin Zhang, Qin-xiang Lin, Xiao-hu Kou, Yun-hai Zhu, Ya-dong Xu & Bin Shi. 2007. Sedimentary facies analysis and sedimentary environment reconstruction from Late Permian to Early Triassic of west Qinling area. *Acta Sedimentologica Sinica*, 25

- (3): 332-342.
- Gibling, M. R., Culshaw, N., Rygel, M. C. & Pascucci, V. 2008. The Maritimes Basin of Atlantic Canada: basin creation and destruction in the collisional zone of Pangea. *Sedimentary Basins of the World*, 5: 211-244.
- Gilman, T., Feineman, M. & Fisher, D. 2009. The Chulitna terrane of south-central Alaska: a rifted volcanic arc caught between the Wrangellia composite terrane and the Mesozoic margin of North America. *Geological Society of America Bulletin*, 121 (7-8): 979-991.
- Glen, J. M. G., Nomade, S., Lyons, J. J., Metcalfe, I., Mundil, R. & Renne, P. R. 2009. Magnetostratigraphic correlations of Permian–Triassic marine-to-terrestrial sections from China. *Journal of Asian Earth Sciences*, 36 (6): 521-540.
- González-León, C. M., Valencia, V. A., Lawton, T. F., Amato, J. M., Gehrels, G. E., Leggett, W. J., Montijo-Contreras, O. & Fernández, M. A. 2009. The lower Mesozoic record of detrital zircon U-Pb geochronology of Sonora, México, and its paleogeographic implications. *Revista Mexicana de Ciencias Geológicas*, 26 (2): 310-314.
- Görge, P., Richter, D.K., Götze, T. & Neuser, R.D.: Use of cathodoluminescence in heavy mineral analytics illustrated by the stable mineral group monazite-xenotime-zircon from Triassic sandstones of NE-Bavaria. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 160 (1): 57-68.
- Gorzela, P. & Salamon, M. A. 2008. Bite marks and signs of regeneration on Triassic crinoids from Poland; preliminary data. *Przeegląd Geologiczny*, 56 (10): 885-886.
- Gorzela, P., Jakubczyk, A., Salamon, M. A. & Konieczynski, K. 2008. The oldest Mesozoic asteroid remains from the Lower Muschelkalk (Lower Anisian, Wellenkalk) of the Holy Cross Mountains. *Przeegląd Geologiczny*, 56 (2): 116-117.
- Götz, A. E., Ruckwied, K., Pálffy, J. & Haas, J. 2009. Palynological evidence of synchronous changes within the terrestrial and marine realm at the Triassic/Jurassic boundary (Csovár section, Hungary). *Review of Palaeobotany and Palynology*, 156 (3-4): 401-409.
- Govender, R., Hancox, P. J. & Yates, A.M., 2008. Re-evaluation of the postcranial skeleton of the Triassic dicynodont *Kannemeyeria simocephalus* from the Cynognathus Assemblage Zone (Subzone B) of South Africa. *Palaeontologia Africana*, 43 (1): 19-37.
- Grasby, S. E. & Beauchamp, B. 2009. Latest Permian to Early Triassic basin-to-shelf anoxia in the Sverdrup Basin, Arctic Canada, *Chemical Geology*, 264 (1-4): 232-246.
- Grauvogel-Stamm, L. & Lugardon, B. 2009. Phylogeny and evolution of the horsetails: evidence from spore wall ultrastructure. *Review of Palaeobotany and Palynology*, 156 (1-2): 116-129.
- Greene, A. R., Scoates, J. S., Weis, D. & Israel, S. 2009. Geochemistry of Triassic flood basalts from the Yukon (Canada) segment of the accreted Wrangellia oceanic plateau. *Lithos*, 110 (1-4): 1-19.
- Guan-bang Liu & Gong-Zheng Yin. 2008. Preliminary researches on mixosaurid fossils from Middle Triassic Guanling Formation in Panxian of Guizhou. *Acta Palaeontologica Sinica*, 47 (1): 73-90.
- Guang-fu Zou, Ming-kui Zhou, Tong-xing Zhu, Jian Wang & Xin-tao Feng. 2007. Sedimentary evolution of the Phanerozoic of north slope area of Mount Qomolangma, Tibet. *Journal of Palaeogeography*, 9 (1): 1-12.
- Guo-han Yan, Bao-lei Mu, Yi-shang Zeng, Jian-hui Cai, Kang-xu Ren & Feng-tang Li. 2007. Igneous carbonates in North China Craton: the temporal and spatial distribution, Sr and Nd isotopic characteristics and their geological significance. *Geological Journal of China Universities*, 13 (3): 463-473.
- Guo Shi, Jing-chun Tian & Mei-yi Yu. 2008. Sedimentary features of carbonate breccia wedges of the Early-Middle Triassic in Huaxi area, Guiyang City. *Journal of Palaeogeography*, 10 (5): 521-528.
- Haas, J., Piro, O. & Lobitzer, H. 2008. Bericht 2008 über Paläokarst-Phänomene im zyklischen Dachsteinkalk der Grotl-Rast auf dem Dachstein Plateau auf Blatt 96 Bad Ischl. *Jahrbuch der Geologischen Bundesanstalt*, Wien, 148 (2): 282-283.
- Haas, J., Piro, O., Görög, A. & Lobitzer, H. 2009. Paleokarst phenomena and peritidal beds in the cyclic Dachstein Limestone on the Dachstein Plateau (Northern Calcareous Alps, Upper Austria). *Jahrbuch der Geologischen Bundesanstalt*, Wien, 149 (1): 7-21.
- Hai-feng Yang, Guang-di Liu, De-wen Lei, Yong-qing, Han, Zhi-long Huang & Gang Guo. 2008. Differences between oil and gas accumulations in Zhongguai, 5th & 8th districts of Karamay oil field, northwestern margin of Junggar Basin. *Geological Journal of China Universities*, 14 (2): 262-268.
- Haijun Song, Jinnan Tong, Chen, Z. Q., Hao Yang & Yongbiao Wang. 2009.
- End-Permian mass extinction of foraminifers in the Nanpanjiang basin, South China. *Journal of Paleontology*, 83 (5): 718-738.
- Harfoot, M. B., Pyle, J. A. & Beerling, D. J. 2008. End-Permian ozone shield unaffected by oceanic hydrogen sulphide and methane releases. *Nature Geosciences*, 1 (4): 247 – 252.
- Hays, L. E., Beatty, T., Henderson, C. M., Love, G. D. & Summons, R. E. 2009. Corrigendum to “Evidence for photic zone euxinia through the end-Permian mass extinction in the Panthalassic Ocean (Peace River Basin, Western Canada)”. *Palaeoworld*, 18 (1): 74-75.
- Hayward, B. W. 2009. Protecting fossil sites in New Zealand. *Carnets de Géologie*, Book 2009/3: 49-64
- Helmkamp, K. E. 2006. Profilvergleich und sedimentologische Entwicklung im Umkreis der Forschungsbohrungen Spitzzeichen 1 und Lindau I. *Geologica Bavarica*, 109: 63-94.
- Hennig, D., Lehmann, B., Frei, D., Belyatsky, B., Zhao, X. F., Cabral, A. R., Zeng, P. S., Zhou, M. F. & Schmidt, K. 2009. Early Permian seafloor to continental arc magmatism in the eastern Paleo-Tethys: U-Pb age and

- Nd-Sr isotope data from the southern Lancangjiang zone, Yunnan, China. *Lithos*, 113 (3-4): 408-422.
- Herbst, R. 2007. *Millerocaulis* (Erasmus) ex Tidwell (Osmundales, Filices) de la Formación Carrizal (Triásico Superior) de Marayes, provincia de San Juan, Argentina. *Revista del Museo Argentino de Ciencias Naturales*, n.s.8 (2): 185-193.
- Heydari, E., Arzani, N. & Hassanzadeh, J. 2009. Reply to comment on "Mantle plume: the invisible serial killer – application to the Permian-Triassic boundary mass extinction", by E. Heydari, N. Arzani and J. Hassanzadeh [Palaeogeography, Palaeoclimatology, Palaeoecology, 264 (2008) 147-162]. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 283 (1-2): 102-105.
- Hips, K. & Haas, J. 2009. Facies and diagenetic evaluation of the Permian–Triassic boundary interval and basal Triassic carbonates: shallow and deep ramp sections, Hungary. *Facies*, 55 (3): 421-442.
- Hoeck, V., Ionescu, C., Balintoni, I. & Koller, F. 2009. The Eastern Carpathians "ophiolites" (Romania): remnants of a Triassic ocean. *Lithos*, 108 (1-4): 151-171.
- Holford, S. P., Green, P. F., Hillis, R. R., Turner, J. P. & Stevenson, C. T. E. 2009. Mesozoic–Cenozoic exhumation and volcanism in Northern Ireland constrained by AFTA and compaction data from Larne No. 2 borehole. *Petroleum Geoscience*, 15 (3): 239-257.
- Hong-fei Zhang, Jing Wang, Wang-chun Xu & Hong-lin Yuan. 2007. Derivation of adakitic magma by partial melting of subducted continental crust. *Geological Journal of China Universities*, 13 (2): 224-234.
- Hong-xia Jiang, Ya-sheng Wu & Sheng-hu Yuan. 2007. Desiccation cracks and erosional surface in the Permian-Triassic boundary section in Chongqing. *Geological Journal of China Universities*, 13 (1): 53-59.
- Horacek, M., Koike, T. & Richoz, S. 2009. Lower Triassic  $\delta^{13}\text{C}$  isotope curve from shallow-marine carbonates in Japan, Panthalassa realm: confirmation of the Tethys  $\delta^{13}\text{C}$  curve. *Journal of Asian Earth Sciences*, 36 (6): 481-490.
- Hori, R. S., Yamakita, S. & Dumitrica, P. 2009. Late Triassic phaeodarian Radiolaria from the Northern Chichibu Belt, Shikoku, Japan. *Paleontological Research*, 13 (1): 53-63.
- Hu Bin, Yang Wen-tao, Song Hui-bo, Wang Min & Zhong Min-yang. 2009. Trace fossils and ichnofabrics in the Heshanggou Formation of lacustrine deposits, Jiyaun area, Henan Province. *Acta Sedimentologica Sinica*, 27 (4): 573-582.
- Hui-ping Han, Chun-ying Wu, Ji-hui Jiang, Yong Li, Bao-qing Wang & Hai-kun Ji. 2008. Characteristics and main controlling factors of Chang-6 reservoir of Triassic Yanchang Formation in Dalugou area, Ordos Basin. *Journal of Earth Sciences and Environment*, 30 (2): 149-155.
- Ilyina, N. V. 2008. The lower and middle Triassic boundary in the Timan-Northern Ural region. *Stratigraphy and sedimentology of oil-gas basins*, 2008/1: 15-30.
- Ingersoll, R. V. 2008. Subduction-related sedimentary basins of the USA Cordillera. *Sedimentary Basins of the World*, 5: 395-428.
- Isozaki, Y. 2009. Integrated "plume winter" scenario for the double-phased extinction during the Paleozoic–Mesozoic transition: the G-LB and P-TB events from a Panthalassan perspective. *Journal of Asian Earth Sciences*, 36 (6): 459-480.
- Jahn, B. M., Litvinovsky, B. A., Zandvilevich, A. N. & Reichow, M. 2009. Peralkaline granitoid magmatism in the Mongolian-Transbaikalian Belt: evolution, petrogenesis and tectonic significance. *Lithos*, 113 (3-4): 521-539.
- Janevski, G. A. & Baumiller, T. K. 2009. Evidence for extinction selectivity through the marine invertebrate fossil record. *Paleobiology*, 35 (4): 553-564.
- Ji-wei Liang, Li Xiao, Xiao-lin Gao & Wen-ming Yang. 2008. Source analysis during the early Late Triassic in Ordos Basin. *Northwestern Geology*, 41 (2): 81-86.
- Jian Wang, Xiu-gen Fu, Wen-xi Chen & Zheng-jiang Wang. 2007. The Late Triassic paleo-weathering crust in the Qiangtang Basin, northern Tibet: geology, geochemistry and significance. *Acta Sedimentologica Sinica*, 25 (4): 487-494.
- Jian-bo Liu, Yoichi, E., Shou-ren Yang, Hai-feng Wang & Natsuko, A. 2007. Age and sedimentology of microbialites after the end-Permian Mass Extinction in Luodian, Guizhou Province. *Journal of Palaeogeography*, 9 (5): 473-486.
- Jian-cheng Jia. 2008. Tectonopalaeogeographic characteristics and evolution of the Mesozoic in Eastern Qiangtang Basin, Tibet. *Journal of Palaeogeography*, 10 (6): 613-625.
- Jiangfeng Qin, Shaocong Lai, Grapes, R., Chunrong Diwu, Yinjuan Ju & Yongfei Li. 2009. Geochemical evidence for origin of magma mixing for the Triassic monzonitic granite and its enclaves at Mishuling in the Qinling orogen (central China). *Lithos*, 112 (3-4): 259-276.
- Jian-feng Zhang, Han-ning Wu, Chun-hua Xu & Bo Dong. 2008. Preliminary evaluation of the Upper Triassic source rocks in Rujigou area and Zhongwei prospecting area of Helan mountains. *Journal of Palaeogeography*, 10 (5): 481-486.
- Jian-min Liu, Yue Zhao, Ya-li Sun, Dun-peng Li, Jian Liu, Bai-lin Chen, Shuan-hong Zhang & Wei-dong Sun. 2010. Recognition of the latest Permian to Early Triassic Cu-Mo mineralization on the northern margin of the North China block and its geological significance. *Gondwana Research*, 17 (1): 125-134.
- Jiarun Yin. 2007. A review on Jurassic sea-level changes in Himalayan Tibet. *Beringeria*, 37: 253-266.
- Jin-cai Lu, Xian-wang Wei, Yu-hong Li & Jian-she Wei. 2009. Gas production rate: the key index for evaluation of industrial values of oil shale-case on He 1 Well in Triassic Yanchang Formation in Ordos Basin. *Journal of Jilin University (Earth Science edition)*, 39 (1): 60-64.
- Jin-hai Yu, Li-juan Wang, Zhen-yang Wei, Tao Sun & Liang-shu Shu. 2007. Phanerozoic metamorphic episodes and characteristics of Cathaysia Block. *Geological Journal of China Universities*, 13 (3): 474-483.

- Jin-hua Liu, Shi-qi Zhang, Yao-ting Sun & Chui-gao Wei. 2007. Correlation and evolution of the Upper Triassic Xujiahe Formation in the west Sichuan Foreland Basin. *Journal of Stratigraphy*, 31 (2): 190-196.
- JinHui Yang & FuYuan Wu. 2009. Triassic magmatism and its relation to decratonization in the eastern North China Craton. *Science in China Series D: Earth Sciences*, 52 (9): 1319-1330.
- Jin-peng Wang, Shi-mi Peng, Ji-an Shi, Qi Wang & Xue-lian Guo. 2008. Reservoir characteristics and its main controlling factors of Chang 6-Chang 8 Formation in Longdong, Ordos Basin. *Xinjiang Geology*, 26 (2): 163-166.
- Jing-shan Chen, Yan Zhuo, Jun Peng, Xiu-cheng Tan, Ming-xin Wang & Ying-chun Gou. 2007. Genetic type and intraformational heterogeneity pattern of low-porosity and low-permeability sandbodies in Fuxian exploration area. *Acta Sedimentologica Sinica*, 25 (1): 53-58.
- Jingsui Yang, Rendeng Shi, Cailai Wu, Xibin Wang & Robinson, P. T. 2009. Dur'ngoi ophiolite in east Kunlun, northeast Tibetan plateau: evidence for paleo-Tethyan suture in northwest China. *Journal of Earth Science*, 20 (2): 303-331.
- Jing Sun, Zhan-kui Jin & Chun-sheng Wang. 2008. A sedimentary facies research on the Lower Karamay Formation of the Triassic, Ba'Er Zone in the northeastern Junggar Basin. *Xinjiang Geology*, 26 (4): 373-376.
- Jin-wen Mao, Gui-qing, Xie, Chun-li Guo, Shun-da Yuan, Yan-bo Cheng & Yu-chuan Chen. 2008. Spatial-temporal distribution of Mesozoic ore deposits in South China and their metallogenic settings. *Geological Journal of China Universities*, 14 (4): 510-526.
- Jinxing Dai, Yunyan Ni, Caineng Zou, Shizhen Tao, Guoyi Hu, Anping Hu, Chun Yang & Xiaowan Tao. 2009. Stable carbon isotopes of alkane gases from the Xujiahe coal measures and implication for gas-source correlation in the Sichuan Basin, SW China. *Organic Geochemistry*, 40 (5): 638-646.
- Jordán, M. M., Martín-Martín, J., D., Sanfeliu, T., Gómez-Gras, D. & de la Fuente, C. 2009. Mineralogy and firing transformations of Permo-Triassic clays used in the manufacturing of ceramic tile bodies. *Applied Clay Science*, 44 (1-2): 173-177.
- Jourdan, F., Marzoli, A., Bertrand, H., Cirilli, S., Tanner, L. H., Kontak, D. J., McHone, G., Renne, P. R. & Bellieni, G. 2009.  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of CAMP in North America: implications for the Triassic-Jurassic boundary and the 40K decay constant bias. *Lithos*, 110 (1-4): 167-180.
- Joyce, W. G., Lucas, S. G., Scheyer, T. M., Heckert, A. B. & Hunt, A. P. 2009. A thin-shelled reptile from the Late Triassic of North America and the origin of the turtle shell. *Proceedings of the Royal Society of London B*, 276 (1656): 507-513.
- Juan-ping Feng, Wen-hou Li, Zheng-jian Ouyang, Fang Yu, Hong-xiao Cao & Yang Zhao. 2008. Major factors controlling reservoir quality of the Upper Triassic Chang 2 sandstones in the Qinghuabian Oilfield, Northern Shaanxi. *Journal of Jilin University (Earth Science edition)*, 38 (3): 417-424.
- Jun Chen, Henderson, C. M. & Shu-zhong Shen. 2008. Conodont succession around the Permian-Triassic boundary at the Huangzhishan section, Zhejiang and its stratigraphic significance. *Acta Palaeontologica Sinica*, 47 (1): 91-114.
- Jun Chen, Beatty, T. W., Henderson, C. M. & Rowe, H. 2009. Conodont biostratigraphy across the Permian-Triassic boundary at the Dawen section, Great Bank of Guizhou, Guizhou Province, South China: implications for the Late Permian extinction and correlation with Meishan. *Journal of Asian Earth Sciences*, 36 (6): 442-458.
- Kaiho, K., Chen, Z. Q. & Sawada, K. 2009. Possible causes for a negative shift in the stable carbon isotope ratio before, during and after the end-Permian mass extinction in Meishan, South China. *Australian Journal of Earth Sciences*, 56 (6): 799-808.
- KaiJun Zhang & XianChun Tang. 2009. Eclogites in the interior of the Tibetan Plateau and their geodynamic implications. *Chinese Science Bulletin*, 54 (15): 2556-2567.
- Kakuwa, Y. 2004. Trace fossils from the Triassic-Jurassic deep water, oceanic radiolarian chert successions of Japan. *Fossils and Strata*, 51: 58-67.
- Kakuwa, Y. 2009. Reply to the comments of Kato and Isozaki on "Evaluation of palaeo-oxygenation of the ocean bottom across the Permian-Triassic boundary" by Y. Kakuwa [*Global Planet. Change* 63 (2008) 40-56]: was the Late Permian deep-superocean really oxyc? *Global and Planetary Change*, 69 (1-2): 82-86.
- Karcz, P. 2009. Organic matter content and petrographical characteristics of the Middle Triassic black facies of western Spitsbergen. *Przeegl?d Geologiczny*, 57 (4): 302-303.
- Karcz, P. 2009. Sedimentary environment and early diagenesis of the Passhatten Member black shales (Middle Triassic, Spitsbergen, Svalbard) in the light of geochemical analysis. *Przeegl?d Geologiczny*, 57 (10): 918-926.
- Karl, H.-V. & Tichy, G. 2006. On the stratigraphic youngest occurrence (Lower Keuper) of *Nothosaurus* (Diapsida: Sauropterygia) in Thuringia. *Studia Geologica Salmanticensia*, 42: 61-66.
- Katemaunzanga, D. & Gunter, C. J. 2009. Lithostratigraphy, sedimentology, and provenance of the Balfour Formation (Beaufort Group) in the Fort Beaufort-Alice area, Eastern Cape Province, South Africa. *Acta Geologica Sinica*, 83 (5): 902-916.
- Kato, Y. & Isozaki, Y. 2009. Comment on "Evaluation of palaeo-oxygenation of the ocean bottom cross the Permian-Triassic boundary" by Kakuwa (2008): was the Late Permian deep-superocean really oxyc? *Global and Planetary Change*, 69 (1-2): 79-81.
- Kaufmann, B. 2009. The Steinplatte complex (Late Triassic, Northern Calcareous Alps, Austria) - subsidence-controlled development of a carbonate-platform-to-

- intrashelf-basin-transition. *Acta Geologica Polonica*, 59 (3): 341-357.
- Kear, B. P. 2009. Proterosuchid archosaur remains from the Early Triassic Bulgo Sandstone of Long Reef, New South Wales. *Alcheringa*, 33 (4): 331 – 337.
- Kearsey, T., Twitchett, R. J., Price, G. D. & Grimes, S. T. 2009. Isotope excursions and palaeotemperature estimates from the Permian/Triassic boundary in the Southern Alps (Italy). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 279 (1-2): 29-40.
- Kenter, J. A. M. & Schlager, W. 2009. Slope angle and basin depth of the Triassic platform-basin transition at the Gosaukamm, Austria. *Austrian Journal of Earth Sciences*, 102 (1): 15-22.
- Kershaw, S., Crasquin, S., Collin, P.-Y., Li, Y., Feng, Q. & Forel, M.-B. 2009. Microbialites as disaster forms in anachronistic facies following the end-Permian mass extinction: a discussion. *Australian Journal of Earth Sciences*, 56 (6): 809-813.
- Kiessling, W., Aberhan, M. & Villier, L. 2008. Phanerozoic trends in skeletal mineralogy driven by mass extinctions. *Nature Geoscience*, 1 (8): 527 – 530.
- Kiessling, W., Roniewicz, E., Villier, L., Léonide, P. & Struck, U. 2009. An early Hettangian coral reef in southern France: implications for the end-Triassic reef crisis. *Palaios*, 24 (10): 657-671.
- Klein, N. 2009. Skull morphology of *Anarosaurus heterodontus* (Reptilia: Sauropterygia: Pachypleurosauria) from the Lower Muschelkalk of the Germanic Basin (Winterswijk, the Netherlands). *Journal of Vertebrate Paleontology*, 29 (3): 665-676.
- Klootwijk, C. 2009. Sedimentary basins of eastern Australia: paleomagnetic constraints on geodynamic evolution in a global context. *Australian Journal of Earth Sciences*, 56 (3): 273-308.
- Knaust, D. 2009. Ichnology as a tool in carbonate reservoir characterization: a case study from the Permian – Triassic Khuff Formation in the Middle East. *GeoArabia*, 14 (3): 17-38.
- Koglin, N., Kostopoulos, D. & Reischmann, T. 2009. The Lesvos mafic-ultramafic complex, Greece: ophiolite or incipient rift? *Lithos*, 108 (1-4): 243-261.
- Kolar-Jurkovšek, T., & Jurkovšek, B. 2009. Holothurian sclerites of Carnian strata in the Mežica area, Slovenia. *Geologija*, 52 (1): 5-10.
- Kondo, Y. & Sano, S.-I. 2009. Origination of extant heteroconch families: ecological and environmental patterns in post-Paleozoic bivalve diversification. *Paleontological Research*, 13 (1): 39-44.
- Konstantinov, K. M. & Gladkov, A. S. 2009. Petromagnetic heterogeneities in sintering zones of Permian-Triassic traps of Komsomolsk pipe deposit (Yakutsk diamond province). *Doklady Earth Sciences*, 427 (1): 880-886.
- Konstantinov, A. G. & Klets, T. V. 2009. Stage boundaries of the Triassic in northeast Asia. *Stratigraphy and Geological Correlation*, 17 (2): 173-191.
- Korsch, R. J. & Totterdell, J. M. 2009. Subsidence history and basin phases of the Bowen, Gunnedah and Surat Basins, eastern Australia. *Australian Journal of Earth Sciences*, 56 (3): 335-353.
- Korsch, R. J., Totterdell, J. M., Fomin, T. & Nicoll, M. G. 2009. Contractional structures and deformational events in the Bowen, Gunnedah and Surat Basins, eastern Australia. *Australian Journal of Earth Sciences*, 56 (3): 477-499.
- Korte, C., Hesselbo, S. P., Jenkyns, H. C., Rickaby, R. E. M. & Spötl, C. 2009. Palaeoenvironmental significance of carbon- and oxygen-isotope stratigraphy of marine Triassic-Jurassic boundary sections in SW Britain. *Journal of the Geological Society, London*, 166 (3): 431-445.
- Kovacevic, J., Nikic, Z. & Papic, P. 2009. Genetic model of uranium mineralization in the Permo-Triassic sedimentary rocks of the Stara Planina eastern Serbia. *Sedimentary Geology*, 219 (1-4): 252-261.
- Kovalenko, V. I., Yarmolyuk, V. V. & Bogatkov, O. A. 2009. The recent supercontinent in the northern hemisphere of the Earth (North Pangea): magmatic and geodynamic evolution. *Doklady Earth Sciences*, 427 (2): 897-901.
- Kowal-Linka, M. 2008. Formalizacja litostratygrafii formacji gogoli?skiej (trias ?rodkowy) na ?l?sku Opolskim. *Geologos*, 14 (2): 125-161.
- Kozur, H. W., Moix, P. & Ozsvart, P. 2009. New Spumellaria (Radiolaria) from the Early Tuvolian Spongortilispinus moixi Zone of southeastern Turkey, with some remarks on the age of this fauna. *Jahrbuch der Geologischen Bundesanstalt, Wien*, 149 (1): 25-59.
- Krajewski, K. P. 2009. The Botneheia Formation (Middle Triassic) in Edgeøya and Barentsøya, Svalbard: lithostratigraphy, facies, phosphogenesis, paleoenvironment. *Polish Polar Research*, 29 (4): 319-364.
- Krajewski, K. P., Karcz, P., Wo?ny, E. & Mørk, A. 2007. Type section of the Bravaisberget Formation (Middle Triassic) at Bravaisberget, western Nathorst Land, Spitsbergen, Svalbard. *Polish Polar Research*, 28 (2): 79-122.
- Krajewski, K. P. & Wozny, E. 2009. Origin of dolomite-ankerite cement in the Bravaisberget Formation (Middle Triassic) in Spitsbergen, Svalbard. *Polish Polar Research*, 30 (3): 231-248.
- Krapovickas, V., Mángano, M. G., Mancuso, A., Marsicano, C. A. & Volkheimer, W. 2008. Triassic ichnofaunas in distal alluvial fans: evidence from the Cerro Puntudo Formation, Cuyo Basin, Argentina. *Ameghiniana*, 45 (2): 463-472.
- Kraus, S. H., Siegert, S., Mette, W., Struck, U. & Korte, C. 2009. Stratigraphic significance of carbon isotope variations in the shallow-marine Seis/Siusi Permian-Triassic boundary section (Southern Alps, Italy). *Fossil Record*, 12 (2): 197-205.
- Krystyn, L. & Mandl, G. W. (eds). 2008-2009. Upper Triassic subdivisions, zonations and events: meeting of the late IGCP 467 and STS, September 28th - October 2nd 2008, Bad Goisern (Upper Austria): Abstracts and Excursion-Guide. *Berichte der Geologischen Bundesanstalt Wien*, 76: 116pp.

- Krystyn, L., Mandl, G. W. & Schauer, M. 2009. Growth and termination of the Upper Triassic platform margin of the Dachstein area (Northern Calcareous Alps, Austria). *Austrian Journal of Earth Sciences*, 102 (1): 23-33.
- Krzywiec, P. 2009. Devonian–Cretaceous repeated subsidence and uplift along the Teisseyre–Tornquist zone in SE Poland - insight from seismic data interpretation. *Tectonophysics*, 475 (1): 142-159.
- Kubo, T. & Benton, M. J. 2009. Tetrapod postural shift estimated from Permian and Triassic trackways. *Palaeontology*, 52 (5): 1029-1037.
- Kukhtinov, D. A., Lozovsky, V. R., Afonin, S. A. & Voronkova, E. A. 2008. Non-marine ostracods of the Permian-Triassic transition from sections of the east European Platform. *Bolletino della Società Geologica Italiana*, 127 (3): 717-726.
- Kusunoki, T., Musashino, M. & Imoto, N. 2007. "Triassic sedimentary complexes on the paper "Upper Permian Takatsuki Formation, Middle Triassic Shimamoto Formation and Triassic sedimentary complex in the Nishiyama area, Osaka and Kyoto Prefectures, SW Japan". *Journal of the Geological Society of Japan*, 113 (1): 33-35.
- Kustatscher, E. & van Konijnenburg-van Cittert, J. H. A. 2008. Considerations on *Phylladelphia strigata* Bronn from the historical Raibl flora (Carnian, lower Upper Triassic, Italy). *Geo. Alp.*, 5: 69–81.
- Kustatscher, E., Hemsley, A. & van Konijnenburg-van Cittert, J. H. A. 2009. *Lugardonia paradoxa* gen. et sp. nov., a new strobilus from the Anisian flora of Kühwiesenkopf, the Dolomites, Italy and its affinities with emphasis on spore ultrastructure. *Review of Palaeobotany and Palynology*, 156 (1-2): 90-97.
- Laas, M., Hampe, O., Schudack, M., Kardjilov, N. & Hilger, A. 2009. Why *Lystrosaurus* survived the Late Permian mass extinction. 7th Annual Meeting of the European Association of Vertebrate Palaeontologists, Berlin. Abstracts volume: 40.
- Larsson, L. L. 2009. Palynostratigraphy of the Triassic-Jurassic transition in southern Sweden. *GFF*, 131 (1-2): 147-163.
- Ledneva, G. V. & Matukov, D. I. 2009. Timing of crystallization of plutonic rocks from the Kuyul ophiolite terrane (Koryak highland): U-Pb microprobe (SHRIMP) zircon dating. *Doklady Earth Sciences*, 424 (1): 11-14.
- Leleu, S., Hartley, A. J. & Williams, B. J. P. 2009. Large-scale alluvial architecture and correlation in a Triassic pebbly braided river system, Lower Wolfville Formation (Fundy Basin, Nova Scotia, Canada). *Journal of Sedimentary Research*, 79 (5): 265-286.
- Le Loeuff, J., Saenyamoon, T., Souillat, C., Suteethorn, V. & Buffetaut, E. 2009. Mesozoic vertebrate footprints of Thailand and Laos. *Geological Society, London, Special Publications*, 315: 245-254.
- Li Chun. 2007. A juvenile *Tanystropheus* sp. (Protosauria, Tanystropheidae) from the Middle Triassic of Guizhou, China. *Vertebrata Palasiatica*, 45 (1): 37-42.
- Lian-xing Gu, Chang-zhi Wu, Zun-zhong Zhang, Xiao-qin Gou, Si-hai Liu, Yuan-chuan Zheng & Guang-hui Zhang. 2007. Geochemistry of the Baishitouquan topaz-bearing amazonite granite: zoning and magma evolution. *Geological Journal of China Universities*, 13 (2): 207-223.
- Li-de Chen & Cheng-yuan Wang. 2009. Conodont-based age of the Triassic Yangliujing Formation in SW Guizhou, China. *Journal of Stratigraphy*, 33 (1): 98-103.
- Li-jun Zhao & Li-wu Lu. 2007. A new genus of Early Triassic perleidid fish from Changxing, Zhejiang, China. *Acta Palaeontologica Sinica*, 46 (2): 238-243.
- Li-jun Zhao, Li-ting Wang & Chun Li. 2008. Studies of the Triassic marine reptiles of China: a review. *Acta Palaeontologica Sinica*, 47 (2): 232-239.
- Li-ming Ji, You-hua Zhu & Shao-fei Wang. 2008. Studies of modality assemblage of *Botryococcus* from the Triassic Yanchang Formation in the Ordos Basin, northwest China. *Acta Palaeontologica Sinica*, 47 (2): 185-194.
- Li-ming Ji, Zhi-guang Song & Jian-feng Li. 2008. Characteristic of biomarkers originating from *Botryococcus* in the Triassic lacustrine hydrocarbon source rocks and crude oils in the Ordos Basin. *Acta Micropalaeontologica Sinica*, 25 (3): 281-290.
- Lingsen Zeng, Jing Liu, Li'e Gao, Fangyuan Chen & Kejia Xie. 2009. Early Mesozoic high-pressure metamorphism within the Lhasa Block, Tibet and implications for regional tectonics. *Earth Science Frontiers*, 15 (2): 140-151.
- Lin-lin Kou, Kang-hui Zhong, Ju-xing Tang, Zhao-chang Liu, Shu-yi Dong & Bo Xie. 2009. Geochemistry discrimination of Late Triassic volcanic rocks in Changdu-Simao tectonic zone. *Northwestern Geology*, 42 (1): 79-87.
- Linol, B., Bercovici, A., Bourquin, S., Diez, J. B., López-Gómez, J., Broutin, J., Durand, M. & Villanueva-Amadoz, U. 2009. Late Permian to Middle Triassic correlations and palaeogeographical reconstructions in south-western European basins: new sedimentological data from Minorca (Balearic Islands, Spain). *Sedimentary Geology*, 220 (1-2): 77-94.
- Li Shu-tong, Wang Duo-yun, Tao Hui-fei, Wang Bin, He Shan-bin, Luan Qin & Zhu Xiao-yao. 2009. The lake distribution and evolution law of the Ordos Basin in the Triassic period. *Acta Sedimentologica Sinica*, 27 (1): 1-8.
- Liu-xiang Ji, Wei Luo, Huai-cheng Zhu & Shu Ouyang. 2008. Middle Triassic spore-pollen assemblages from northern Qilian, Qinghai and their significance in sedimentology. *Acta Palaeontologica Sinica*, 47 (1): 58-72.
- Long Jin & Xiao-qi Ding. 2009. Research on sedimentary facies of the Chang-8 Member of the Yanchang Formation in Zhenjing oilfield, Ordos Basin. *Xinjiang Geology*, 27 (2): 160-163.
- Long-yi Shao, Jing Lu, Long-ming Ran, Shi-cai Su, Ke-min Wei, Ying-zhu Sun, Jiang-feng Chen & Xiao-hui Yu. 2008. Late Triassic sequence stratigraphy and coal accumulation in Baoding Basin of Sichuan Province. *Journal of Palaeogeography*, 10 (4): 355-361.

- Lucas, S. G. 2009. Timing and magnitude of tetrapod extinctions across the Permo-Triassic boundary. *Journal of Asian Earth Sciences*, 36 (6): 491-502.
- Luo Bing, Tan Xiu-cheng, Liu Hong, Li Ling, Xia Ji-wen, Zou Juan & Hai Tao. 2009. Genetic mechanism analysis on oolitic reservoir of Lower Triassic Feixianguan Formation in the Shunan area, Sichuan Basin. *Acta Sedimentologica Sinica*, 27 (3): 404-409.
- Ma Qiang, Qu Hong-jun, Yan Yao-zu, Hu Chun-hua & Bai Guo-juan. 2009. Study on sedimentary microfacies and its oil-bearing properties in Chang 6 Member in the middle part of Yi-Shan slope in Ordos Basin. *Acta Sedimentologica Sinica*, 27 (3): 443-451.
- Mackintosh, P. W. & Robertson, A. H. F. 2009. Structural and sedimentary evidence from the northern margin of the Tauride platform in south central Turkey used to test alternative models of Tethys during Early Mesozoic time. *Tectonophysics*, 473 (1-2): 149-172.
- Mancuso, A. C. 2009. Taphonomic analysis in lacustrine environments: two different contexts for Triassic lake paleofloras from Western Gondwana (Argentina). *Sedimentary Geology*, 222 (1-2): 149-159.
- Mao Luo, Guo Shi & Yi-ming Gong. 2007. Early Triassic trace fossils in Huaxi region of Guiyang and their implications for biotic recovery after the end-Permian Mass Extinction. *Journal of Palaeogeography*, 9 (5): 519-532.
- Marshall, C. R. & Jacobs, D. K. 2009. Flourishing after the end-Permian mass extinction. *Science*, 325 (5944): 1079-1080.
- Martinelli, A. G., de la Fuente, M. & Abdala, F. 2009. *Diademodon tetragonus* Seeley, 1894 (Therapsida: Cynodontia) in the Triassic of South America and its biostratigraphic implications. *Journal of Vertebrate Paleontology*, 29 (3): 852-862.
- Martini, R., Peybernés, B. & Moix, P. 2009. Late Triassic foraminifera in reefal limestones of SW Cyprus. *Journal of Foraminiferal Research*, 39 (3): 218-230.
- Martín-Closas, C., Jurkovšek, B. & Kolar-Jurkovšek, T. 2009. Triassic charophytes from Slovenia: palaeogeographic implications. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 252 (2): 249-255.
- Martin-Rojas, I., Somma, R., Delgado, F., Estévez, A., Iannace, A., Perrone, V. & Zamparelli, V. 2009. Triassic continental rifting of Pangaea: direct evidence from the Alpujarride carbonates, Betic Cordillera, SE Spain. *Journal of the Geological Society, London*, 166 (3): 447-458.
- Mata, S. A. & Bottjer, D. J. 2009. The paleoenvironmental distribution of Phanerozoic wrinkle structures. *Earth Science Reviews*, 96 (3): 181-195.
- Maurer, F., Martini, R., Rettori, R., Hillgärtner, H. & Cirilli, S. 2009. The geology of Khuff outcrop analogues in the Musandam Peninsula, United Arab Emirates and Oman. *GeoArabia*, 14 (3): 125-158.
- Mayhew, P. J., Jenkins, G. B. & Benton, T. G. 2008. A long-term association between global temperature and biodiversity, origination and extinction in the fossil record. *Proceedings of the Royal Society of London B*, 275 (1630): 47-53.
- McElwain, J. C., Wagner, P. J. & Hesselbo, S. P. 2009. Fossil plant relative abundances indicate sudden loss of Late Triassic biodiversity in East Greenland. *Science*, 324 (5934): 1554-1556.
- McGowan, A. 2009. The ammonoid hunter in the snow: a wintry fieldtrip around the Trias of Jena. *Palaeontological Association Newsletter*, 70: 71-74.
- McGowan, A. J., Smith, A. B. & Taylor, P. D. 2009. Faunal diversity, heterogeneity and body size in the Early Triassic: testing post-extinction paradigms in the Virgin Limestone of Utah, USA. *Australian Journal of Earth Sciences*, 56 (6): 859-872.
- Mehrotra, N. C., Aswal, H. S., Singh, K. & Raju, D. S. N. 2008. High resolution biostratigraphy of petroliferous basins of India based on dinoflagellate cysts with supportive spores-pollen data. *Geological Society of India Memoir*, 17: 45-65.
- Metcalf, I. 2009. Late Palaeozoic and Mesozoic tectonic and palaeogeographical evolution of SE Asia. *Geological Society, London, Special Publications*, 315: 7-23.
- Metcalf, I. & Isozaki, Y. 2009. Current perspectives on the Permian–Triassic boundary and end-Permian mass extinction: Preface. *Journal of Asian Earth Sciences*, 36 (6): 407-412.
- Metcalf, I., Foster, C. B., Afonin, S. A., Nicoll, R. S., Mundil, R., Wang Xiaofeng & Lucas, S. G. 2009. Stratigraphy, biostratigraphy and C-isotopes of the Permian–Triassic non-marine sequence at Dalongkou and Lucaogou, Xinjiang Province, China. *Journal of Asian Earth Sciences*, 36 (6): 503-520.
- Mette, W. 2008. Upper Permian and lowermost Triassic stratigraphy, facies and ostracods in NW Iran – implications for the P/T extinction event. *Stratigraphy*, 5 (2): 205-219.
- Meyer, C. A., Thüring, B., Costeur, L. & Thüring, S. 2009. The early rise of sauropods – evidence from the Late Triassic of the eastern Swiss Alps. 7th Annual Meeting of the European Association of Vertebrate Palaeontologists, Berlin. Abstracts volume: 48.
- Miall, A. D. 2008. The Paleozoic Western Craton margin. *Sedimentary Basins of the World*, 5: 181-209.
- Miall, A. D. 2008. The southern Midcontinent, Permian Basin, and Ouachitas. *Sedimentary Basins of the World*, 5: 297-327.
- Miall, A. D., Balkwill, H. R. & McCracken, J. 2008. The Atlantic margin basins of North America. *Sedimentary Basins of the World*, 5: 473-504.
- Miall, A. D. & Blakey, R. C. 2008. The Phanerozoic tectonic and sedimentary evolution of North America. *Sedimentary Basins of the World*, 5: 1-29.
- Mikami, T., Ishida, K., & Suzuki, S. 2008. Conodont biostratigraphy across the Carnian-Norian boundary in the Jifukudani Creek, Tamba Terrane, SE Kyoto, Japan. *Stratigraphy*, 5 (2): 163-178.
- Milà, J. & Gierlinski, G. 2004. A probable thyreophoran (Dinosauria, Ornithischia) footprint from the Upper



- Triassic of southern Sweden. *Bulletin of the Geological Society of Denmark*, 51 (1): 71–75.
- Miller, A. I., Aberhan, M., Buick, D. P., Bulinski, K. V., Ferguson, C. A., Hendy, A. J. W. & Kiessling, W. 2009. Phanerozoic trends in the global geographic disparity of marine biotas. *Paleobiology*, 35 (4): 612-630.
- Ming-hua Tao, Bo Li, Shu-ping He, Gui-qin Hu & Wen-bo Ren. 2009. The Triassic strata in the Erlian Basin, Inner Mongolia. *Journal of Stratigraphy*, 33 (3): 260-267.
- Mogutcheva, N. K. & Krugovykh, V. V. 2009. New data on the stratigraphic chart for Triassic deposits in the Tunguska syncline and Kuznetsk basin. *Stratigraphy and Geological Correlation*, 17 (5): 510-518.
- Montenat, C. 2009. The Mesozoic of Afghanistan. *GeoArabia*, 14 (1): 147-210.
- Moore, A. E., Cotterill, F. P. D., Broderick, T. & Plowes, D. 2009. Landscape evolution in Zimbabwe from the Permian to present, with implications for kimberlite prospecting. *South African Journal of Geology*, 112 (1): 65-88.
- Morton, N. 2008. The International Commission on Jurassic Stratigraphy. *Proceedings of the Geologists' Association*, 119 (1): 97-103.
- Muttoni, G., Gaetani, M., Kent, D. V., Sciunnach, D., Angiolini, L., Berra, F., Garzanti, E., Mattei, M. & Zanchi, A. 2009. Opening of the Neo-Tethys Ocean and the Pangea B to Pangea A transformation during the Permian. *GeoArabia*, 14 (4): 17-48.
- Muttoni, G., Mattei, M., Balini, M., Zanchi, A., Gaetani, M. & Berra, F. 2009. The drift history of Iran from the Ordovician to the Triassic. *Geological Society, London, Special Publications*, 312: 7-29.
- Nakazawa, K., Batten, R. L., Suzuki, S. & Uwada, H. 2008. Permian and Triassic molluscan fossils from the Maizuru Zone, Okayama City, southwest Japan. *Okayama University Earth Science Reports*, 15 (1): 1-8.
- Nan-sheng Qiu, Jian-zhang Qin, McInnes, B. I. A., Jie Wang, Tenger & Lun-ju Zhen. 2008. Tectonothermal evolution of the northeastern Sichuan Basin: constraints from apatite and zircon (U-Th)/He ages and vitrinite reflectance data. *Geological Journal of China Universities*, 14 (2): 223-230.
- Németh, K. & Budai, T. 2009. Diatremes cut through the Triassic carbonate platforms in the Dolomites? Evidences from and around the Latemar, northern Italy. *Episodes*, 32 (2): 74-83.
- Nesbitt, S. J., Irmis, R. B., Parker, W. G., Smith, N. D., Turner, A. H. & Rowe, T. 2009. Hindlimb osteology and distribution of basal dinosauromorphs from the Late Triassic of North America. *Journal of Vertebrate Paleontology*, 29 (2): 498-516.
- Nevenka, ?. & Natašam G. 2008. Late Triassic radiolarians from the Ov?ar-Kablar gorge (SW Serbia). *Geoloski anali Balkanskog poluostrva*, 69: 39-47.
- Nian Liu, Yong Zhu, ZongXian Wei, Jie Chen, QingBiao Wang, Shu Guang Jian, DangWei Zhou, Jing Shi, Yong Yang & Yang Zhong. 2009. Phylogenetic relationships and divergence times of the family Araucariaceae based on the DNA sequences of eight genes. *Chinese Science Bulletin*, 54 (15): 2648-2655.
- Niedzwiedzki, G. 2008. Theropod dinosaur tracks from Rhaetian deposits of Seebergen, Thuringia, Germany. *Przeł?d Geologiczny*, 56 (7): 539-544.
- Niedzwiedzki, G., Kin, A., Remín, Z. & Malkiewicz, M. 2007. Middle Triassic vertebrate ichnofauna from the 'Krynki Beds' in the Holy Cross Mountains – preliminary review. *Przeład Geologiczny*, 55 (10): 870-879.
- Ning Tian, Yong-dong Wang, Xiao-ju Yang, Qing Ni & Zi-kun Jiang. 2008. Preliminary study on Late Triassic to Early Jurassic strata and floral variation in Hechuan region of Chongqing, southern Sichuan Basin. *Global Geology (Jilin University)*, 11 (3): 125-129.
- Nollet, S., Koerner, T., Kramm, U. & Hilgers, C. 2009. Precipitation of fracture fillings and cements in the Buntsandstein (NW Germany). *Geofluids*, 9 (4): 373-385.
- Nosotti, S. 2007. *Tanystropheus longobardicus* (Reptilia, Protorosauria): reinterpretations of the anatomy based on new specimens from the Middle Triassic of Besano (Lombardy, Northern Italy). *Memorie della Società italiana di Scienze naturali e del Museo civico di Storia naturale di Milano*, 35, Fasc. III.
- O'Dogherty, L., Carter, E. S., Dumitrica, P., Gorican, S., De Wever, P., Hungerbühler, A., Bandini, A. N. & Takemura, A. 2009. Catalogue of Mesozoic radiolarian genera. Part 1: Triassic. *Geodiversitas*, 31 (2): 231-270 (range chart – 483-492).
- Ogg, J. G., Ogg, G. & Gradstein, F. M. 2008. *The Concise Geologic Time Scale*. Cambridge, Cambridge University Press, 177pp.
- Onoue, T. Chablais, J. & Martini, R. 2009. Upper Triassic reefal limestone from the Sambosan accretionary complex in Japan and its geological implication. *Journal of the Geological Society of Japan*, 115 (6): 292-295.
- Ottone, E. G. & Mancuso, A. C. 2007. Algas Chlorococcales como indicadores paleoambientales: nuevos datos de la Formación Los Rastros, Triásico del centro-oeste de Argentina. *Revista del Museo Argentino de Ciencias Naturales*, n.s.8 (2): 209-220.
- Pace, D. W., Gastaldo, R. A. & Neveling, J. 2009. Early Triassic aggradational and degradational landscapes of the Karoo Basin and evidence for climate oscillation following the P–Tr event. *Journal of Sedimentary Research*, 79 (5): 316-331.
- Pagés, J.-S. 2009. The GeoPark of Haute-Provence, France - geology and palaeontology protected for sustainable development. *Carnets de Géologie*, Book 2009/3: 29-34.
- Pandey, D., Singh, S., Sinha, M. & MacGregor, L. 2009. Structural imaging of Mesozoic sediments of Kachchh, India, and their hydrocarbon prospects. *Marine and Petroleum Geology*, 26 (7): 1043-1050.
- Payne, J. L., Lehrmann, D. J., Follett, D., Seibel, M., Kump, L. R., Riccardi, A., Altiner, D., Sano, H. & Jiayong Wei. 2009. Erosional truncation of uppermost

- Permian shallow-marine carbonates and implications for Permian-Triassic boundary events: Reply. *Geological Society of America Bulletin*, 121 (5-6): 957-959.
- Pechersky, D. M. 2006. Geomagnetic field in the vicinity of the Paleozoic-Mesozoic boundary and the Siberian superplume. *Russian Journal of Earth Sciences*, 8 (1).
- Peng-wu Li, Rui Gao, Ye Guan & Qiu-sheng Li. 2009. The closure time of the Paleo-Asian Ocean and the Paleo-Tethys Ocean: implication for the tectonic cause of the End-Permian Mass Extinction, *Journal of Jilin University (Earth Science edition)*, 39 (3): 521-527.
- Perevoznikova, E. V. & Miroshnichenko, N. V. 2009. Tausonite and aluminum-fluorine titanite from the metamorphosed metalliferous sediments of the Triassic chert formation of the Sikhote Alin. *Russian Journal of Pacific Geology*, 3 (3): 294-297.
- Petrov, O. V., Sobolev, N. N., Koren, T. N., Vasiliev, V. E., Petrov, E. O., Larssen, G. B. & Smelror, M. 2008. Palaeozoic and Early Mesozoic evolution of the East Barents and Kara Seas sedimentary basins. *Norwegian Journal of Geology*, 88 (4): 227-234.
- Phillipe, M., Hong-en Jiang, Kyungsik Kim, Changhwan Oh, Gromyko, D., Harland, M., In-sung Paik & Thévenard, F. 2009. Structure and diversity of the Mesozoic wood genus *Xenoxylon* in Far East Asia: implications for terrestrial palaeoclimates. *Lethaia*, 42 (4): 393-406.
- Pie?kowski, G. & Schudack, M. E. (co-ordinators) and 22 others. 2008. Jurassic. Pp. 823-922 in McCann, T. (ed.) *The Geology of Central Europe. Volume 2: Mesozoic and Cenozoic*. Geological Society, London.
- Posenato, R. 2009. Survival patterns of macrobenthic marine assemblages during the end-Permian mass extinction in the western Tethys (Dolomites, Italy). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 280 (1-2): 150-167.
- Pott, C., Kerp, H. & Krings, M. 2008. Sphenophytes from the Carnian (Upper Triassic) of Lunz am See (Lower Austria). *Jahrbuch der Geologischen Bundesanstalt, Wien*, 148 (2): 183-199.
- Powell, M. G. 2009. The latitudinal diversity gradient of brachiopods over the past 530 million years. *Journal of Geology*, 117 (6): 585-594.
- Powers, C. M. & Bottjer, D. J. 2009. Behavior of lophophorates during the end-Permian mass extinction and recovery. *Journal of Asian Earth Sciences*, 36 (6): 413-419.
- Prasad, B. & Phor, L. 2009. Palynostratigraphy of the subsurface Gondwana and post-Gondwana Mesozoics of the Cauvery Basin, India. *Journal of the Palaeontological Society of India*, 54 (1): 41-71.
- Preto, N., Spötl, C. & Guaiumi, C. 2009. Evaluation of bulk carbonate  $^{13}\text{C}$  data from Triassic hemipelagites and the initial composition of carbonate mud. *Sedimentology*, 56 (5): 1329-1345.
- Putignano, M. L. & Schiattarella, M. 2008. Struttura, esumazione ed evoluzione morfologica del nucleo mesozoico del Monte Motola (Cilento, Italia meridionale). *Bolletino della Società Geologica Italiana*, 127 (3): 477-493.
- Qi Yong-an, Zhang Zhou, Zhou Min & Zhang Wei. 2009. Lithofacies and sedimentary facies from Middle Triassic fluvial deposits of Youfangzhuang Formation, Ji Yuan area, western Henan. *Acta Sedimentologica Sinica*, 27 (2): 254-264.
- Qing-hua Bai, Yi-qun Liu & Ting-ting Fajn. 2009. Genesis and distribution of laumontite in Yanchang Formation of Upper Triassic in Ordos Basin Northwestern Geology, 42 (2): 100-107.
- Qinglai Feng, Zijiang Yang, Xianyang Li & Crasquin, S. 2009. Middle and Late Triassic radiolarians from northern Tibet: implications for the Bayan Har Basin evolution. *Geobios*, 42 (5): 581-601.
- Qing-song Xia & Jing-chun Tian. 2007. Characteristics of sublacustrine fan of Interval 6 of Yanchang Formation of Upper Triassic in southwestern Ordos Basin. *Journal of Palaeogeography*, 9 (1): 33-43.
- QinXian Wang, JinNan Tong, HaiJun Song & Hao Yang. 2009. Ecological evolution across the Permian/Triassic boundary at the Kangjiaping section in Cili County, Hunan Province, China. *Science in China Series D: Earth Sciences*, 52 (6): 797-806.
- QiYue Zhang, ChangYong Zhou, Tao Lu, Tao Xie, XiongYing Lou, Wei Liu, YuanYuan Sun, JinYuan Huang & LaiShi Zhao. 2009. A conodont-based Middle Triassic age assignment for the Luoping Biota of Yunnan, China. *Science in China Series D: Earth Sciences*, 52 (10): 1673-1678.
- Quan, T. M., van de Schootbrugge, B., Field, M. P., Rosenthal, Y. & Falkowski, P. G. 2008. Nitrogen isotope and trace metal analyses from the Mingolsheim core (Germany): evidence for redox variations across the Triassic-Jurassic boundary. *Global Biogeochemical Cycles*, 22, GB2014, doi:10.1029/2007GB002981
- Racey, A. 2009. Mesozoic red bed sequences from SE Asia and the significance of the Khorat Group of NE Thailand. *Geological Society, London, Special Publications*, 315: 41-67.
- Racey, A. & Goodall, J. G. S. 2009. Palynology and stratigraphy of the Mesozoic Khorat Group red bed sequences from Thailand. *Geological Society, London, Special Publications*, 315: 69-83.
- Radley, J. D. 2009. The geological evolution of Warwickshire. *Mercian Geologist*, 17 (2): 75-85.
- Rahimpour-Bonab, H., Asadi-Eskandar, A. & Sonei, R. 2009. Effects of the Permian-Triassic boundary on reservoir characteristics of the South Pars gas field, Persian Gulf. *Geological Journal*, 44 (3): 341-364.
- Raju, D. S. N. 2008. The preserved rock record, stratigraphic gaps and cycles of sea-level fluctuations/paleoenvironments in the Proterozoic and Phanerozoic sequences of India: an overview with a mega chart. *Geological Society of India Memoir*, 71: 1-44.
- Ramos, V. A. 2009. Anatomy and global context of the Andes: main geologic features and the Andean orogenic cycle. *Geological Society of America Memoirs*, 204: 31-65.

- Rayfield, E. J., Barrett, P. M. & Milner, A. R. 2009. Utility and validity of Middle and Late Triassic 'Land Vertebrate Faunachrons'. *Journal of Vertebrate Paleontology*, 29 (1): 80-87.
- Renesto, S. & Lucas, S. G. 2009. Cynodont teeth from the Carnian (Late Triassic) of northern Italy. *Acta Palaeontologica Polonica* 54 (2): 357-360.
- Renesto, S. C., Spielmann, J. A. & Lucas, S. G. 2009. The oldest record of drepanosaurids (Reptilia, Diapsida) from the Late Triassic (Adamanian Placerias Quarry, Arizona, USA) and the stratigraphic range of the Drepanosauridae. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 252 (3): 315-325.
- Renesto, S. & Stockar, R. 2009. Exceptional preservation of embryos in the actinopterygian *Saurichthys* from the Middle Triassic of Monte San Giorgio, Switzerland. *Swiss Journal of Geosciences*, 102 (3): 323-330.
- Retallack, G. J. 2009. Greenhouse crises of the past 300 million years. *Geological Society of America Bulletin*, 121 (9-10): 1441-1455.
- Resak, M., Glasmacher, U. A., Narkiewicz, M. & Littke, R. 2010. Maturity modelling integrated with apatite fission-track dating: implications for the thermal history of the Mid-Polish Trough. *Marine and Petroleum Geology*, 27 (1): 108-115.
- Ricketts, B. D. 2008. Cordilleran sedimentary basins of Western Canada record 180 million years of terrane accretion. *Sedimentary Basins of the World*, 5: 363-394.
- Riedel, G.-R. 2006. Die Seelilien (Crinoidea) aus dem Muschelkalk Thüringens in den Sammlungen des Naturkundemuseums Erfurt. *Veröffentlichungen des Naturkundemuseums Erfurt*, 25: 73-79
- Ritts, B. D., Weislogel, A., Graham, S. A. & Darby, B. J. 2009. Mesozoic tectonics and sedimentation of the Giant Polyphase Nonmarine Intraplate Ordos Basin, Western North China Block. *International Geology Review*, 51 (2): 95-115.
- Robertson, A., Karamata, S. & Šari?, K. 2009. Overview of ophiolites and related units in the Late Palaeozoic–Early Cenozoic magmatic and tectonic development of Tethys in the northern part of the Balkan region. *Lithos*, 108 (3-4): 1-36.
- Robertson, A. H. F. & Ustaömer, T. 2009. Formation of the Late Palaeozoic Konya Complex and comparable units in southern Turkey by subduction–accretion processes: implications for the tectonic development of Tethys in the Eastern Mediterranean region. *Tectonophysics*, 473 (1-2): 113-148.
- Romano, C. & Brinkmann, W. 2009. Reappraisal of the lower actinopterygian *Birgeria stensioei* Aldinger, 1931 (Osteichthyes; Birgeriidae) from the Middle Triassic of Monte San Giorgio (Switzerland) and Besano (Italy). *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 252 (1): 17-31.
- Ruban, D. A. 2007. Major Paleozoic-Mesozoic unconformities in the Greater Caucasus and their tectonic re-interpretation: a synthesis. *GeoActa*, 6: 91-102.
- Ruban, D. A., Zeffass, H. & Wan Yang. 2007. A new hypothesis on the position of the Greater Caucasus Terrane in the Late Palaeozoic–Early Mesozoic based on palaeontologic and lithologic data. *Trabajos de Geología*, 27: 19-27.
- Ruban, D. A. 2009. Phanerozoic changes in the high-rank suprageneric diversity structure of brachiopods: linear and non-linear effects. *Palaeoworld*, 18 (4): 263-277.
- Ruban, D. A., Zeffass, H. & Pugatchev, V. I. 2009. Triassic synthems of southern South America (southwestern Gondwana) and the Western Caucasus (the northern Neotethys), and global tracing of their boundaries. *Journal of South American Earth Sciences*, 28 (2): 155-167.
- Ruckwied, K. & Götz, A. E. 2009. Climate change at the Triassic/Jurassic boundary: palynological evidence from the Furkaska section (Tatra Mountains, Slovakia). *Geologica Carpathica*, 60 (2): 139-149.
- Ruckwied, K., Götz, A. E., Pálffy, J. & Torök, A. 2008. Palynology of a terrestrial coal-bearing series across the Triassic/Jurassic boundary (Mecsek Mts, Hungary). *Journal of Central European Geology*, 51 (1): 1-15.
- Ruhl, M., Kürschner, W. M. & Krystyn, L. 2009. Triassic–Jurassic organic carbon isotope stratigraphy of key sections in the western Tethys realm (Austria). *Earth & Planetary Science Letters*, 281 (3-4): 169-187.
- Ruta, M., Pisani, D., Lloyd, G. T. & Benton, M. J. 2007. A supertree of temnospondyli: cladogenetic patterns in the most species-rich group of early tetrapods. *Proceedings of the Royal Society of London B*, 274 (1629): 3087-3095.
- Saddiqi, O., El Haimer, F.-Z., Michard, A., Barbarand, J., Ruiz, G. M. H., Mansour, E. M., Leturmy, P. & Frizon de Lamotte, D. 2009. Apatite fission-track analyses on basement granites from south-western Meseta, Morocco: paleogeographic implications and interpretation of AFT age discrepancies. *Tectonophysics*, 475 (1): 29-37.
- Sadlok, G. 2008. Trace *Diplopodichnus biformis* Brady, 1947 (Middle Triassic, Jaworzno, Upper Silesia) – potential indicator of subaerial conditions. *Przegląd Geologiczny*, 56 (11): 964-966.
- Sadlok, G. & Bujok, A. 2008. Do ichnotaxonomic differences between lacertoid tracks from the Tumlin Sandstone reflect biotaxonomic differences? *Przegląd Geologiczny*, 56 (11): 1005-1010.
- Saesaengseerung, D., Sashida, K. & Sardud, A. 2008. Discovery of Middle Triassic radiolarian fauna from the Nan area along the Nan-Uttaradit suture zone, northern Thailand. *Paleontological Research*, 12 (4): 397-409.
- Sahney, S. & Benton, M. J. 2008. Recovery from the most profound mass extinction of all time. *Proceedings of the Royal Society of London B*, 275 (1636): 759-765.
- Salamon, T. 2009. Subglacial origin of gorge valleys in western part of the Middle Triassic ridge and the row of hills near Goglin. *Przegląd Geologiczny*, 57 (3): 243-251.
- Sameeni, S. J. 2009. The Salt Range: Pakistan's unique field museum of geology and paleontology. *Carnets de Géologie*, Book 2009/3: 65-73.

- Sartori, A. F. & Harper, E. M. 2009. Sticky bivalves from the Mesozoic: clues to the origin of the anomalodesmatan arenophilic system. *Lethaia*, 42 (4): 486-494.
- Savchenko, V. I. & Eremin, N. A. 2009. New data on the geology of the northeastern Sea of Azov. *Doklady Earth Sciences*, 426 (1): 556-558.
- Schlager, W. & Reijmer, J. J. G. 2009. Carbonate platform slopes of the Alpine Triassic and the Neogene - a comparison. *Austrian Journal of Earth Sciences*, 102 (1): 4-14.
- Schoch, R. R. & Witzmann, F. 2009. Osteology and relationships of the temnospondyl genus *Sclerocephalus*. *Zoological Journal of the Linnean Society*, 157 (1): 135-168.
- Schweitzer, H.-J., Schweitzer, U., Kirchner, M., van Konijnenburg – van Cittert, J. H. A., van der Burgh, J. & Ashraf, R. A. 2009. The Rhaeto-Jurassic flora of Iran and Afghanistan. 14. Pterophyta – Leptosporangiateae. *Palaeontographica B*, 279 (1-6): 1-108.
- Schwendemann, A. B., Taylor, T. N., Taylor, E. L., Krings, M. & Dotzler, N. 2009. *Combresomyces cornifer* from the Triassic of Antarctica: evolutionary stasis in the Peronosporomycetes. *Review of Palaeobotany and Palynology*, 154 (1-4): 1-5.
- Schwendemann, A. B., Taylor, T. N. & Taylor, E. L. 2009. Pollen of the Triassic cycad *Delemaya spinulosa* and implications on cycad evolution. *Review of Palaeobotany and Palynology*, 156 (1-2): 98-103.
- Sellwood, B. W. & Valdes, P. J. 2007. Mesozoic climates. *The Micropalaeontological Society Special Publication 2*: 201-224. London, The Geological Society.
- Sellwood, B. W. & Valdes, P. J. 2008. Jurassic climates. *Proceedings of the Geologists' Association*, 119 (1): 5-17.
- Sengor, A. M. C. & Atayman, S. 2009. The Permian extinction and the Tethys: an exercise in global geology. *Geological Society of America Special Papers*, 448: 1-85.
- Senter, P. 2008. Voices of the past: a review of Paleozoic and Mesozoic animal sounds. *Historical Biology*, 20 (4): 255-287.
- Senowbari-Daryan, B. 2009. Coralline Schwämme aus dem norisch-rhätischen Dachstein-Riff des Gosaukammes (Nördliche Kalkalpen, Österreich). *Jahrbuch der Geologischen Bundesanstalt, Wien*, 149 (1): 111-166.
- Senowbari-Daryan, B. & Stanley, G. D. Jr. 2009. Taxonomic affinities and paleogeography of *Stromatomorpha californica* Smith, a distinctive Upper Triassic reef-adapted demosponge. *Journal of Paleontology*, 83 (5): 783-793.
- Senowbari-Daryan, B., Iannace, A. & Zamparelli, V. 2009. *Discosiphonella minima* Senowbari-Daryan & Link and *Solenolmia? parva* n. sp. ("Sphinctozoa", Porifera) from the Upper Triassic (Norian) of the southern Apennines (northern Calabria/Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 115 (2): 199-208.
- Sephton, M. A., Visscher, H., Looy, C. V., Verchovsky, A. B. & Watson, J. S. 2009. Chemical constitution of a Permian-Triassic disaster species. *Geology* 37 (10): 875-878.
- Seyed-Emami, K., Fürsich, F. T., Wilmsen, M., Majidifard, M. R. & Shekarifard, A. 2009. Upper Triassic (Norian) cephalopods from the Ekrasar Formation (Shemshak Group) of northern Alborz, Iran. *Rivista Italiana di Paleontologia e Stratigrafia*, 115 (2): 189-198.
- Shang-lin Li, Gen-hou Wang, Bo-yong Ma, Wen-rui Yang, Wen-tao Zhao & Lei Liao. 2008. Discovery and its significance of earthquake event deposits of the Upper Triassic Bolila Formation in Mashuangbu, Biru County, Northern Tibet. *Journal of Jilin University (Earth Science edition)*, 38 (6): 973-979.
- Shang Qing-Hua & Li Chun. 2009. On the occurrence of the ichthyosaur *Shastasaurus* in the Guanling biota (Late Triassic), Guizhou, China. *Vertebrata Palasiatica*, 47 (3): 178-193.
- Shekarifard, A., Baudin, F., Schnyder, J. & Seyed-Emami, K. 2009. Characterization of organic matter in the fine-grained siliciclastic sediments of the Shemshak Group (Upper Triassic-Middle Jurassic) in the Alborz range, northern Iran. *Geological Society, London, Special Publications*, 312: 161-174.
- Sheng-bin Feng, Xiao-qi Yuan, Jing He, Gu-wie Xie, Jing Huang & Peng Yin. 2008. Geological environment of Upper Triassic sediment in Shigouyi region of western Ordos Basin and its geological significance. *Global Geology (Changchun)*, 27 (4): 378-386.
- Sheng-he Wu, Zhen-lin Yi, Chang-fu Xu, Jiang-gang Guo, Bao-guo Zhang & Xiao-jun Wu. 2008. High frequency base-level cycles of alluvial fan and distribution patterns of sandbodies of Lower Karamay Formation (Triassic) in Middle 6th District of Karamayi Oilfield, Xinjiang. *Geological Journal of China Universities*, 14 (2): 157-163.
- Shi Guo, Yu Mei-yi, Luo Mao & Tian Jing-chun. 2009. Trace fossils and their depositional environments of the Early Triassic Daye Formation in Huaxi area, Guiyang. *Acta Sedimentologica Sinica*, 27 (3): 427-434.
- Shiskin, M. A. 2009. The origin of the Metoposauridae (Amphibia, Temnospondyli). 7th Annual Meeting of the European Association of Vertebrate Palaeontologists, Berlin. Abstracts volume: 63.
- Shi-yan Hao, Xian-yang Wei & Jian-she Wei. 2009. Research on reservoir conditions of Chang 2 reservoir in Yanchang Formation of Zhaike area, Zhidan oil field. *Northwestern Geology*, 42 (3): 86-94.
- Shu, L. S., Zhou, X. M., Deng, P., Wang, B., Jiang, S. Y., Yu, J. H. & Zhao, X. X. 2009. Mesozoic tectonic evolution of the Southeast China Block: new insights from basin analysis. *Journal of Asian Earth Sciences*, 34 (3): 376-391.
- Shu Ouyang & Huai-cheng Zhu. 2007. Query assumption of "End-Permian Fungal Spike Event", with special reference to Permo-Triassic transitional palynofloras. *Acta Palaeontologica Sinica*, 46 (4): 394-410.
- Shu-ping Chen, Jun Kuang, Ji-shan Liu, Dong-meng

- Qu & Meng-si Sun. 2008. Major unconformities and their dynamic conditions in Ke-Bai area, northwestern margin of Junggar Basin. *Geological Journal of China Universities*, 14 (2): 199-205.
- Shuan-Hong Zhang, Yue Zhao, Xiao-Chun Liu, Dun-Yi Liu, Fukun Chen, Lie-Wen Xie & Hai-Hong Chen. 2009. Late Paleozoic to Early Mesozoic mafic-ultramafic complexes from the northern North China Block: constraints on the composition and evolution of the lithospheric mantle. *Lithos*, 110 (1-4): 229-246.
- Siblik, M. 2008. Bericht 2008 über Untersuchungen von Brachiopoden in den Raibler Schichten auf Blatt 65 Mondsee. *Jahrbuch der Geologischen Bundesanstalt*, Wien, 148 (2): 276-277.
- Si-jiang Huang, Hong-peng Tong, Ke-ki Huang, Li-hong Liu & Xue-hua Zhang. 2008. Application of cathodoluminescence analysis to the recovery of feldspar content in sandstone - a case study of Upper Paleozoic of Ordos Basin and Xujiahe Formation of Western Sichuan Depression, Sichuan Basin. *Advances in Earth Science*, 23 (10): 1013-1019.
- Si-jiang Huang, Hairuo Qing, Zuo-wei Hu, Ming-liang Zou, Wen-li Feng, Chun-mei Wang, Xiao-yong Gao & Qing-dong Wang. 2007. Influence of sulphate reduction on diagenesis of Feixianguan carbonate in Triassic, NE Sichuan Basin of China. *Acta Sedimentologica Sinica*, 25 (6): 815-824.
- Simpson, C. & Harnik, P. G. 2009. Assessing the role of abundance in marine bivalve extinction over the post-Paleozoic. *Paleobiology*, 35 (4): 631-647.
- Skaberne, D., Kralj, P. & Budkovi?, T. 2009. Soils on the Late Triassic carbonate rocks in the West Karavanke Mountains and the high plateaus of the Julian Alps (Slovenia). *Geologija*, 52 (1): 49-68
- Soares, A. P., Soares, P. C. & Holz, M. 2008. Conflicting stratigraphic correlations in the Permo-Triassic boundary in south Paraná Basin: the contact between two sequences and implications on Guarani aquifer system. *Revista Pesquisas em Geociências*, 35 (2): 115-133.
- Sokolov, S. D., Ledneva, G. V. & Pease, V. L. 2009. New data on the age and genesis of igneous rocks in the Kolyuchinskaya Guba (eastern Chukotka). *Doklady Earth Sciences*, 425 (2): 384-388.
- Song, H., Tong, J. & Chen, Z. Q. 2009. Two episodes of foraminiferal extinction near the Permian-Triassic boundary at the Meishan section, South China. *Australian Journal of Earth Sciences*, 56 (6): 765-773.
- Song-lin Gong, Neng-song Chen, Xiao-yan Li & Xiaoming Liu. 2007. LA-ICPMS U-Pb dating of zircons from two types of leucosomes in North Dabie Unit: evidences for Paleoproterozoic anatexis and Triassic subduction? *Geological Journal of China Universities*, 13 (3): 574-580.
- Spalletti, L. A. & Zavattieri, A. M. 2009. The lacustrine system of the Mollar Formation in the Triassic Santa Clara depocenter (Mendoza Province, Argentina). *Andean Geology*, 36 (2): 236-263.
- Stanley, S. M. 2009. Evidence from ammonoids and conodonts for multiple Early Triassic mass extinctions. *Proceedings of the National Academy of Sciences*, 106 (36): 15264-15267.
- Sterli, J., de la Fuente, M. S. & Rougier, G. W. 2007. Anatomy and relationships of *Palaeochersis talampayensis*, a Late Triassic turtle from Argentina. *Palaeontographica A*, 281 (1-3): 1-61.
- Sulej, T. 2009. Modification of reconstruction of the *Tatrasuchus* skull based on interpretation of its phylogeny. *Przeł?d Geologiczny*, 57 (8): 719-722.
- Sun Zuo-yu, Hao Wei-cheng, Sun Yuan-lin & Jiang Da-yong. 2009. The conodont genus *Nicoraella* and a new species from the Anisian of Guizhou, South China. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 252 (2): 227-235.
- Szulc, J. 2007. Tatra and Upper Silesian Triassic. State of examinations. *Przeł?d Geologiczny*, 55 (11): 947-950.
- Takahashi, S., Oba, M., Kaiho, K., Yamakita, S. & Sakata, S. 2009. Panthalassic oceanic anoxia at the end of the Early Triassic: a cause of delay in the recovery of life after the end-Permian mass extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 274 (3-4): 185-195.
- Tankard, A., Welsink, H., Aukes, P., Newton, R. & Stettler, E. 2009. Tectonic evolution of the Cape and Karoo basins of South Africa. *Marine and Petroleum Geology*, 26 (8): 1379-1412.
- Taylor, G. K., Tucker, C., Twitchett, R. J., Kearsley, T., Benton, M. J., Newell, A. J., Surkov, M. V. & Tverdokhlebov, V. P. 2009. Magnetostratigraphy of Permian/Triassic boundary sequences in the Cis-Urals, Russia: No evidence for a major temporal hiatus. *Earth & Planetary Science Letters*, 281 (1-2): 36-47.
- Tevelev, Al. V., Kosheleva, I. A., Furina, M. A. & Belyatskii, B. V. 2009. Triassic magmatism in the South Urals: geochemistry, isotopic composition, and geodynamics. *Moscow University Geology Bulletin*, 64 (2): 92-101.
- Tian Zhang & Yue-qiao Zhang. 2007. Geochronological sequence of Mesozoic intrusive magmatism in Jiaodong Peninsula and its tectonic constraints. *Geological Journal of China Universities*, 13 (2): 323-336.
- Ting-shan Zhang, Xiao-hui Chen, Zhao-yong Jiang, Dong-feng Hu, Gang-ping Xie, Shi-wei Huang & Guang-zhi Lan. 2008. Controls of Luzhou Uplift on sedimentary environment and facies distribution in Early and Middle Triassic, Chishui, Guizhou Province. *Acta Sedimentologica Sinica*, 26 (4): 583-592.
- Todesco, R., Wachtler, M., Kustatscher, E. & Avanzini, M. 2008. Preliminary report on a new vertebrate track and flora site from Piz da Peres (Anisian-Illyrian): Olange Dolomites, northern Italy. *Geo. Alp*, 5: 121-137.
- Tomašových, A. 2008. Composition of Hettangian brachiopod communities in the West Carpathians: implications for recovery after the end-Triassic mass extinction event. *Fossils and Strata*, 54: 173-181.
- Totterdell, J. M., Moloney, J., Korsch, R. J. & Krassay, A. A. 2009. Sequence stratigraphy of the Bowen-Gunnedah and Surat Basins in New South Wales. *Australian Journal of Earth Sciences*, 56 (3): 433-459.

- To-yun Lyang, Yong-jiang Liu, Jun-jie Li, Jing-zhe Bai & Cheng-xian Liu. 2009. Structural framework of Korean peninsula in Middle Paleozoic-Early Mesozoic. *Global Geology (Changchun)*, 28 (2): 157-165.
- Tuchkova, M. I., Sokolov, S. & Kravchenko-Berezhnoy, I. R. 2009. Provenance analysis and tectonic setting of the Triassic clastic deposits in western Chukotka, northeast Russia. *Stephan Mueller Special Publications Series*, 4: 177-200.
- Twitchett, R. J. 2007. Climate change across the Permian – Triassic boundary. *The Micropalaeontological Society Special Publication 2*: 191-200 London, The Geological Society.
- Underhill, J. R. 2009. Role of intrusion-induced salt mobility in controlling the formation of the enigmatic “Silverpit Crater”, UK Southern North Sea. *Petroleum Geoscience*, 15 (3): 197-216.
- Urlichs, M. 2009. Further details on dimorphism in Ceratites (Ammonoidea) from the Germanic Upper Muschelkalk (Middle Triassic), with revision of some species. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 251 (2): 199-223.
- Van de Schootbrugge, B., Quan, T. M., Lindström, S., Püttmann, W., Heunisch, C., Pross, J., Fiebig, J., Petschick, R., Röhlings, H.-G., Richoz, S., Rosenthal, Y. & Falkowski, P. G. 2009. Floral changes across the Triassic/Jurassic boundary linked to flood basalt volcanism. *Nature Geoscience*, 2 (8): 589 – 594.
- Vargas, H., Gaspar-Escribano, J. M., López-Gómez, J., Van Wees, J.-D., Cloetingh, S., de la Horra, R. & Arche, A. 2009. A comparison of the Iberian and Ebro Basins during the Permian and Triassic, eastern Spain: a quantitative subsidence modelling approach. *Tectonophysics*, 474 (1-2): 160-183.
- Veevers, J. J. 2009. Palinspastic (pre-rift and –drift) fit of India and conjugate Antarctica and geological connections across the suture. *Gondwana Research*, 16 (1): 90-108.
- Veevers, J. J. & Saeed, A. 2009. Permian–Jurassic Mahanadi and Pranhita–Godavari rifts of Gondwana India: provenance from regional paleoslope and U–Pb/Hf analysis of detrital zircons. *Gondwana Research*, 16 (3-4): 633-654.
- Veiga de Oliveira, T., Schultz, C. L. & Soares, M. B. 2009. A partial skeleton of Chiniquodon (Cynodontia, Chiniquodontidae) from the Brazilian Middle Triassic. *Revista Brasileira de Paleontologia*, 12 (2): 113-122.
- Veselovskiy, R. V. & Pavlov, V. E. 2006. New paleomagnetic data for the Permian-Triassic Trap rocks of Siberia and the problem of a non-dipole geomagnetic field at the Paleozoic-Mesozoic boundary. *Russian Journal of Earth Sciences*, 8 (1).
- Vijaya, Prasad, G. V. R. & Singh, K. 2009. Late Triassic palynoflora from the Pranhita-Godavari Valley, India: evidence from vertebrate coprolites. *Alcheringa*, 33 (2): 91-111.
- Vishnevskaya, V. S., Djeric, N. & Zakariadze, G. S. 2009. New data on Mesozoic Radiolaria of Serbia and Bosnia, and implications for the age and evolution of oceanic volcanic rocks in the central and northern Balkans. *Lithos*, 108 (1-4): 72-105.
- Volery, C., Davaud, E., Foubert, A. & Caline, B. 2009. Shallow-marine microporous carbonate reservoir rocks in the Middle East: relationship with seawater Mg/Ca ratio and eustatic sea level. *Journal of Petroleum Geology*, 32 (4): 313-325.
- Volokhin, Yu. G. & Karabtsov, A. A. 2009. Noble metals in Triassic carbonaceous cherts of the Sikhote-Alin. *Doklady Earth Sciences*, 426 (1): 574-579.
- Von Hillebrandt, A. & Krystyn, L. 2009. On the oldest Jurassic ammonites of Europe (Northern Calcareous Alps, Austria) and their global significance. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, 253 (2-3): 163-195.
- Vörös, A., Budar, T. & Szabó, I. 2008. The base of the Curionii Zone (Ladinian, Triassic) in Fels?örs (Hungary): improved correlation with the Global Stratotype Section. *Central European Geology*, 51 (4): 325-339.
- Wallmann, K. 2008. Mesozoic climate: liverworts and all. *Nature Geoscience*, 1 (1): 14 – 15.
- Waltham, T. 2009. Nottingham’s Castle Rock. *Mercian Geologist*, 17 (2): 128.
- Waltham, T. 2009. Nag’s Head caves, Nottingham. *Mercian Geologist*, 17 (2): 129.
- Wang Nian-zhong, Jin Fan, Wang Wei & Zhu Xiang-shui. 2007. Actinopterygian fishes from the Permian?Triassic boundary beds in Zhejiang and Jiangxi provinces, South China and fish mass extinction, recovery and radiation. *Vertebrata Palasiatica*, 45 (4): 307-329.
- Wang Nian-zhong, Zhu xiang-Shui, Jin Fan & Wang Wei. 2007. Chondrichthyan microremains under Permian-Triassic boundary both in Zhejiang and Jiangxi provinces, China — Fifth report on the fish sequence study near the Permian-Triassic boundary in South China. *Vertebrata Palasiatica*, 45 (1): 13-36.
- Wang Xiaofeng, Chen Xiaohong, Wang Chuanshang & Cheng Long (2009)
- The Triassic Guanling fossil Group - a key GeoPark from Barren Mountain, Guizhou Province, China. *Carnets de Geologie*, Book 2009/3: 11-28.
- Warrington, G., Cope, J. C. W. & Ivimey-Cook, H. C. 2009. The St Audrie’s Bay – Doniford Bay section, Somerset, England: updated proposal for a candidate Global Stratotype Section and Point for the base of the Hettangian Stage, and the Jurassic System. *International Subcommission on Jurassic Stratigraphy Newsletter*, 35: 2-66.
- Waschbusch, P., Korsch, R. J. & Beaumont, C. 2009. Geodynamic modelling of aspects of the Bowen, Gunnedah, Surat and Eromanga Basins from the perspective of convergent margin processes. *Australian Journal of Earth Sciences*, 56 (3): 309-334.
- Wei Zhao, Fei-hu Jiang & Shu-yan Teng. 2007. The geologic age, stratigraphic subdivision and correlation of the “High Resistivity Red Bed” in the Dongpu Depression, Bohai Sea Coastal Basin. *Journal of Stratigraphy*,

- 31 (1): 50-55.
- Weissflog, L., Elansky, N. F., Kott, K., Keppler, F., Pfenningdorff, A., Lange, C. A., Putz, E. & Lisitsyna, L. V. 2009. Late Permian changes in conditions of the atmosphere and environments caused by halogenated gases. *Doklady Earth Sciences*, 425 (1): 291-295.
- Werneburg, R. 2009. The Permian-Triassic branchiosaurid *Tungusogyrinus* Efremov, 1939 (Temnospondyli, Dissorophoidea) from Siberia restudied. *Fossil Record*, 12 (2): 105-120.
- Wetzel, A., Uchman, A., Blechschmidt, I. & Matter, A. 2009. Omanichnus and Vitichnus – two new graphoglyptid ichnogenera from Upper Triassic deep-sea fan deposits in Oman. *Ichnos*, 16 (3): 179-185.
- Whiteside, J. H., Olsen, P. E., Kent, D. V., Fowell, S. J. & Et-Touhami, M. 2007. Synchrony between the Central Atlantic magmatic province and the Triassic–Jurassic mass-extinction event? *Palaeogeography, Palaeoclimatology, Palaeoecology*, 244 (1-4): 345-367.
- Whittaker, J. E. & Hart, M. B. 2009. Ostracods in British Stratigraphy. *The Micropalaeontological Society Special Publications*, viii+496pp.
- Wignall, P. B., Kershaw, S., Collin, P.-Y. & Crasquin-Soleau, S. 2009. Erosional truncation of uppermost Permian shallow-marine carbonates and implications for Permian-Triassic boundary events: Comment. *Geological Society of America Bulletin*, 121 (5-6): 954-956.
- Wignall, P. B. & Racki, G. 2009. Comment on “Mantle plume: the invisible serial killer – application to the Permian-Triassic boundary mass extinction”, by E. Heydari, N. Arzani and J. Hassanzadeh [*Palaeogeography, Palaeoclimatology, Palaeoecology*, 264 (2008) 147-162]. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 283 (1-2): 99-101.
- Wilmsen, M., Fürsich, F. T., Seyed-Emami, K. & Majidifard, M. R. 2009. An overview of the stratigraphy and facies development of the Jurassic System on the Tabas Block, east-central Iran. *Geological Society, London, Special Publication*, 312: 323-343.
- Wiszniewska, J. 2009. The Permian-Triassic A-type volcanic-plutonic igneous suite of Corsica – IGCP 510 Workshop and EUROGRANITES 2008 – Corsica. *Przeglad Geologiczny*, 57 (2): 108-113.
- Witzmann, F., Schoch, R. R. & Maisch, M. W. 2009. A relict basal tetrapod from Germany: first evidence of a Triassic chroniosuchian outside Russia. *Naturwissenschaften*, 95 (1): 67-72.
- Witzmann, F., Scholz, H. & Ruta, M. 2009. Morphospace occupation of temnospondyl growth series: a geometric morphometric approach. *Alcheringa*, 33 (3): 237-255.
- Woods, A. D. 2009. Anatomy of an anachronistic carbonate platform: Lower Triassic carbonates of the southwestern United States. *Australian Journal of Earth Sciences*, 56 (6): 825-839.
- Wopfner, H. & Jin, X. C. 2009. Pangea megasequences of Tethyan Gondwana-margin reflect global changes of climate and tectonism in Late Palaeozoic and Early Triassic times—a review. *Palaeoworld*, 18 (2-3): 169-192.
- Wu Xiao-chun, Cheng Yen-nien, Tamaki, S. & Shan Hsi-yin. 2009. *Miodontosaurus brevis* Cheng et al., 2007 (Diapsida: Thalattosauria): its postcranial skeleton and phylogenetic relationships. *Vertebrata Palasiatica*, 47 (1): 1-20.
- Xianzhi Pei, Zuochen Li, Saping Ding, Jianyun Feng, Ruibao Li, Yu Sun, Yafeng Zhang & Zhanqing Liu. 2009. Post-orogenic granites in Pingwu region, northwest Sichuan: evidence for North China block and Yangtze block collision during Triassic. *Journal of Earth Science*, 20 (2): 250-273.
- Xiao-dong Zhou, Chang-jian Yin & Yu-jing Peng. 2009. Origin and further understanding on Kedao Group from Yanbian area, Jilin. *Global Geology (Changchun)*, 28 (1): 37-44.
- Xiao Hui & Hai-feng Zhang. 2009. Characters of sand bodies in Chang 6 section of Yanchang Formation in the central lake basin of Ordos Basin. *Journal of Earth Sciences and Environment*, 31 (1): 53-57.
- Xiao, W. J., Windley, B. F., Huang, B. C., Han, C. M., Yuan, C., Chen, H. L., Sun, M., Sun, S. & Li, J. L. 2009. End-Permian to mid-Triassic termination of the accretionary processes of the southern Altaids: implications for the geodynamic evolution, Phanerozoic continental growth, and metallogeny of Central Asia. *International Journal of Earth Sciences*, 98 (6): 1189-1217.
- Xiao, W. J., Windley, B. F., Huang, B. C., Han, C. M., Yuan, C., Chen, H. L., Sun, M., Sun, S. & Li, J. L. 2009. Erratum to: End-Permian to mid-Triassic termination of the accretionary processes of the southern Altaids: implications for the geodynamic evolution, Phanerozoic continental growth, and metallogeny of Central Asia (*International Journal of Earth Sciences*, 98 (6): 1189-1217). *International Journal of Earth Sciences*, 98 (6): 1219-1220.
- Xiaofeng Wang, Xiaohong Chen, Chuanshang Wang & Long Cheng. 2009. The Triassic Guanling fossil group – a key GeoPark from Barren Mountain, Guizhou Province, China. *Carnets de Géologie, Book 2009/3*: 11-28.
- Xiaohui Zhang, Hongfu Zhang, Mingguo Zhai, Wilde, S. A. & Liewen Xie. 2009. Geochemistry of Middle Triassic gabbros from northern Liaoning, North China. *Geological Magazine*, 146 (4): 540-551.
- Xiao-ming Zhao, Zhi-jun Niu, Oi-fa Duan, Chao-yang Tang, Hua-zhou Yao, Bo-fu Zeng & Bing Tu. 2007. Trace fossils of the Upper Triassic Bayanharshan Group in the Qumarleb-Zhidoi area, southern Qinghai. *Acta Palaeontologica Sinica*, 46 (1): 122-134.
- Xiao-ming Zhao, Jian-xiong Wang, Zhi-jun Niu, Zho-yang Tang & Hua-zhou Yao. 2008. Discussion on the tectonic setting and geothermal characteristics of sandstones from Carboniferous to Triassic in Zhidoi-Zadoi area, southern Qinghai. *Acta Sedimentologica Sinica*, 26 (1): 11-20.
- Xiao-qi Ding, Shao-nan Zhang & Yan Liu. 2008. Relationship between pre-Jurassic palaeogeomorphology and oil distribution of Zhenjing oilfield in South Ordos Basin. *Journal of Earth Sciences and Environment*, 30

- (4): 385-388.
- Xiao-ying Zeng, Xiao-qing Zhang & Yu-mei Zhong. 2007. Origin of calcarenaceous sandstone gas formation of the 4th Member of Xujiache Formation in the middle part of western Sichuan Depression. *Acta Sedimentologica Sinica*, 25 (6): 896-902.
- Xin-gui Zhou, Lin-yan Zhang & Kun Fan. 2008. Characteristics and distribution of tectonic fractures in Chang 6<sup>1</sup> low-permeable reservoir in Wuqi area in Ordos Basin. *Journal of Jilin University (Earth Science edition)*, 38 (1): 43-49.
- Xin Wang, Nan Li, YongDong Wang & ShaoLin Zheng. 2009. The discovery of whole-plant fossil cycad from the Upper Triassic in western Liaoning and its significance. *Chinese Science Bulletin*, 54 (17): 3116-3119.
- Xinan Mu, Kershaw, S., Yue Li, Li Guo, Yuping Qi & Reynolds, A. 2009. High-resolution carbon isotope changes in the Permian-Triassic boundary interval, Chongqing, South China; implications for control and growth of earliest Triassic microbialites. *Journal of Asian Earth Sciences*, 36 (6): 434-441.
- Xing Zhao, Jiang-hai Li & Hai-yan Cheng. 2009. Paleozoic salt structure styles of Yingmai 2 Work District in Yingmaili Area, Western Tabei Uplift. *Geological Journal of China Universities*, 15 (1): 115-125.
- Xiu-gen Fu, Jian Wang, Fu-wen Tan, Ming Chen & Wenbin Chen. 2010. The Late Triassic rift-related volcanic rocks from eastern Qiangtang, northern Tibet (China): age and tectonic implications. *Gondwana Research*, 17 (1): 135-144.
- Xue-gang Liu, Zhi-lin Cui & Juan Wang. 2008. Sedimentary microfacies of the Chang-6 reservoir in the vicinity of Sai 160 well. *Northwestern Geology*, 41 (3): 86-91.
- Ya-jun Zhu, Jian-yu Miao & Jing Zhu. 2008. On the diagenesis of Chang 4+5 reservoir of Triassic Yanchang Formation in Zhidan-Danba area, Ordos Basin. *Northwestern Geology*, 41 (4): 118-123.
- Ya-lin Qi, Jiang-hai Song, Li-she Wang & Tian-you Han. 2009. Reservoir diagenesis of Chang 6-8 in Yangchang Formation of Zhengning area in Ordos Basin. *Northwestern Geology*, 42 (3): 95-101.
- Yan Liu, Hongfei Liu, Theye, T. & Massonne, H.-J. 2009. Evidence for oceanic subduction at the NE Gondwana margin during Permo-Triassic times. *Terra Nova*, 21 (3): 195-202.
- Yang Yu, Wenliang Xu, Fuping Pei, Debin Yang & Quanguo Zhao. 2009. Chronology and geochemistry of Mesozoic volcanic rocks in the Linjiang area, Jilin Province and their tectonic implications. *Acta Geologica Sinica*, 83 (2): 245-257.
- Yao, A. 2009. Spatio-temporal changes in Paleozoic-Mesozoic radiolarian faunas in Japan and paleoenvironmental changes. *Paleontological Research*, 13 (1): 45-52.
- Yates, A. M. 2008. A second specimen of *Blikanasaurus* (Dinosauria: Sauropoda) and the biostratigraphy of the lower Elliot Formation. *Palaeontologia Africana*, 43: 39-43.
- Yi-bo Feng, Sho-nan Zhang, Xiao-qi Ding & Peng-kun Liu. 2009. Characteristics of sandbody pore structure and its affecting factors analysis of the Yan 9-Chang 6-Chang 8 member in Zhenjing oilfield. *Xinjiang Geology*, 27 (1): 66-69.
- Yi-gang Wang, Ying-chu Wen, Hai-tao Hong, Mao-long Xia, Ting-ting He & Shu-jun Song. 2007. Diagenesis of Triassic Feixianguan Formation in Sichuan Basin, southwest China. *Acta Sedimentologica Sinica*, 25 (6): 831-839.
- Ying-shi Li, De-xian Qin, Tao Zhou, Fu-ju Jia, Chao-ying Wan, Cai-xia Sun & Nian-sheng Zhou. 2008. Geochemical features and tectonic settings of Ladinian basalts in Gejiu, Yunnan Province. *Journal of Jilin University (Earth Science edition)*, 38 (4): 624 -630.
- Yong-an Qi, Bin Hu, Guo-cheng Zhang & Yi-ming Gong. 2007. Ichnofacies and their environmental interpretation from Middle Triassic Youfangzhuang Formation, Jiyuan region, western Henan Province. *Acta Sedimentologica Sinica*, 25 (3): 372-379.
- Yong-sheng Chen, Hong Zhao, Xiao-jie Zheng, Zhou-quan Yan, Yu-qin Jia & Li-ping Long. 2009. Reservoir characteristics and evaluation of Yanchang Formation in Zhidan area, Ordos Basin. *Northwestern Geology*, 42 (2): 83-88.
- Yoonsup Kim, Chang-Sik Cheong, Yuyoung Lee & Williams, I. S. 2009. SHRIMP allanite U-Th-Pb dating of bimodal Triassic metamorphism of Neoproterozoic tonalitic gneisses, Daeijak Island, central Korea. *Geosciences Journal*, 13 (3): 305-315.
- Yoshiaki, S. 2007. "Reply to the comments on "Upper Permian Takatsuki Formation, Middle Triassic Shimamoto Formation and Triassic sedimentary complex in the Nishiyama area, Osaka and Kyoto prefectures, SW Japan". *Journal of the Geological Society of Japan*, 113 (1): 36-38.
- Yoshiaki, A., Noritoshi, S., Kaoru, O. & Toyosaburo, S. 2009. Bipolar distributions of Recent and Mesozoic Radiolaria. *Fossils*, 85: 25-42.
- Yoshida, A. & Onoue, T. 2008. Lithostratigraphy, conodont ages, and oceanic plate stratigraphic correlation of deep-water pelagic limestone from Kutajimia island, Kagoshima, southwest Japan. *Journal of the Geological Society of Japan*, 114 (5): 246-249.
- Youchong Hong, Zhijun Zhang, Xinrong Guo & Heie, O. E. 2009. A new species representing the oldest aphid (Hemiptera, Aphidomorpha) from the Middle Triassic of China. *Journal of Paleontology*, 83 (5): 826-831.
- You-ying Chang, Jian-fang Li, Jun Zhang, Sheng-xiu Cao, Ping-ping Li & Hai-qing Chen. 2009. Study of environment and chronology of Late Triassic intrusive rocks in East Nalinggele River of Qinghai. *Northwestern Geology*, 42 (1): 57-65.
- YuanBao Wu. 2009. Multistage evolution of continental collision orogen: a case study for western Dabie orogen. *Chinese Science Bulletin*, 54 (15): 2568-2579.
- Yuan-dong Zhao, Xiao-guo Chi, Ji-ying Che, Jian-feng Lui & Zhi Zhao. 2009. Geochemical characteristics and



- tectonic setting of Late Triassic granites in Yanbian-Dongning area. *Journal of Jilin University (Earth Science edition)*, 39 (3): 425-434.
- Yuejun Wang, Guochun Zhao, Xiaoping Xia, Yanhua Zhang, Weiming Fan, Chao Li, Xianwu Bi & Sanzhong Li. 2009. Early Mesozoic unroofing pattern of the Dabie Mountains (China): constraints from the U-Pb detrital zircon geochronology and Si-in-white mica analysis of synorogenic sediments in the Jiangnan Basin. *Chemical Geology*, 266 (3-4): 231-241.
- Yu-hong Li, Jin-chao Li, Ting Jiang, Jian-she Wei, Jin-cai Lu & Jian Hang. 2009. Characteristics of the Triassic oil shale in the Hejiafang area, Ordos Basin. *Journal of Jilin University (Earth Science edition)*, 39 (1): 65-71.
- Yui, T. F., Okamoto, K., Usuki, T., Lan, C. Y., Chu, H. T. & Liou, J. G. 2009. Late Triassic-Late Cretaceous accretion/subduction in the Taiwan region along the eastern margin of South China - evidence from zircon SHRIMP dating. *International Geology Review*, 51 (4): 304-328.
- Zagorchev, I. & Budurov, K. 2007. Stratigraphic problems of the Moesian Group (Upper Triassic, peri-Tethyan type), Bulgaria. *Geologica Balcanica*, 36 (1-2): 31-53.
- Zai-xing Jiang, Ji-jun Tian, Gui-jun Chen, Xi-zhe Li & Man-lang Zheng. 2007. Sedimentary characteristics of the Upper Triassic in western Sichuan Foreland Basin. *Journal of Palaeogeography*, 9 (2): 143-154.
- Zakharov, Yu. D., Jingeng Sha, Popov, A. M., Safronov, P. P., Shorochova, S. A., Volynets, E. B., Biakov, A. S., Burago, V. I., Zimina, V. G. & Konovalova, I. V. 2009. Permian to earliest Cretaceous climatic oscillations in the eastern Asian continental margin (Sikhote-Alin area), as indicated by fossils and isotope data. *GFF*, 131 (1-2): 25-47.
- Zanchi, A., Zanchetta, S., Berra, F., Mattei, M., Garzanti, E., Molyneux, S. G., Nawab, A. & Sabouri, J. 2009. The Eo-Cimmerian (Late? Triassic) orogeny in north Iran. *Geological Society, London, Special Publications*, 312: 31-55.
- Zanchi, A., Zanchetta, S., Garzanti, E., Balini, M., Berra, F., Mattei, M. & Muttoni, G. 2009. The Cimmerian evolution of the Nakhla-Anarak area, central Iran, and its bearing on the reconstruction of the history of the Eurasian margin. *Geological Society, London, Special Publications*, 312: 261-286.
- Zatón, M., Niedzwiedzki, G. & Pienkowski, G. 2009. Gastropod egg capsules preserved on bivalve shells from the Lower Jurassic (Hettangian) of Poland. *Palaios*, 24 (9): 586-577.
- Zavattieri, A. M. & Mego, N. 2008. Palynological record of the Paso Flores Formation (Late Triassic) on the southeastern side of the Limay River, Patagonia, Argentina. *Ameghiniana*, 45 (2): 483-502.
- Ze-hong Cui, Liang-jie Tang & Zhi-xin Wang. 2007. Basin-formation evolution and its effect on petroleum formation in the southern and northern margins of Bogda. *Acta Sedimentologica Sinica*, 25 (1): 59-64.
- Zeng Lianbo & Li Xiang-Yang. 2009. Fractures in sandstone reservoirs with ultra-low permeability: a case study of the Upper Triassic Yanchang Formation in the Ordos Basin, China. *AAPG Bulletin*, 93 (4): 461-477.
- Zhan-feng Qiao, Guo-rong Li, Tao Li, Xin Wang, Hai-bo Yu & Xiao-jiang Deng. 2008. Sequence-stratigraphic features and their controls on carbonate reservoirs for the Triassic Jialingjiang Formation of Luzhou Paleohigh in Sichuan Basin. *Acta Sedimentologica Sinica*, 26 (1): 92-99.
- Zhang-you Xu, Sheng-he Wu, Xiao-qing Zhang, Yan Zhao, Xiao-ying Zeng & Xiao-yu Zhang. 2008. Diagenetic-reservoir facies and their evolutionary sequences of the members 4 and 2 of upper Triassic Xujiahe Formation in Xinchang gasfield, western Sichuan Depression. *Journal of Palaeogeography*, 10 (5): 447-458.
- Zheng Rong-cai, Luo Ping, Wen Qi-bin, Xu Fa-bo, Li Yu & Geng Wei. 2009. Characteristics of sequence-based lithofacies and palaeogeography, and prediction of oolitic shoal of the Feixianguan Formation in the northeastern Sichuan. *Acta Sedimentologica Sinica*, 27 (1): 1-8.
- Zhao Li-jun, Li Chun, Liu Jun & He Tao. 2008. A new armored placodent from the Middle Triassic of Yunnan Province, southwestern China. *Vertebrata Palasiatica*, 46 (3): 171-177.
- Zhao-yang Tang, Hua-zhou Yao, Zhi-jun Niu, Oi-fa Duan, Xiao-ming Zhao & Jian-xiong Wang. 2007. Preliminary discussion on bivalve assemblages and their environments of the Bagong Formation of Upper Triassic in Geladandong area, Yangtze source region. *Journal of Palaeogeography*, 9 (1): 59-68.
- Zhen-dong Gao, Jing-zhou Zhao, Qing Cao & Yan-jun Du. 2008. Geochronological analysis of oil accumulation in Triassic Yanchang Formation, Ordos Basin. *Northwestern Geology*, 41 (3): 92-98.
- Zhen-sheng Shi, Wei Yang, Chang-min Guo, Zeng-ye Xie, Hui Jin, Qiu-ying Zhu & Man-cang Liu. 2007. Ichnocoenosis of shore-shallow lacustrine Upper Triassic in central and south Sichuan Province. *Acta Palaeontologica Sinica*, 46 (4): 453-463.
- Zheng-quan Guo, Li-rong Zhang, Mei-juan Chu & Jin-xiu Huang. 2008. Pre-Jurassic palaeogeomorphic control on the hydrocarbon accumulation in the lower Yan'an Formation in southern Ordos Basin. *Journal of Palaeogeography*, 10 (1): 63-71.
- Zhi-sheng Zhang, Guo-min Fu, Hai-feng Meng, Jin-wang Song, Chao-hui Wu & Lei Sun. 2008. Study on residual oil distribution law and potential of Chang-2 reservoirs in Tanjiaying oilfield of Ansai oil field. *Northwestern Geology*, 41 (3): 106-111.
- Zhong Luo, Ping Luo, Xing-yang Zhang, Liu-hong Liu, Fei Chen & Xuan-jie Zhang. 2007. Effect of sequence boundary on sandstone diagenesis and reservoir quality: an outcrop study from the Upper Triassic Yanchang Formation, Ordos Basin, northwest China. *Acta Sedimentologica Sinica*, 25 (6): 903-914.
- Zidarov, N., Tarassova, E., Peytcheva, I., von Quadt, A., Andreichev, V. & Titorenkova, R. 2007. Petrology, geochemistry and age dating of Skrut granitoids - new

- evidence for Early Triassic magmatism in Belassitsa Mountain (SW Bulgaria), *Geologica Balcanica*, 36 (1-2): 17-29.
- ZiFu Zhao & YongFei Zheng. 2009. Remelting of subducted continental lithosphere: petrogenesis of Mesozoic magmatic rocks in the Dabie-Sulu orogenic belt. *Science in China Series D: Earth Sciences*, 52 (9): 1295-1318.
- Zi-kun Jiang, Yong-dong Wang & Ning Tian. 2008. Preliminary investigations on fossil diversity variation of Mesozoic Marattiaean ferns in China. *Global Geology (Jilin University)*, 11 (3): 130-134.
- Zodrow, E. L., D'Angelo, J. A., Mastalerz, M. & Keefe, D. 2009. Compression–cuticle relationship of seed ferns: insights from liquid–solid states FTIR (Late Palaeozoic–Early Mesozoic, Canada–Spain–Argentina). *International Journal of Coal Geology*, 79 (3): 61-73.
- Zuoyu Sun, Tintori, A., Dayong Jiang, Lombardo, C., Rusconi, M., Weicheng Hao & Yuanlin Sun. 2009. A new perleidiform (Actinopterygii, Osteichthyes) from the Middle Anisian (Middle Triassic) of Yunnan, South China. *Acta Geologica Sinica*, 83 (3): 460-470.



The  
Geological  
Society

## Special Publication 334 The Triassic Timescale



Edited by S. G. Lucas

- ISBN: 978-1-86239-296-0
- May 2010
- TBC Pages
- Hardback
- Subject Categories:  
Stratigraphy  
Palaeontology and  
geobiology
- Price:  
List  
£120.00/\$240.00  
GSL  
£60.00/\$120.00  
Other Qualifying Societies  
£72.00/\$144.00

**Order Online Now:**

[www.geolsoc.org.uk/  
bookshop](http://www.geolsoc.org.uk/bookshop)

### Geological Society Publishing House

Unit 7 Brassmill Enterprise centre,  
Brassmill Lane, Bath BA1 3JN, UK

Tel: +44 (0) 1225 445046

Fax: +44 (0) 1225 442836

Email: [sales@geolsoc.org.uk](mailto:sales@geolsoc.org.uk)

#### Postage:

UK: +5% (£4.00 minimum) Europe: +15%  
(£8.00 minimum) Rest of world: +15%  
(£12.50 minimum)

Please allow up to 28 days for delivery of in stock items  
in the UK. Parcels to Europe and the Rest of the World  
are sent by surface mail and can take 6 to 12 weeks to  
arrive. (Air courier rates available on request).

All prices and postage valid until  
31 December 2010.

The Mesozoic Era begins with the approximately 50-million-year-long Triassic Period, a major juncture in Earth history when the vast Pangaeon supercontinent completed its assembly and began its fragmentation, and the global biota diversified and modernized after the end-Permian mass extinction, the most extensive biotic decimation of the Phanerozoic. The temporal ordering of geological and biotic events during Triassic time thus is critical to the interpretation of some unique and pivotal events in Earth history. This temporal ordering is mostly based on the Triassic timescale, which has been developed and refined for nearly two centuries. This book reviews the state of the art of the Triassic timescale and includes comprehensive analyses of Triassic radio-isotopic ages, magnetostratigraphy, isotope-based and cyclostratigraphic correlations and timescale -relevant marine and non-marine biostratigraphy.

### Contents and Authors

Lucas, S. G. The Triassic timescale: an introduction	Orchard, M. J. Triassic conodonts and their role in stage boundary defini- tion	Cirilli, S. Upper Triassic – lowermost Jurassic palynology and paly- nostratigraphy: a review
Lucas, S. G. The Triassic chronostrati- graphic scale: history and status	O'Dogherty, L. Carter, E. S. Gorican, S. Dumitrica, P. Triassic radiolarian biostrati- graphy	Kozur, H. W. Weems, R. E. The biostratigraphic impor- tance of conchostracans in the continental Triassic of the northern hemisphere
Mundil, R. Palfy, J. Renne, P. R. Brack, P. The Triassic timescale: new constraints and a review of geochronological data	McRoberts, C. A. Biochronology of Triassic bivalves	Klein, H. Lucas, S. G. Tetrapod footprints – their use in biostratigraphy and bio- chronology of the Triassic
Hounslow, M. W. Muttoni, G. The geomagnetic polarity timescale for the Triassic: linkage to stage boundary definitions	Balini, M. Lucas, S. G. Jenks, J. F. Spielmann, J. A. Triassic ammonoid biostrati- graphy: an overview	Lucas, S. G. The Triassic timescale based on nonmarine tetrapod bio- stratigraphy and biochronol- ogy
Tanner, L. H. The Triassic isotope record	Kurschner, W. M. Waldemarr Herngreen, G.F. Triassic palynology of central and northwestern Europe: a review of palynofloral diver- sity patterns and biostrati- graphic subdivisions	
Tanner, L. H. Cyclostratigraphic record of the Triassic: a critical examina- tion		



The Lyell Collection: Journals, Special Publications and books online: [www.geolsoc.org.uk/lyellcollection](http://www.geolsoc.org.uk/lyellcollection)

---

---

**Future Meetings**

---

---



## ***Prague 2010 - ICS Workshop***

### **The GSSP Concept**

Prague, Czech Republic

30 May – 3 June 2010

## **2<sup>nd</sup> Circular**

### **Invitation**

The Organizing Committee warmly invites all members of the full commission of ICS (ICS executive officers and chairs of all subcommissions), all members of ICS subcommissions (both titular and corresponding) and other interested members of the stratigraphic community, including young scientists, to attend the ICS workshop in Prague. Both plenary, topical, and subcommissions workshops will be held in lecture rooms of the Geoscience Building of the Faculty of Science of Charles University in Prague. Field trip scheduled for the second day will bring participants to Lower Paleozoic GSSPs situated near Prague along with some Carboniferous, Cretaceous and Quaternary outcrops of stratigraphic importance.

### **Sponsors:**

International Commission on Stratigraphy; International Union of Geological Sciences; Institute of Geology and Palaeontology, Charles University; Institute of Geology, Academy of Sciences of the Czech Republic; National Museum, Prague; Stratigraphic Commission of the Czech Republic; Czech National Geological Committee

### **Organizing Committee:**

Stan Finney (Chair – ICS); Shanchi Peng (Vice-chair – ICS); Paul Bown (Secretary – ICS); Petr Kraft (Inst. of Geology and Palaeontology, Charles University, Prague); Petr Storch (Inst. of Geology, Academy of Sciences of the Czech Republic, Prague)

### **Objectives:**

The goals of the workshop are expressed in the list of agenda items. The primary focus is on the success of the GSSP process. Discussion will include examples of successes and their broader implications, but also problems that have arisen will be discussed with suggestions for best addressing them. Preparing GSSP proposals, leading ICS subcommissions, resolving differences in usage of stratigraphic nomenclature and classifications, revising ICS statutes, setting ICS standards are additional topics that will receive considerable attention. If possible, recommendations will be made on some of these issues and formal votes may be taken on them by the ICS full commission.

### **Format of Workshop:**

No abstracts will be submitted; no publications will be produced directly from the workshop. The format will be open discussions in both full meetings of all participants and smaller groups focusing on specific agenda items. Of course, we will recruit specific presentations that lead or open discussions, and we will consider requests of participants to make specific presentations, but these will be accepted and organized solely for promotion of the agenda. Focused group discussions on agenda items should result, in most instances, in recommendations to the ICS full commission on the closing day of the workshop and possibly formal votes on them. Of course, publications based upon these recommendations may be produced after the workshop.

### **Agenda Items:**

1. The GSSP Concept: its success, its shortcomings, problems that have arisen, difficult boundary issues remaining.
2. The exemplary GSSP proposal – essential components, definition and correlation; how best to present a GSSP proposal.
3. Leadership of ICS subcommissions: ensuring progress on GSSPs; addressing difficult boundaries; managing conflicts, rivalries, and difficult personalities. (restricted to subcommission chairs)
4. New subcommission initiatives.
5. Future of ICS and its role in IUGS.
6. Dual versus single stratigraphic classification of geologic time and time-rock units.
7. Dual usage of “Stage”.
8. Integration of varied stratigraphic records and calibrated ages with the International Chronostratigraphic Chart.
9. Revisions to ICS statutes.
10. Collaboration with national stratigraphic committees.
11. The ICS website and educational products and outreach.
12. Suggestions for additional items are welcome.

### **Program:**

30 May	Welcoming Reception (evening) at National Museum central hall
31 May	Opening ceremony, Review of ICS and Subcommission matters; Discussion groups address agenda items (afternoon)
1 June	Discussion groups address agenda items (morning); Discussion groups report to full meeting (afternoon); ICS Commission considers recommendations of discussion groups; Walking tour of Old Town, Prague (evening)
2 June	Field Excursion (base Devonian GSSP at Klonk, base Pridoli GSSP at Pozary, base Pragian GSSP at Velka Chuchle, Silurian succession in Kosov Quarry, Upper Carboniferous and Upper Cretaceous in Pecinov Quarry, Quaternary at Svaty Jan). Two alternative routes will be organized in case of larger number of participants.
3 June	Full meeting for final discussion of workshop recommendations and votes, if appropriate; directives

---

for further deliberations (morning);

Workshop Dinner (evening)

## **Patrons:**

Each system-based subcommission chair can rely on Czech or Slovak advisor or patron – a person familiar with local stratigraphy and research on the respective “System”. Principal task of such patrons will be to arrange for special meetings and requirements of the subcommissions. Subcommission chairs are encouraged to get in touch with respective patrons in advance.

Precambrian and Neoproterozoic -	Doc. Václav Kachlík;	<a href="mailto:kachlik@natur.cuni.cz">kachlik@natur.cuni.cz</a>
Cambrian –	Doc. Olda Fatka;	<a href="mailto:fatka@natur.cuni.cz">fatka@natur.cuni.cz</a>
Ordovician –	Doc. Petr Kraft;	<a href="mailto:kraft@natur.cuni.cz">kraft@natur.cuni.cz</a>
Silurian –	Dr. Petr Štorch;	<a href="mailto:storch@gli.cas.cz">storch@gli.cas.cz</a>
Devonian –	Dr. Petr Budil;	<a href="mailto:petr.budil@geology.cz">petr.budil@geology.cz</a>
Carboniferous –	Prof. Jiří Kalvoda (marine);	<a href="mailto:dino@sci.muni.cz">dino@sci.muni.cz</a>
	Doc. Stanislav Opluštil (continental)	<a href="mailto:oplustil@natur.cuni.cz">oplustil@natur.cuni.cz</a>
Permian –	Dr. Jaroslav Zajíc;	<a href="mailto:zajic@gli.cas.cz">zajic@gli.cas.cz</a>
Triassic –	Doc. Jozef Michalík;	<a href="mailto:geolmich@savba.sk">geolmich@savba.sk</a>
Jurassic –	Doc. Petr Skupien;	<a href="mailto:petr.skupien@vsb.cz">petr.skupien@vsb.cz</a>
Cretaceous –	Doc. Martin Košťák (marine);	<a href="mailto:kostys@centrum.cz">kostys@centrum.cz</a>
	Dr. Jiří Kvaček (continental);	<a href="mailto:jiri_kvacek@nm.cz">jiri_kvacek@nm.cz</a>
Paleogene –	Doc. Ján Soták;	<a href="mailto:sotak@savbb.sk">sotak@savbb.sk</a>
Neogene –	Doc. Katarina Holcová;	<a href="mailto:holcova@natur.cuni.cz">holcova@natur.cuni.cz</a>
Quaternary–	Dr. Jaroslav Kadlec;	<a href="mailto:kadlec@gli.cas.cz">kadlec@gli.cas.cz</a>

Subcommission on Stratigraphic Classification and Subcommission for Stratigraphic Information will be supported by Petr Storch ([storch@gli.cas.cz](mailto:storch@gli.cas.cz)) and Petr Kraft ([kraft@natur.cuni.cz](mailto:kraft@natur.cuni.cz)).

## **Registration and fee:**

**Registration fee 250 USD** involves costs of Welcoming Reception, Workshop Dinner, public transportation in Prague, workshop materials, and one-day field excursion. Accommodation will be paid separately.

## **Payment:**

Payments must arrive before March 31, 2010 by **international bank transfer** on the following bank account. Cheques and credit card payments are not accepted. Transfer costs must be covered by participants.

**IBAN :** CZ76 0100 0000 0000 3853 3021  
**SWIFT :** KOMBCZPP  
**Bank Name:** Komerční banka a.s.

**Bank address:** Václavské nám. 42, Prague 1  
**Account Name:** Přírodovědecká fakulta UK  
**Account Address:** Albertov 6, Prague 2  
**Account number:** 38533021/0100  
**ID number:** 90-910 599  
Posting text: your name (important to recognize sender)

**\*\*\*\*\*Registration and payment are due until March 31, 2010.\*\*\*\*\***

***Please register early!***

**Venue:**

Lecture rooms at Faculty of Science of the Charles University, Albertov 6, Praha 2

**Lodging:**

Participants are encouraged to make hotel reservation on their own. A broad selection of housing facilities is available in the city of Prague

**Downtown hotels in a close vicinity of the Faculty of Sciences:**

Best Western City Hotel Moran \*\*\*\* 100,- EUR (No 7 on the map)

[http://www.bestwestern.at/hotels/Česká\\_republika-Praha-City\\_Hotel\\_Moran-rates-66-cz.html](http://www.bestwestern.at/hotels/Česká_republika-Praha-City_Hotel_Moran-rates-66-cz.html)

Hotel U Šemíka \*\*\* 100,- EUR (No 8 on the map)

<http://www.usemika.cz/en/hotel/>

Hotel U Sv. Jana Accom plus \*\*\* 70,- EUR (No 3 on the map)

<http://www.accomprague.cz/praha-hotel-u-sv-jana.htm>

Green garden hotel \*\*\*\* 70,- EUR (No 4 on the map)

<http://www.hotelgreengarden.cz/index.html?page=home>

Royal Court Boutique Hotel and Spa \*\*\*\* 70,- EUR (No 5 on the map)

<http://www.hotel-praha-ubytovani.cz/praha-2/royalcourt/>

Hotel Standard \*\*\* 60,- EUR (No 6 on the map)

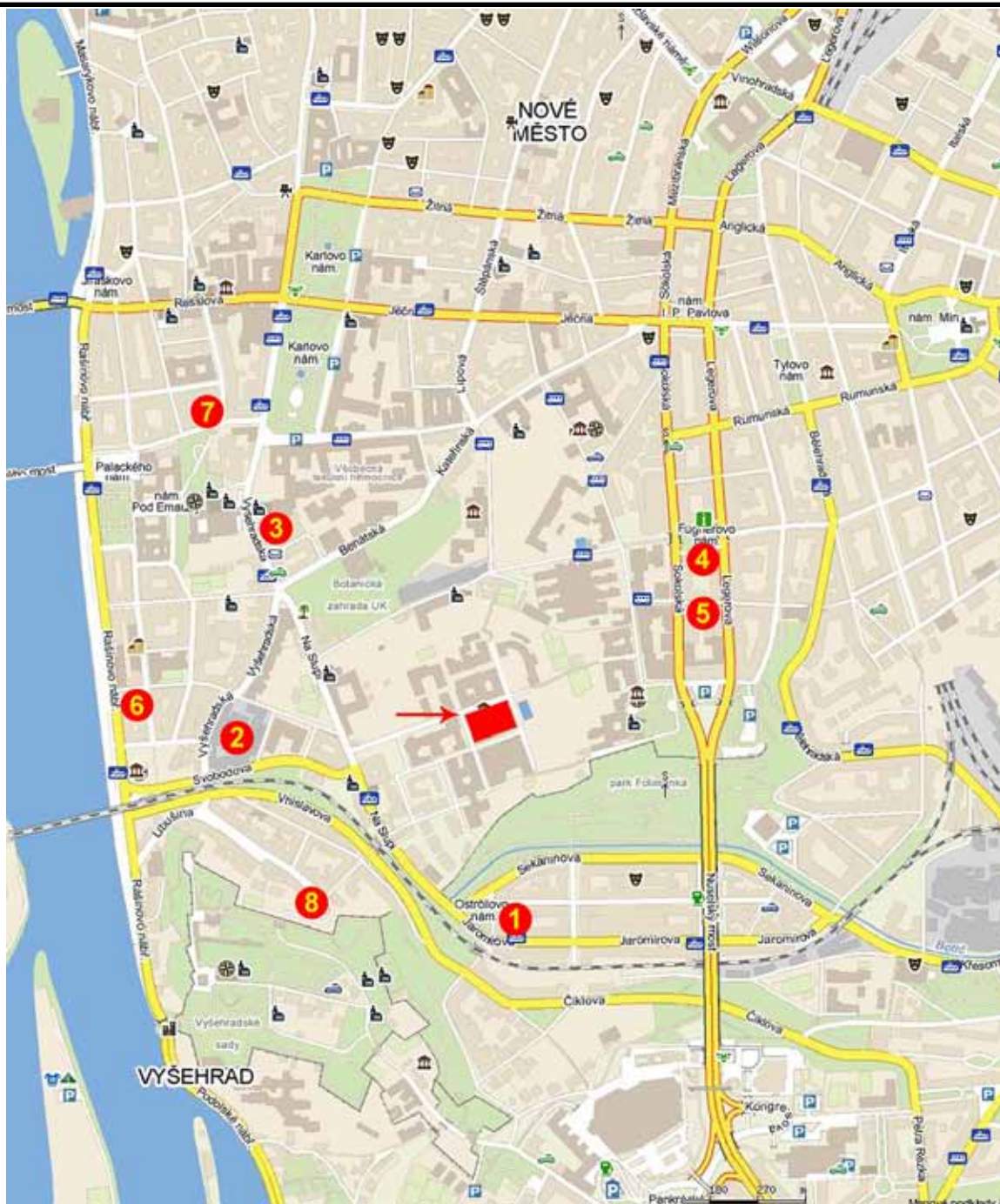
[http://www.hotele.cz/praha-2-hotel-standard\\_detail-c-standardhotel.cz.html](http://www.hotele.cz/praha-2-hotel-standard_detail-c-standardhotel.cz.html)

Park Inn Prague \*\*\*\* 70,- EUR (No 2 on the map)

<http://www.prague.parkinn.cz/>

Hotel Union Praha \*\*\*\* 60,- EUR (No 1 on the map)

<http://www.hotelunion.cz/>



**Other hotels of interest (outside of the map):**

Hotel Kampa Garden Accom tgravel \*\*\* 85,- EUR (hotel situated in historical and quiet part of Mala Strana district)

<http://www.hotelsprague.cz/kampagarden>

Hotel Krystal \*\*\* 45,- EUR (University hotel in Praha 6, on the way to Prague Airport)

<http://www.ubytovani-hotel-krystal.cz/>



**Many more hotels can be found on the following web addresses:**

<http://www.booking.com/city/cz/prague.html?aid=320737&label=GE0czech>

<http://www.hrs.com/web3/>

<http://www.book-travel-prague.com/accommodation/hotels/prague-2/>

**University Host House** (bed and breakfast 430.- Kč : ca **24 USD**) will be reserved by organizers. If applicable, e-mail to conference secretary Mrs Ilona Horychova: [horycho@natur.cuni.cz](mailto:horycho@natur.cuni.cz)

**Dining:**

Neighboring student dining hall offers daily menu for about 4 EUR or 5 USD. There are also various restaurants in the walking distance from the Faculty with lunch menu for almost the same price.

**Transportation:**

Prague Airport is offering direct flights from 108 destinations in 50 countries. Transfer from the airport involves taxi, shuttle minivans or buses. Visitors can take advantage of dense network of public transport based on trams and underground (metro).

**Third circular:**

*Third circular with detailed program and excursion itinerary will be distributed in April 2010.*

Participants will be encouraged to register and pay the fee as soon as possible since the number of the workshop participant is limited to 150.

---

Pre-Registration form:

The International Workshop on

**New Developments on Triassic integrated Stratigraphy**

12-16 September 2010, Palermo, Sicily, Italy

First Name: \_\_\_\_\_ Last Name: \_\_\_\_\_

Title: \_\_\_\_\_ Sex (M/F): \_\_\_\_\_

PhD or graduate Student?: YES-NO

Institution: \_\_\_\_\_

Full Address: \_\_\_\_\_

Country: \_\_\_\_\_

Telephone: \_\_\_\_\_ Fax: \_\_\_\_\_

E-mail: \_\_\_\_\_

I plan to attend the Symposium (please mark with **X**)

*very probably:*

*probably:*

*unlikely:*

I plan to contribute with (please mark with **X**)

*oral presentation:*

*poster:*

Tentative title(s):

1) .....

...

2) .....

...

3) .....

...

I plan to attend the field excursion (please mark with **X**)

*very probably:*

*probably:*

*unlikely:*

Comments/Suggestions/Special requests:

.....

...

.....

...

.....

...

Date:

Signature:

Please complete and return by March 31, 2010 to

E-mail: [triassic2010@gmail.com](mailto:triassic2010@gmail.com)

## GUIDELINES FOR THE SUBMISSION OF MANUSCRIPTS TO ALBERTIANA

Albertiana is published twice a year. Contributions should be sent to the editor. In order to facilitate the production of this newsletter and reduce typing errors, authors are kindly requested to submit their contributions electronically, preferably by email. Those who are unable to submit a manuscript in electronic format are kindly requested to send flat (unfolded), clearly typed manuscripts in a 12-point typeface (sans serif) with single line spacing.

Text files can be submitted formatted as \*.wpd, \*.doc or \*.rtf files and illustrations as pixel based graphics (e.g: \*.bmp, \*.tif, \*.gif or \*.jpeg) or vector based graphics (e.g: \*.ai, \*.cdr) that can be directly imported into Adobe PageMaker. Please provide good, clean, flat, printed copies (NOT xerox copies) of any illustrations, which MUST be designed to fit on an A4 page (centered, with at least 2.54 cm wide margins left and right, and 4 cm margins at the top and bottom).

Special attention should be paid to grammar and syntax - linguistic corrections will be minimal. In case of doubt, send your manuscript to a colleague for proof reading. References should be in the format used in the 'New Triassic Literature' section in issue 25 of Albertiana. Please write all Journal titles in full length. The use of names of biostratigraphic units should be in accordance with the International Stratigraphic Guide:

The formal name of a biostratigraphic unit should be formed from the names of one, or preferably no more than two, appropriate fossils combined with the appropriate term for the kind of unit in question."

The writing and printing of fossil names for stratigraphic units should be guided by the rules laid down in the International Code of Zoological Nomenclature and in the International Code of Botanical Nomenclature. The initial letter of generic names should be capitalized; the initial letter of the specific epithets should be in lowercase; taxonomic names of genera and species should be in italics. The initial letter of the unit-term (Biozone, Zone, Assemblage Zone) should be capitalized; for example, Exus albus Assemblage Zone."

The name of the fossil or fossils chosen to designate a biozone should include the genus name plus the specific epithet and also the subspecies name, if there is one. Thus Exus albus Assemblage Zone is correct. After the first

letter; for example, Exus albus may be shortened to E. albus. On the other hand, the use of the specific epithet alone, in lowercase or capitalized, in italics or not (albus Assemblage zone, Albus Assemblage zone, albus Assemblage zone, or Albus Assemblage zone), is inadvisable because it can lead to confusion in the case of frequently used species names. However, once the complete name has been cited, and if the use of the specific epithet alone does not cause ambiguous communication, it may be used, in italics and lowercase, in the designation of a biozone; for example, uniformis Zone."

From: Salvador, A. (ed.), 1994. International Stratigraphic Guide. Second Edition. International Commission on Stratigraphic Classification of IUGS International Commission on Stratigraphy. IUGS/GSA, Boulder, Co, p. 66.

## **Subcommission on Triassic Stratigraphy**

*STS Chairman*

*Prof. Marco Balini, Dipartimento di Scienze della Terra "Ardito Desio" Università degli Studi di Milano Via  
Mangiagalli 34, 20133 Milano, Italy*

*Vice Chairman*

*Dr. Ying Hongfu, Office of the President, China University of Geosciences, Yujiashan, Wuhan, Hubei, 430074,  
People's Republic of China*

*STS Secretary General*

*Dr Chris McRoberts Department of Geology State University of New York at Cortland  
P.O. Box 2000 Cortland, New York 13045 USA*

**Deadline for the next ALBERTIANA issue (39) is the 30<sup>th</sup> of  
July 2010.**