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Contents

The primary aim of ALBERTIANA is to promote the interdisciplinary collaboration and understanding among members of the I.U.G.S. Subcommission 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

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 Subcommission. 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 Caira (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 7th 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 IOWG, 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 January10 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)

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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 *Eoprotrachyceras 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 Subcommission 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 *Eoprotrachyceras 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 Subcommission 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

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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 disappearance 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 magnetochronolgy is, however, disputed (Gallet et al., 2007 vs. Muttoni et al., 2009).

The $\delta 13C_{carb}$ 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).

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Orbituaries

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) hwere 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 Pamuçak 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

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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 doctorial 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, desribed 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)

***Lytophiceras 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 *Lytophiceras* sp; bivalves *Claraia intermedia* Bittner (Zakharov, 1985) and *C. stachei* Bittner (Kotlyar, 1991) and conodonts *Hindeodus parvus* (Kozur and Pjatakova), *H.*

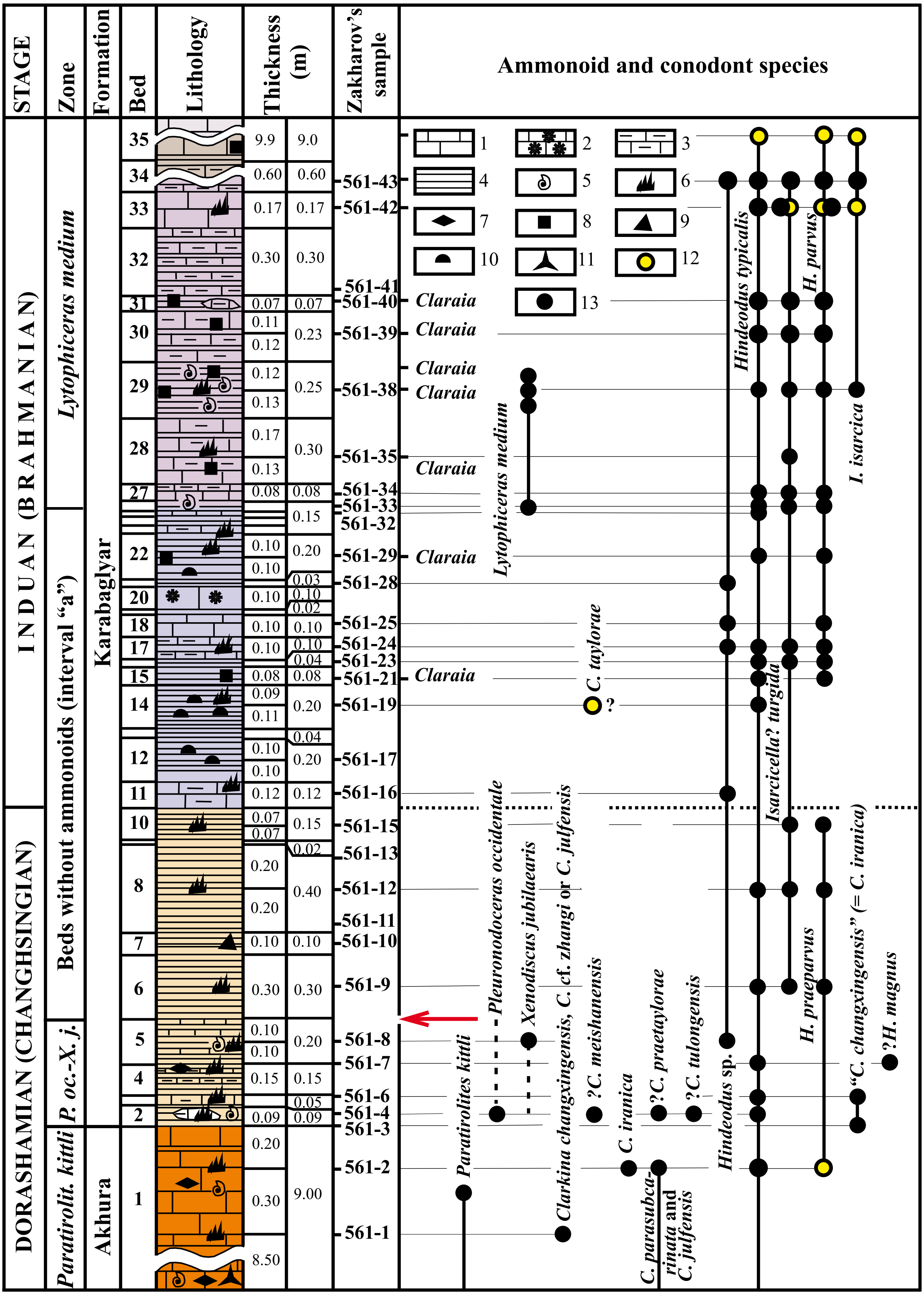

Figure 1. Stratigraphical ranges of principal ammonoids and conodonts through the P/T boundary interval at the Dorasham-II-3 section, stratotype of the Dorashamian (Dzhulfa area, Transcaucasia). 1 – limestone, 2 – algal limestone, 3 – marl, 4 – mudstone, 5 – ammonoids, 6 – conodonts, 7 – brachiopods, 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: *Paratirolit. kittli - Paratirolites 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 *Lytophiceras* 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" changxingensis* 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. changxingensisis* 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 Grigorian (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

Stage	Meishan, South China (Yin et al., 1996; Zhao, 2005) Formation	Meishan Conodont zone	Meishan Bed	Zal, NW Iran (Korte et al., 2004; Kozur, 2007) Formation	Zal Unit	Zal Conodont zone	Transcaucasia Formation	Transcaucasia Ammonoid zone	Sovetashen (Zakharov et al., 2005) Conodont zone	Sovetashen Bed	Dorasham II-3 Conodont zone	Dorasham II-3 Bed
Induan	Yinkong	*I. isarcica*	28	Elikah	Unit a	*I. isarcica*	Karabaglyar	*Lytophiceras medium*	*I. isarcica*	12-13	*I. isarcica*	26-35
Induan	Yinkong	*H. parvus*	27 d, c	Elikah	Unit a	*I. parvus*	Karabaglyar	Interval *a* (beds without ammonoids)	*H. parvus*	11	*I. parvus*	11-25
Changhsingian	Yinkong	*C. changxingensis*: *H. typicalis* assemblage	27 b, a	Elikah	Unit a / BC	*M. ultima-S.? mostleri*; *C. meishanensis-H. praeparvus*	Karabaglyar	*Pleuronodoceras occidentale-Xenodiscus jubilaearis*	*C. meishanensis-H. praeparvus-*	10	*C. meishanensis-H. praeparvus-*	3-10
Changhsingian	Yinkong	*C. changxingensis*: *H. latidentatus-C. meishanensis* assemblage	26	Hambast	Unit 7	*C. hauschkei*	Akhura	*Paratirolites kittli*	-	9	*C. hauschkei*	2
Changhsingian	Yinkong	*C. changxingensis*: *H. latidentatus-C. meishanensis* assemblage	25	Hambast	Unit 7	*C. iranica*	Akhura	*Paratirolites kittli*	*C. iranica*	9	*C. iranica*	1
Changhsingian	Yinkong	*C. changxingensis*: *H. latidentatus-C. meishanensis* assemblage	25	Hambast	Unit 7	*C. yini-C. zhangi*	Akhura	*Paratirolites kittli*	-	9	-	1
Changhsingian	Changx.	*C. changxingensis*: *C. changxingensis-C. deflecta-C. subcarinata* assemblage	e	Hambast	Unit 7	*C. changxingensis-C. deflecta*	Akhura	*Paratirolites kittli*	*C. changxingensis-C. deflecta*	9	*C. changxingensis-C. deflecta*	1

Figure 2. Biostratigraphical correlation of the P/T boundaryinterval 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 *Pleronodoceras-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 bondary (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 *Lytophiceras* fauna, found in the Dorasham II-3 section, is common for many sections in Transcaucasia, including the Karabaglar area, where it is represented by *Lytophiceras medium* Griesbach (Kotlyar et al., 1983).

Implications of the new data for P-T chronostratigraphy

We propose the aforementioned sectiones (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 (Meiashan 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.

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

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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, Prosphingitoides, 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 ideed 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 Russin 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., *Prosphingitoides 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,

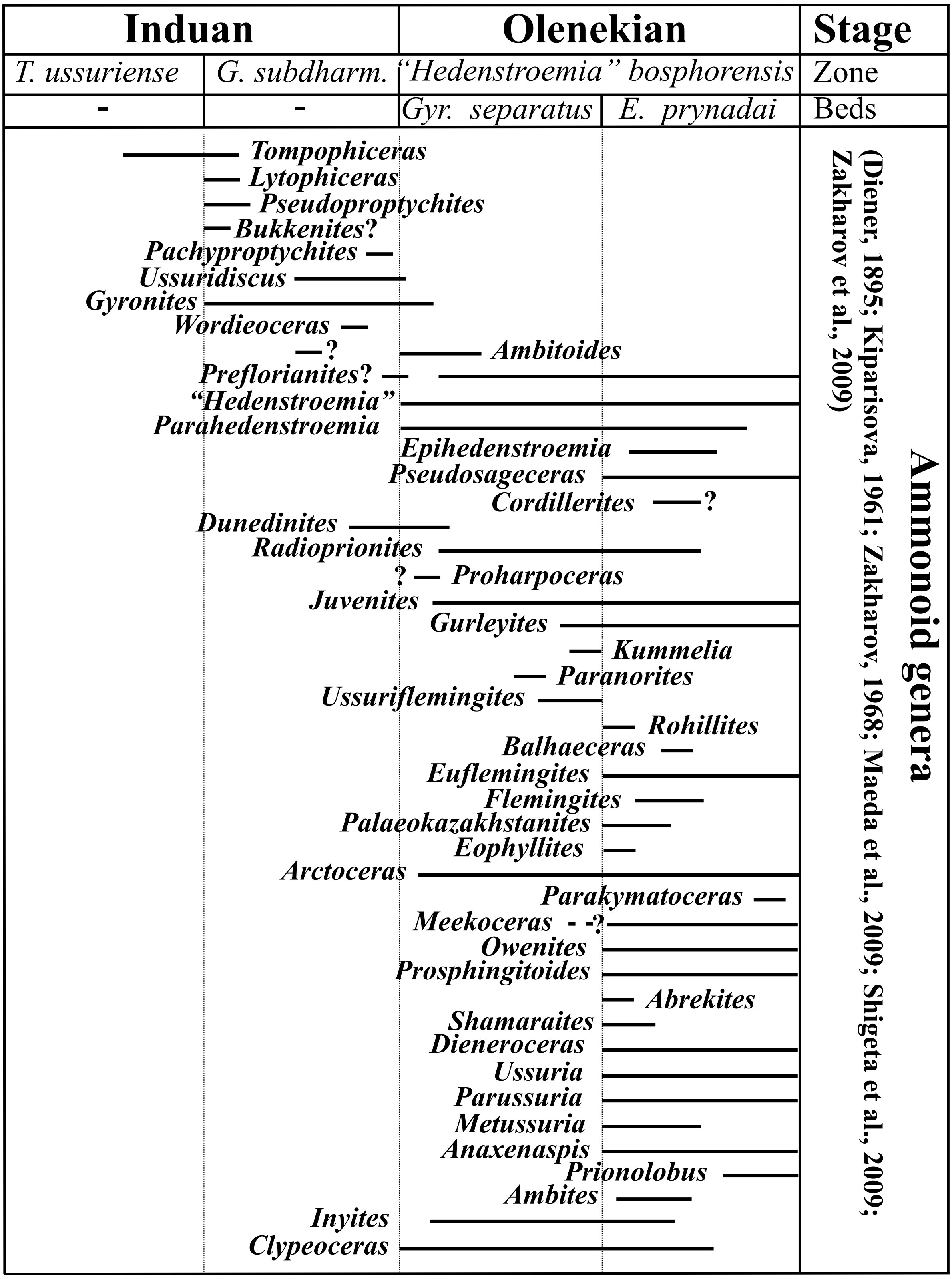

Figure 1. Vertical range of the Induan and early Olenekian ammonoid genera in South Primorye.

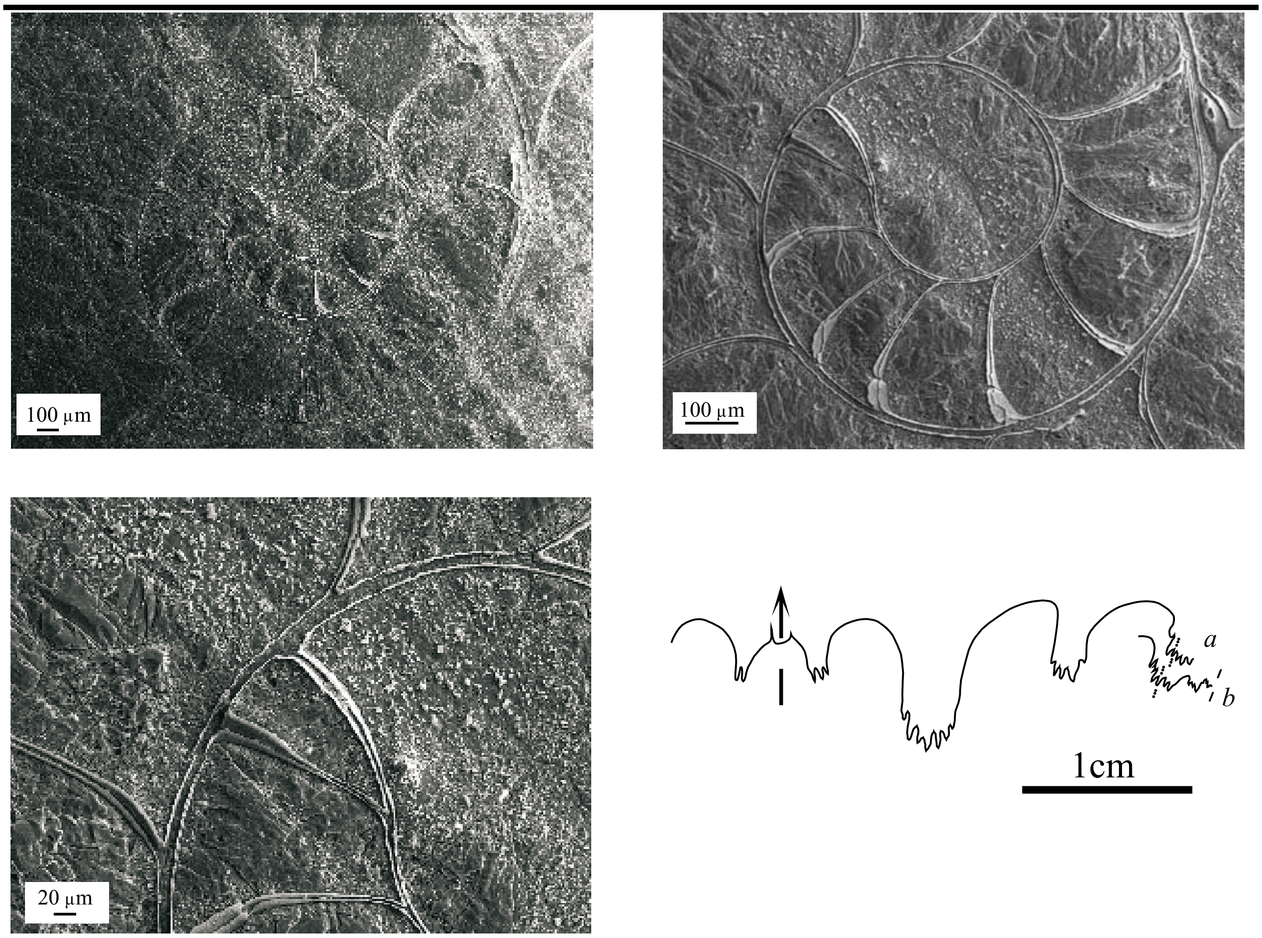

Figure 2. Inner structure of the *Meekoceras subcristatum* Kiparisova shell, showing protoconch, ammonitella, embryonic and early postembryonic septa, and its suture line at H=20 mm (a) and H=19.5 mm (b) (the coecum and prosiphon investigated earlier were lost during the later polishing). DVGI 5/888 (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, *Prosphingitoides hexagonalis* (Zakharov), *Prosphingitoides 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. *posterrolongatus* 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: *Pseudosageceras multilobatum* Noetling, *Parahedenstroemia conspicienda* Zakharov, *"Meekoceras"* sp., *Clypeoceras timorense* (Wanner), *Euflemingites prynadai* (Kiparisova), *Flemingites radiatus* Waagen, *Flemingites* aff. *glaber* Waagen, *Flemingites* sp., *Palaeokazakhstanites ussuriensis* (Zakharov), *Dieneroceras* sp.*, Preflorianites* sp.*, Prionolobus subevolvense* Zakharov, *Prosphingitoides 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).

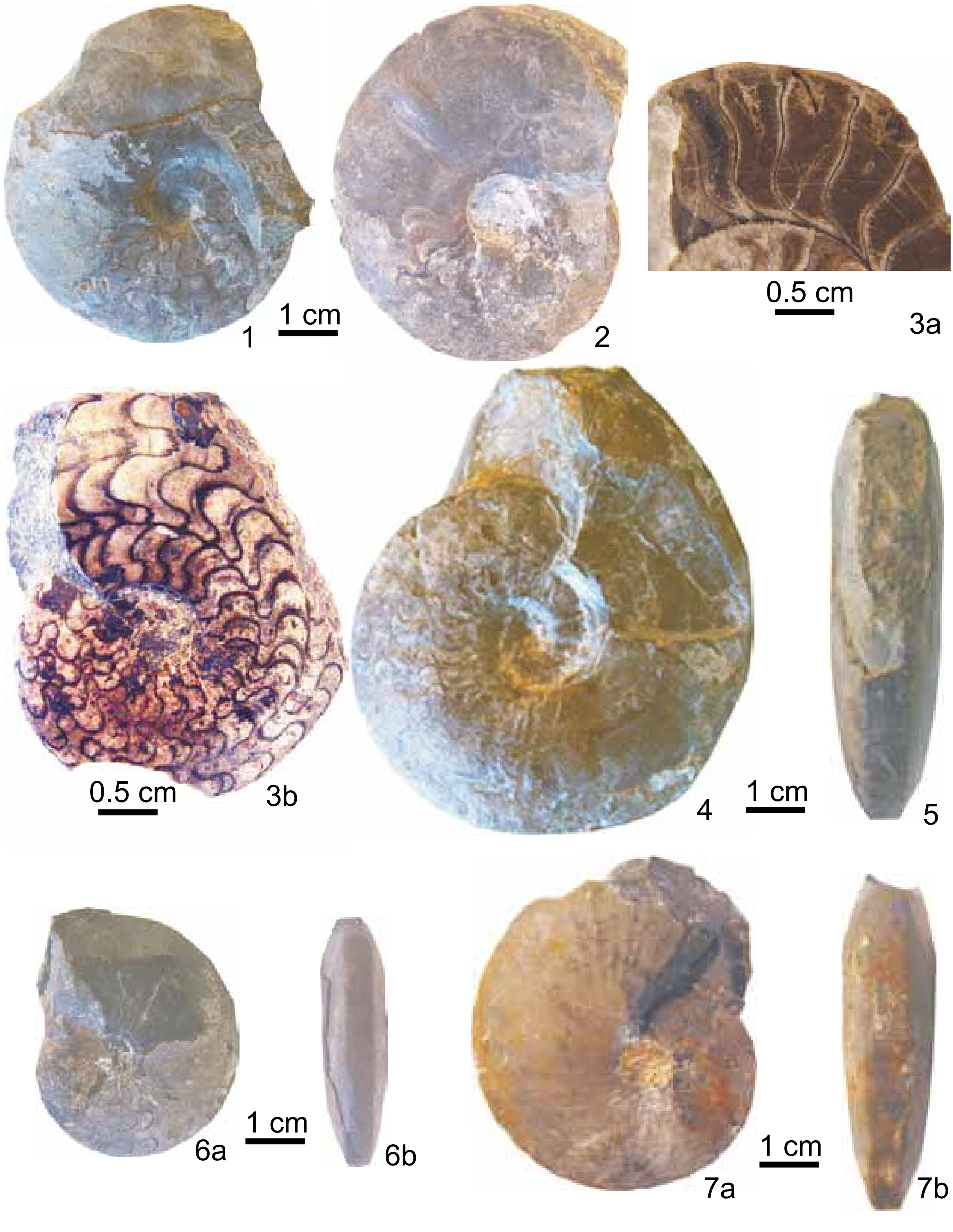

Figure 3. External morphology of *Meekoceras* shells: 3.1-3.6 - *Meekoceras subcristatum* Kiparisova; “*Hedenstroemia” bosphorensis* Zone; “SMID” quarry (Artyom), South Primorye: 3.1 – DVGI 6/888 (locality 743-3a-4), 3.2 - DVGI 7/888 (locality 743-3b), 3.3 – DVGI 5/888 (locality 741), 3-4 – DVGI 8/888 (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.).

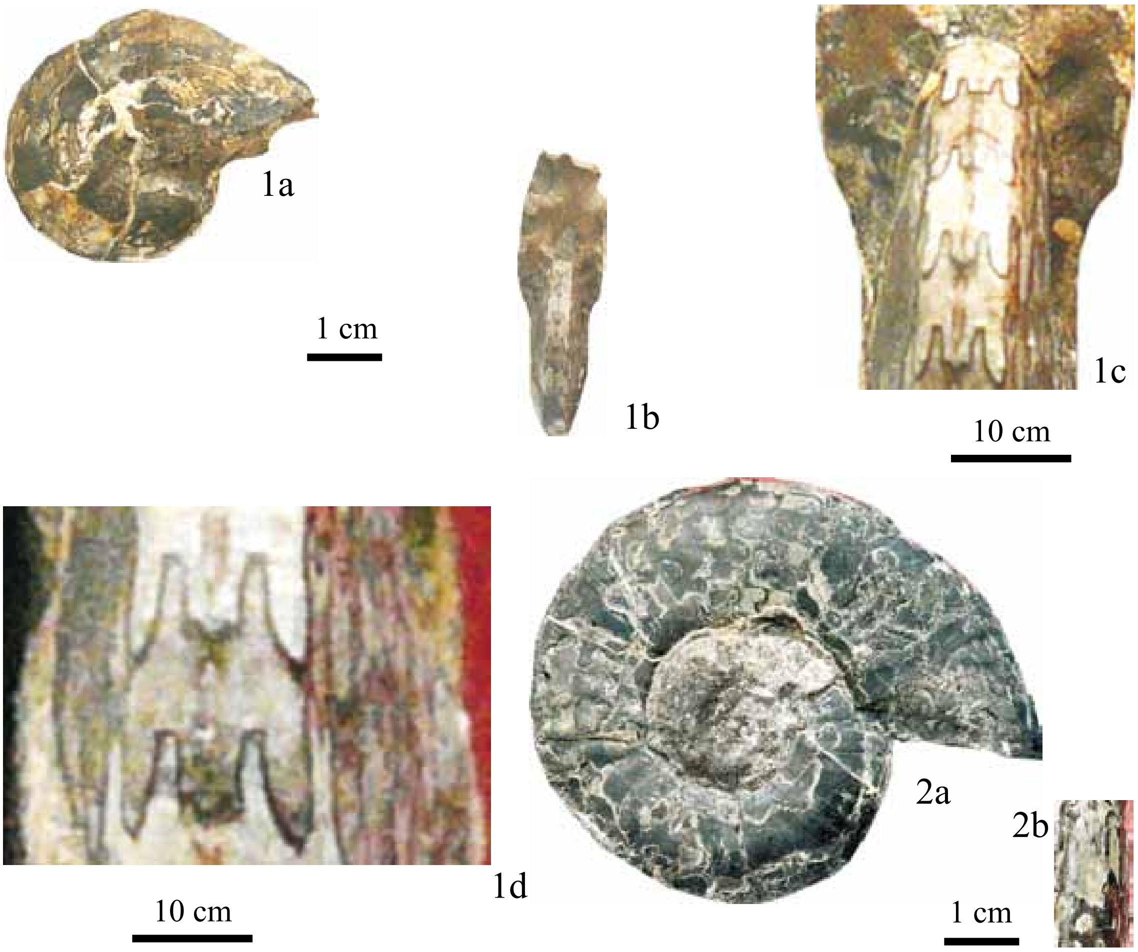

Figure 4. Early Olenekian *"Hedenstroemia"* and *Inyoites* from the *Hedenstroemia" bosphorensis* Zone of the "SMID" quarry: 4.1 - "*Hedenstroemia"* sp. nov. Zakharov and Smyshlyaeva, DVGI 1/888 (locality AK-1); *Inyoites* sp. nov. Zakharov and Smyshlyaeva, DVGI 2/888 (locality OC-1).

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 stratigrapical distribution of the main elements of the *Meekoceras* fauna: the former contains them in both *"Hedenstroemia" bosporensis* 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" bosporensis* 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 timorense* (Wanner), *Meekoceras subcristatum* Kiparisova, *Owenites koeneni* Hyatt and Smith, *Prosphingitoides ovalis* Kiparisova, *Arctoceras septentrionale* (Diener), *Arctoceras subhydaspis* (Kiparisova) , and flemingitid *Guangxiceras tobisinense* (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 Russiam 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"*

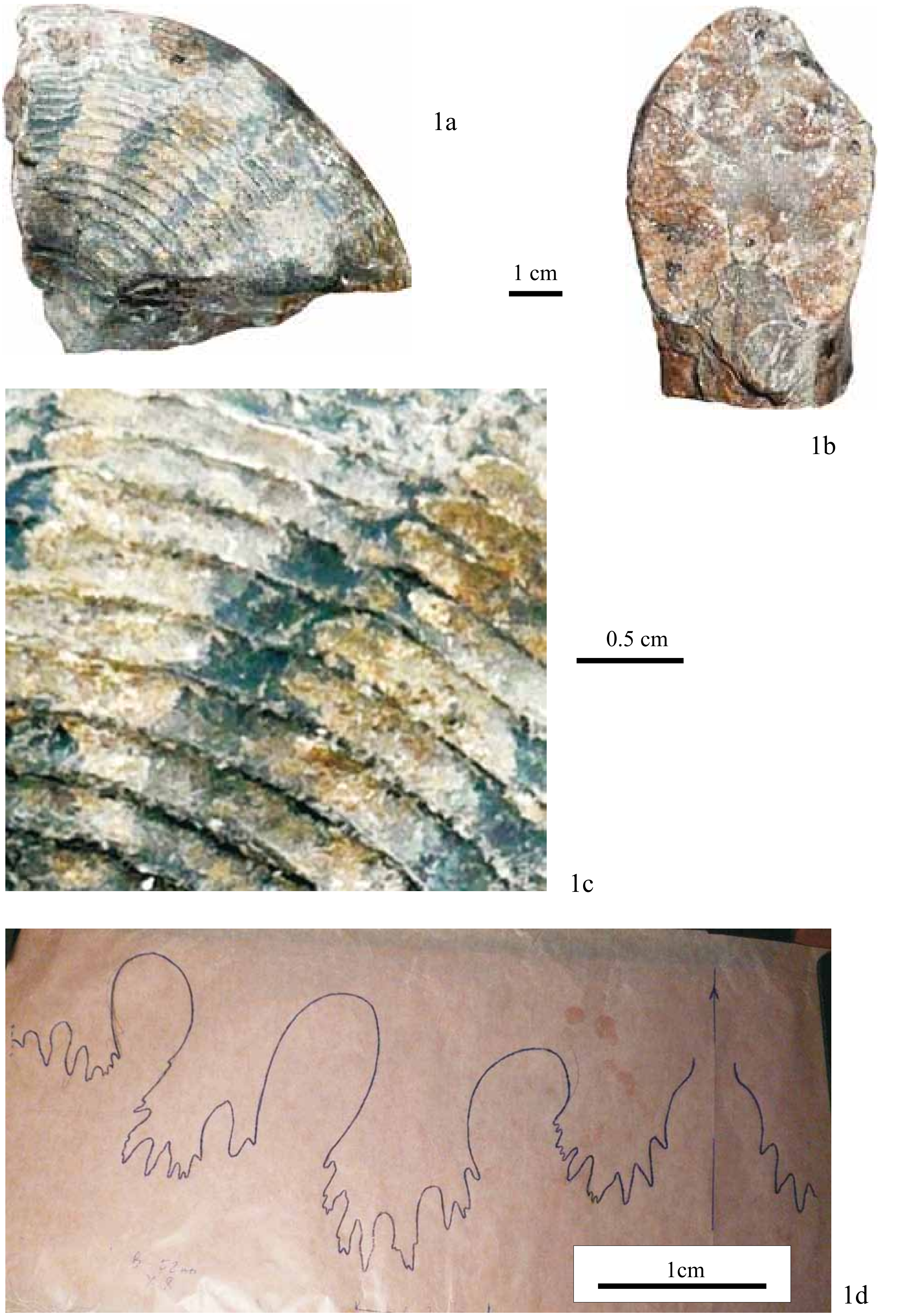

Figure 5. *Flemingites* aff. *trilobatum* Waagen, DVGI 3/888 (locality OC-2), suture line at H=52 mm; "*Hedenstroemia*" *bosphorensis* Zone; "SMID" quarry (Artyom), South Primorye.

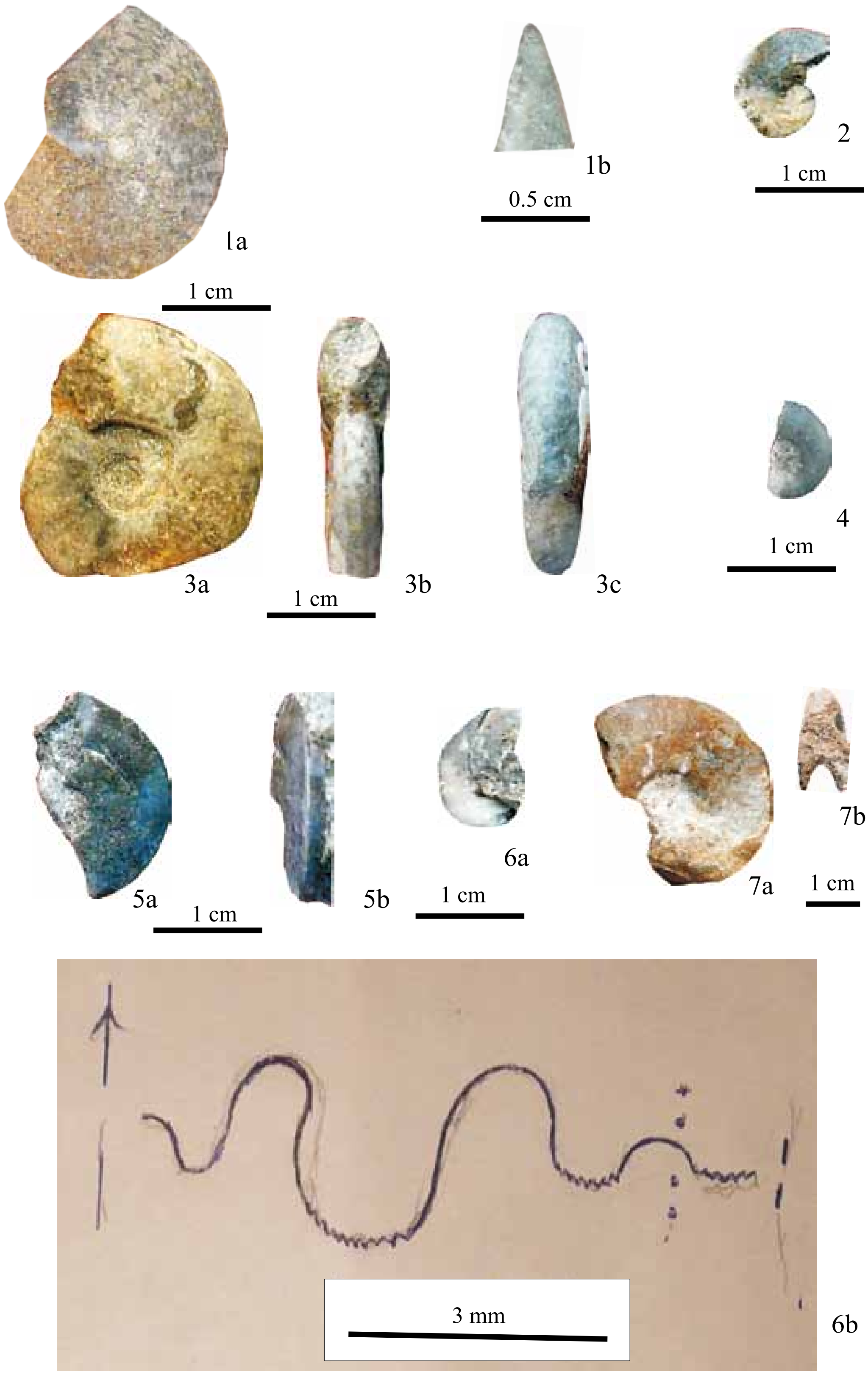

Figure 6. Ammonoid fossils, found at the base of the Olenekian (*Gyronites separatus* Beds) on the western coast of Ussuri Gulf: 6.1 – *Pseudosageceras* cf. *multilobatum* Noetling (="Hedenstroemia cf. *bosphorensis"*), DVGI 948/801 (Kontaktnyj Creek, locality 988-7, basal layer 401-8 of the *"Hedenstroemia" bosphorensis* Zone); 6.2 – *Parahedenstroemia* sp., DVGI 950/801 (Kontaktnyj Creek, locality 988-7, basal layer 401-8 of the *"Hedenstroemia" bosphorensis* Zone); 6.3 – *Gyronites separatus* Kiparisova, DVGI 935/801 (Kontaktnyj Creek, locality 988-7, basal layer 401-8 of the *"Hedenstroemia" bosphorensis* Zone); 6.4-6.6 – *Ambitoides* cf. *orientalis* Shigeta and Zakharov (Kontaktnyj 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 *Meekoceras* shells from the Olenekian "*Hedenstroemia*" *bosphorensis* Zone (*Euflemingites prynadai* Beds) of South Primorye

Species	Facies	Locality	Type of the hydrostatic apparatus	Dimension of the protoconch, mm			Dimension of the ammonitella, mm		Dimension of the cecum, mm		L_{pc}, mm
				D^1_p	D^2_p	W_p	D_a	α°	D^1_c	D^2_c	
M. subcristatum (original data)	Shallow-water sandy facies	"SMID" quarry	Meekoceras-type	0.40-0.49	0.38	-	0.9-0.92	250?	0.13	0.09	0.14
M. subcristatum (Zakharov, 1978)	Deeper silty-clayey facies	Ayax Bay	Meekoceras-type	0.43-0.45	0.31-0.39	0.50	-	-	0.13	0.09	0.14

Species	Facines	Locality	Position of the siphuncle within the whorls I-IV				Type of the septal necks				
			I	II	III	IV	I	II	III	IV	V
M. subcristatum (original data	Shallow-water sandy facies	"SMID" quarry	V	V	V	V	-	-	-	R	R
M. subcristatum (Zakharov, 1978)	Deeper silty-clayey facies	Ayax Bay	V	V	V	-	-	-	R	R	R-A

Designations: D^1_p – biggest diameter of the protoconch, D^2_p – least diameter of the protoconch, W_p – width of the protoconch, D_a – diameter of the ammonitella, α – position of the nepionic constriction (in degrees), D^1_c - biggest diameter of the cecum, D^2_c – least diameter of the cecum, L_{pc} – length of the prosiphon, R – retrochoanitic, A- amphichoanitic.

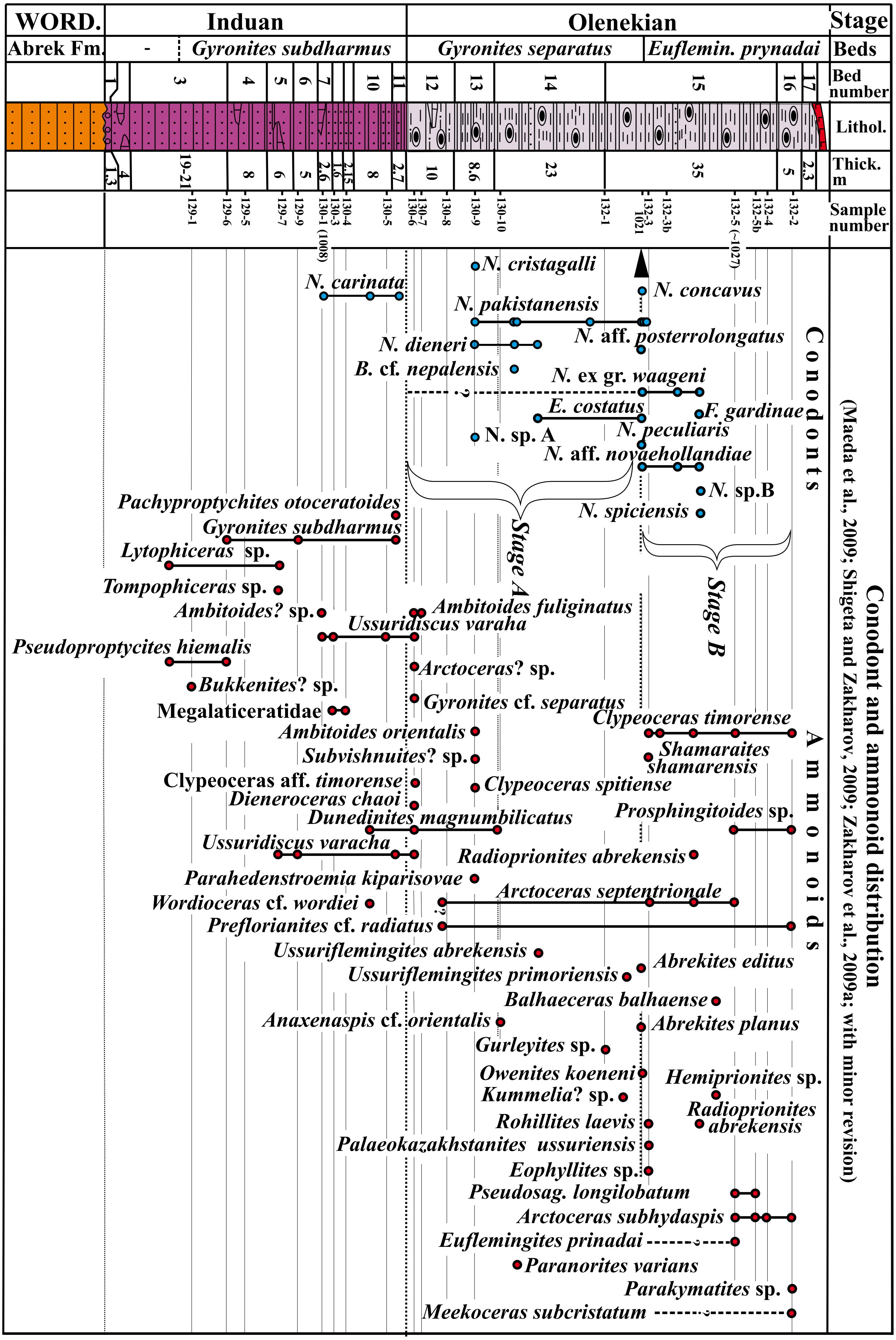

Figure 7. Vertical range and zonation of ammonoids in the IOB in Abrek Bay, South Primorye (new version).

bosphorenses 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), *Ambitoidesorientalis* Shigeta and Zakharov (Fig. 6.4-6.6) in the Kontaktnyj 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 Ayax 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 abrekensis, 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 usefull 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 wiith 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.

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Stratigraphic potential of the Upper Triassic benthic foraminifers

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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 Lallemant *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

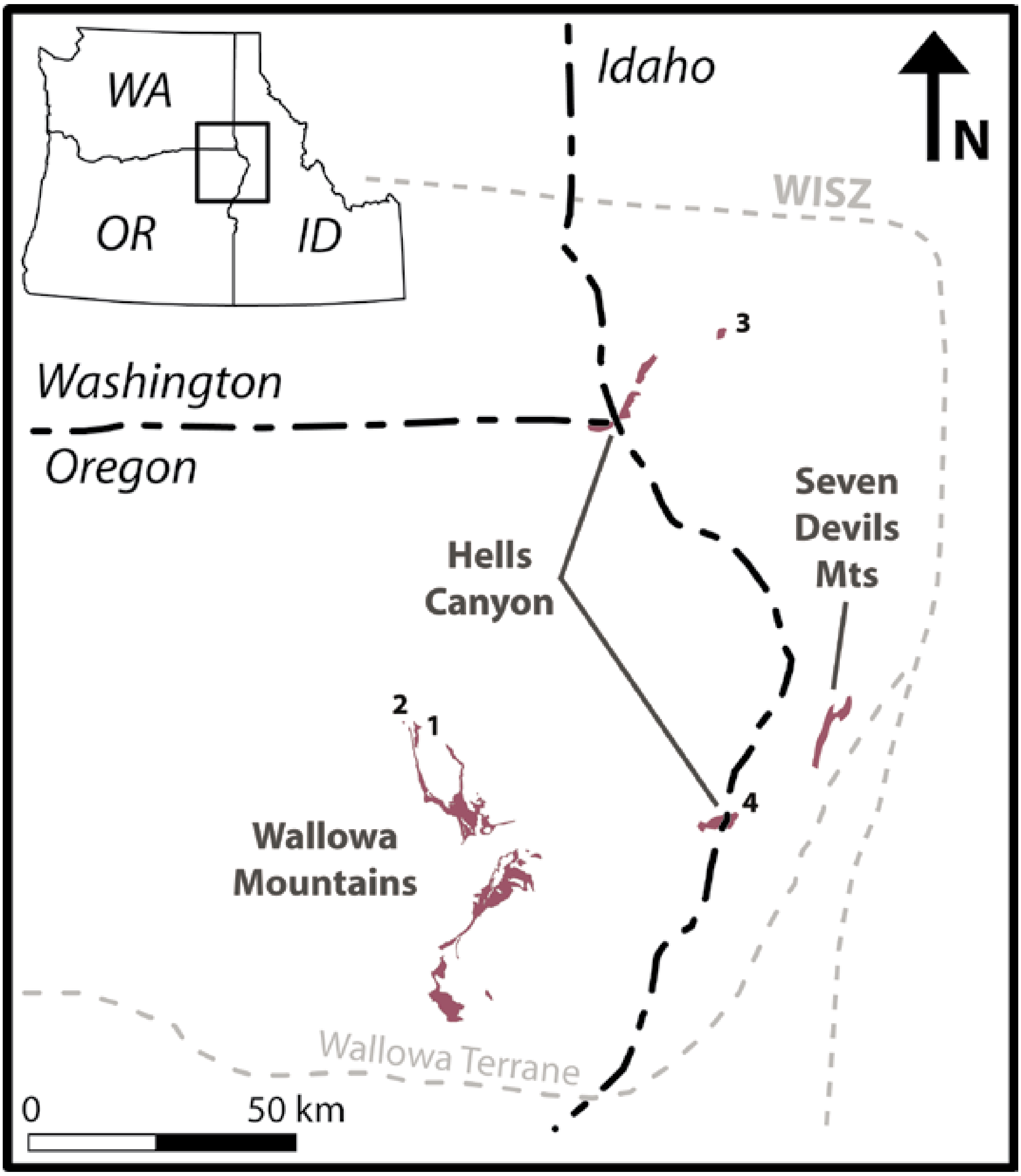

Figure 1: General map of the Wallowa terrane. Gray patches indicate the main Upper Triassic limestone outcrops and numbers, the localities mentioned in the text (1: Black Marble Quarry; 2: Lostine River; 3: Mission Creek Quarry; 4: Kinney Creek).

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 teem within the firsts 44 meters of the BMQ succession (see Fig. 2). Along this portion, the foraminiferal assemblages are dominated by abundant aragonitic foraminifers, Textularoidea, 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 multispirus* (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* (Oravecz-Scheffer), *Semimeandrospira* ex gr. *karnica-planispira* (Oravecz-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; Oravecz-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 Stuores/Stuores Wissen section of Northern Italy (Broglio Loriga *et al.*, 1998; Broglio 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 carbonate 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.

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

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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 Tuvalian." 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 Tuvalian (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 Tuvalian" 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 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 Tuvalian. 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 Tuvalian 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 Tuvalian, 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 Tuvalian.

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 *Kyrtomisporis 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 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 though the Hassberge Formation of the Germanic Basin, where the ranges of *Metoposaurus* 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 though 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

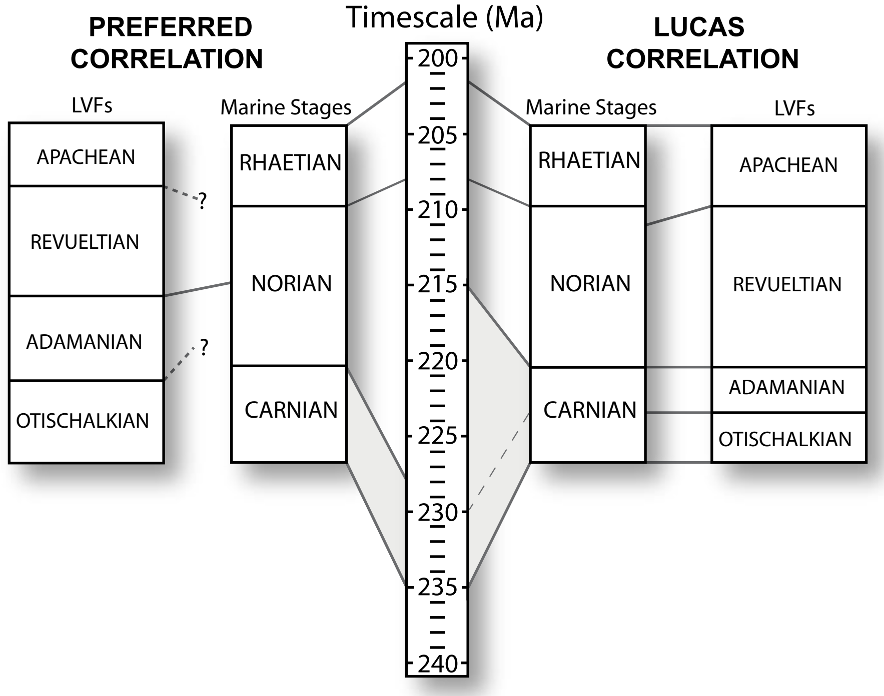

Figure 1. Alternative hypotheses for correlating Late Triassic land-vertebrate faunachrons (LVFs) to the marine stages and numerical timescale. Correlation on the right follows Lucas et al. (2007), Lucas (2009), and Heckert et al. (2009).

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 Tuvalian because of its presence in Tuvalian 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 Tuvalian 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 (Silickà Brezovà, 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 Pangaean 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

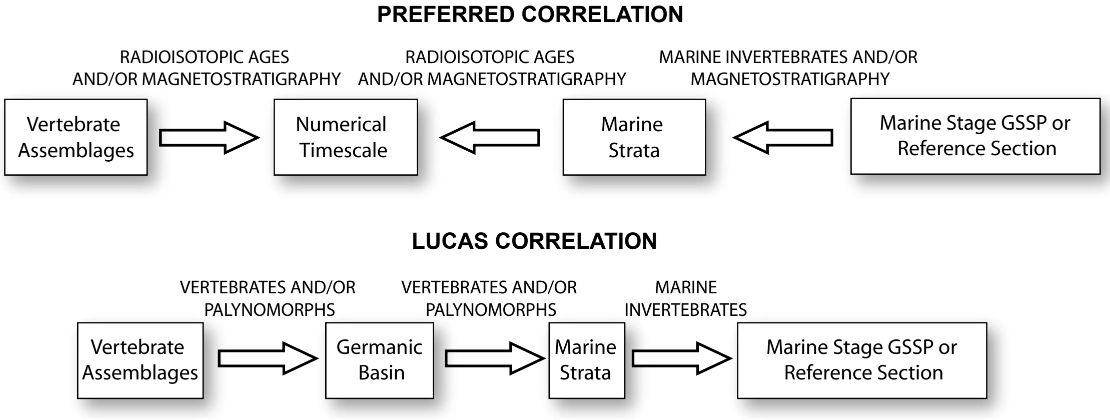

Figure 2. Number of steps and types of data used in correlations for the two hypotheses in Fig. 1.

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 Tuvalian" 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.

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Future Meetings

Prague 2010 - ICS Workshop

The GSSP Concept

Prague, Czech Republic

30 May – 3 June 2010

2nd 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;	kachlik@natur.cuni.cz
Cambrian –	Doc. Olda Fatka;	fatka@natur.cuni.cz
Ordovician –	Doc. Petr Kraft;	kraft@natur.cuni.cz
Silurian –	Dr. Petr Štorch;	storch@gli.cas.cz
Devonian –	Dr. Petr Budil;	petr.budil@geology.cz
Carboniferous –	Prof. Jiří Kalvoda (marine);	dino@sci.muni.cz
	Doc. Stanislav Opluštil (continental)	oplustil@natur.cuni.cz
Permian –	Dr. Jaroslav Zajíc;	zajic@gli.cas.cz
Triassic –	Doc. Jozef Michalík;	geolmich@savba.sk
Jurassic –	Doc. Petr Skupien;	petr.skupien@vsb.cz
Cretaceous –	Doc. Martin Košťák (marine);	kostys@centrum.cz
	Dr. Jiří Kvaček (continental);	jiri_kvacek@nm.cz
Paleogene –	Doc. Ján Soták;	sotak@savbb.sk
Neogene –	Doc. Katarina Holcová;	holcova@natur.cuni.cz
Quaternary–	Dr. Jaroslav Kadlec;	kadlec@gli.cas.cz

Subcommission on Stratigraphic Classification and Subcommission for Stratigraphic Information will be supported by Petr Storch (storch@gli.cas.cz) and Petr Kraft (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 adress: Václavské nám. 42, Prague 1
Account Name: Přirodovědecká fakulta UK
Account Adress: 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

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)

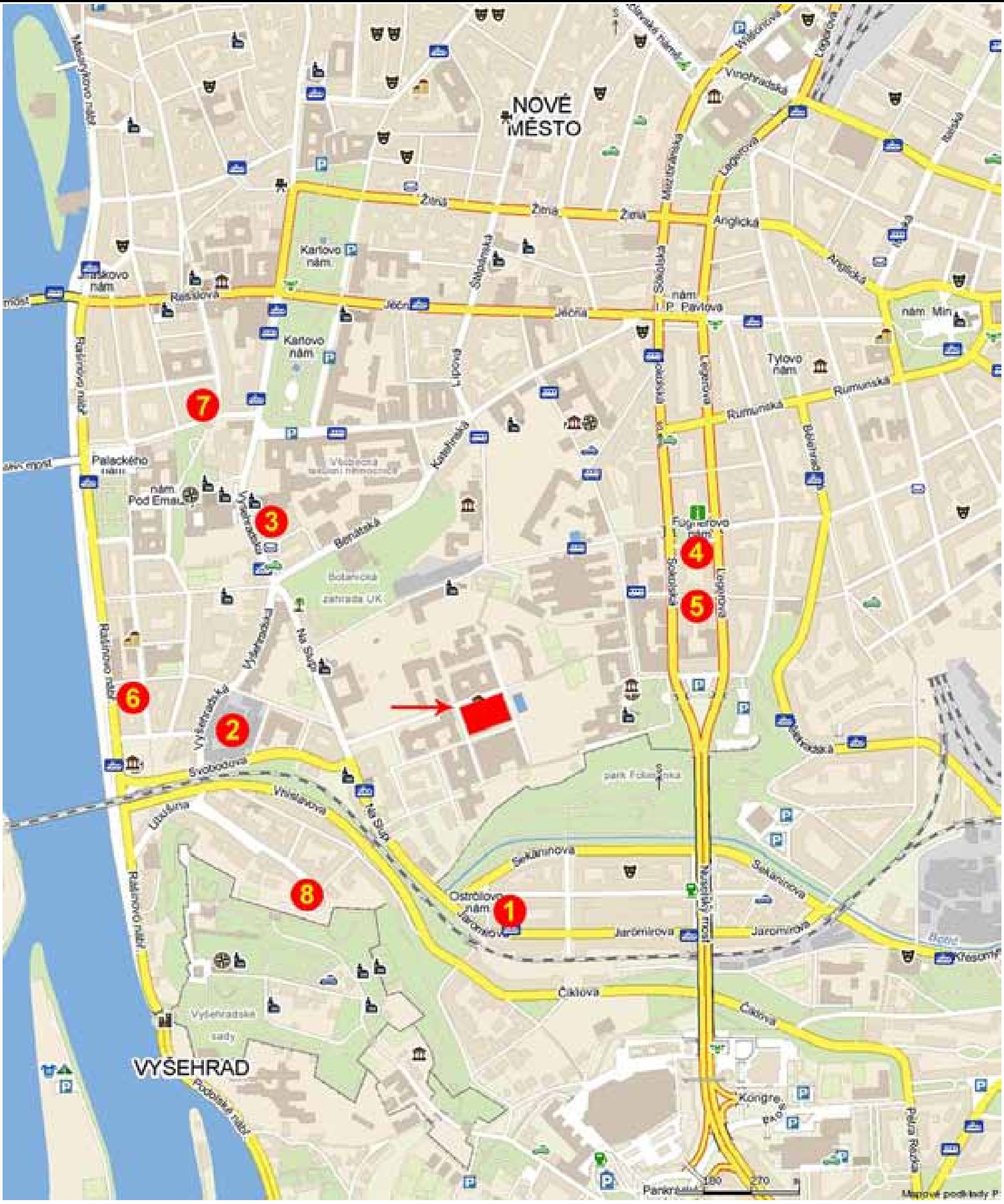
http://www.hotele.cz/praha-2-hotel-standard,detail-c-standardhotel.cz.html

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=GEOczech

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

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

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

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