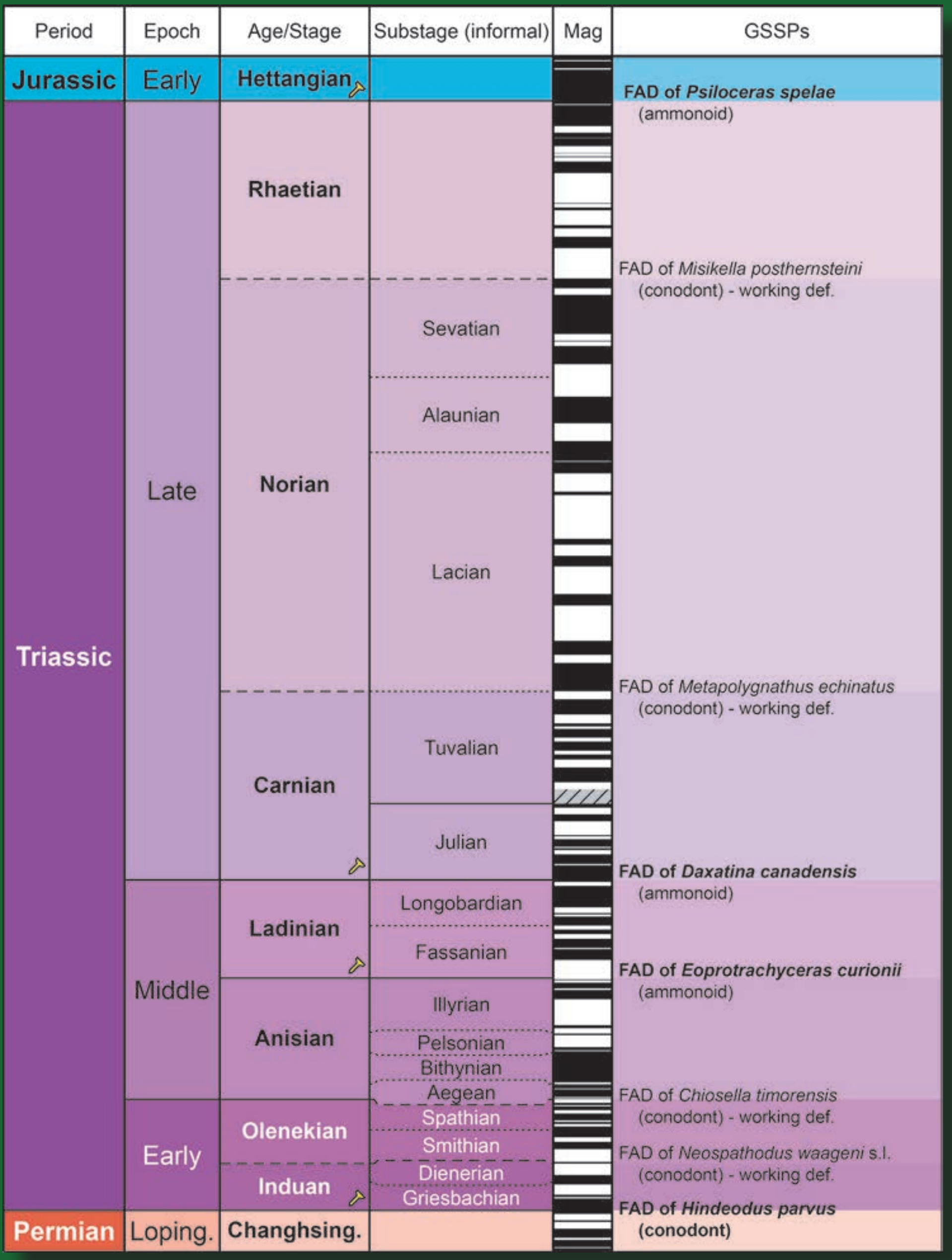
ALBERTIANA



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Albertiana is the international journal of Triassic research. 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. *Albertiana* serves as the primary venue for the dissemination of orignal research on Triassic System. *Albertiana* also serves as a newsletter for the announcement of general information and as a platform for discussion of developments in the field of Triassic stratigraphy. *Albertiana* thus encourages the publication of contributions in which information is presented relevant to current interdisciplinary Triassic research and at provides a forum for short, relevant articles including. original research articles, reports on research and works in progress, reports on conferences, news items and conference announcements, *Albertiana* Forum: letters, comment and reply, and literature reviews. *Albertiana* is published bianually by SUNY Cortland's Paleontological Laboratory for the Subcommission on Triassic Stratigraphy. *Albertiana* is available as PDF at http://paleo.cortland.edu/Albertiana/

Cover Image: Triassic time scale. See Ogg et al., p. 3

Editorial Note

Dear Friends of the Triassic.

As I begin my tenure as Editor-in-Chief of *Albertiana*, I look upon this opportunity as both an honor and a real challenge. Since the first volume was published in 1983, *Albertiana* has served the Triassic research community and Triassic Subcommission providing a vehicle for dissemination of original research, as a newsletter for the announcement of general information and as a platform for discussion of developments in the field of Triassic stratigraphy, biostratigraphy, paleontology, geochronology, magnetostratigraphy and other related disciplines. I am very grateful to Subcommission on Triassic Stratigraphy Chair Marco Balini for offering me this opportunity to serve as the new Editor-in-Chief.

Before going any further, I wish to publicly thank Wolfram Kürschner for his many years of service as editor to *Albertiana*. Under Wolfram's stewardship, *Albertiana* really transformed itself into a professional and vital means of dissemination of research and news to the Triassic community — all this while overseeing the transition from print to an online format. Wolfram will continue his relationship as an associate editor and member of the editorial board. The editorial board has now expanded to 10 dedicated scientists whose expertise covers a broad range of disciplines and extensive experience in the Triassic. The board will be managing individual manuscript submissions and their peer reviews.

We are striving to improve not only the quantity and quality of submissions to *Albertiana*, but to raise the stature of the journal making it the "go to place" to publish new and original research of interest to the Triassic community. Other components of the journal (e.g., news, reviews, announcements, bibliographies, etc.) will remain in place. We will continue to publish *Albertiana* twice a year in electronic format and I have made it one of my primary goals to keep journal production to a regular schedule.

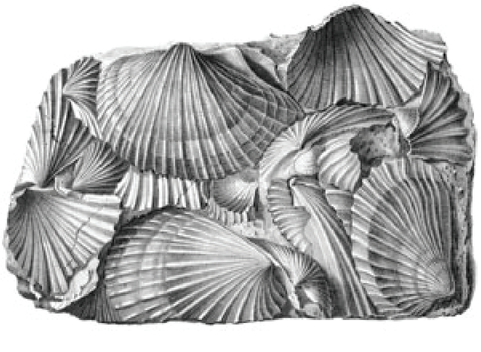
This issue's feature article by Jim Ogg and others is a review of the Triassic time scale and should look somewhat familiar to most of you. This invited contribution is not meant to be an authoritative technical research paper in which new data are presented, but instead, is essentially a republication of Jim's chapter in *The Geologic Time Scale 2012* (published by Elsevier). It is my desire that this review contribution will stimulate discussion and debate on the more pressing issues impeding progress in developing a robust and integrated timescale for the entire Triassic and the business of the Subcommission (e.g., establishing the remining GSSPs).

A couple of changes of the journal are now in place and others will soon be implemented. This edition of *Albertiana* inaugurates a somewhat modified format – one that will likely change as I learn the ins-and-outs of Adobe InDesign©. We have also revamped the submission and review processes to both strengthen the quality of research and to streamline the path from submission to publication. Additionally, I am also in the process of migrating *Albertiana*'s web site (as well as other sites hosted on paleo.cortland.edu) over to a new sever. The new instructions for authors and of course past issues of *Albertiana* will always be available on the journal's website whose URL will not change: paleo.cortland.edu/albertiana.

With this note, I am asking that you consider submitting your research to be published in *Albertiana*. Although *Albertiana* may not be able to compete with ISI journals in its impact factor, it is the perfect place to publish your Triassic research (including preliminary research/results) and other contributions like reviews and/or discussion-type papers. We would also, of course, like to publish any news, announcements, or other information that would be of interest to the Triassic research community. Given that *Albertiana* is a digital-only publication and electrons are relatively cheep we would be happy to publish lengthy articles, all-color images and would consider special thematic issue requests.

Finally, once again, I look forward to working with the editorial team, our reviewers and authors.

Christopher A. McRoberts
Editor-in-Chief, *Albertiana*
Secretary General, Subcommission on Triassic Stratigraphy



Executive Note

Dear Friends of the Triassic.

It has been a long time since the last issue of *Albertiana* was published, but we finally have a new issue ready. As you will notice, we have a new Editor; Chris McRoberts who has enthusiastically agreed to accept responsibility for publication of the newsletter. *Albertiana* now has a new layout. The Editorial Board has been updated, and I warmly welcome aboard new members Arnaud Brayard, Margaret Fraser, Piero Gianolla, Mark Hounslow, Wolfram Kürschner and Yuri Zakharov, who are joining Aymon Baud, Spencer Lucas, Mike Orchard and me. I also would like to very warmly thank Wolfram Kürschener for the tremendous amount of work he put forth over the past years as Editor of our Newsletter. He has invested lot of time collecting and editing manuscripts and perhaps most importantly, improving the layout of *Albertiana* from the original "basic" layout and paper print to its current much more effective two column organization and free PDF distribution.

I am confident that the new Editor and Board will come together in short order and work efficiently to produce a quality newsletter of which we all can be proud. We are hopeful that these new improvements will also stimulate the discussion of Triassic topics. After all, the mission of the STS is to define standards by solving problems, and problems cannot be solved without discussions.

Albertiana is ready to host discussions on those Triassic GSSPs whose definitions are still pending. During the past few years, these discussions and in a broader sense, the activities of the STS Working Groups, have been significantly delayed. The reasons behind these delays can be largely traced to the economic crisis, which reflects budget cuts for scientific research in many countries and the different methods for dissemination of the results with respect to what was the standard at the end of the 20th century. Now-a-days, we feel pressure to publish our scientific results in journals with a high impact factor and with major emphasis on fascinating and fashionable topics such as climate change, mass extinction and recovery, each of which ensures a high number of citations in a short time. Taxonomy as well as much of the work necessary to define a GSSP does not set well with this general trend, but nevertheless, this work must be done. Most discussions regarding GSSPs, chronostratigraphy and time scales would never be published in ISI journals, but Triassic specialists have the opportunity to publish them in *Albertiana*. Authors may even submit a short summary of research to *Albertiana*, which will be more fully described in a manuscript under review or in press.

Albertiana is again scheduled to be published twice per year. Again, this is an advantage for authors, who can have their contributions printed in a short time, and it is also an important enticement to shorten the time of discussions. Much time has been spent and ultimately lost during recent years while waiting for final acceptance by ISI journals of data critical to the discussion of GSSPs. A delay of one year from the informal announcement of new data and their presentation might be the exception, but it surely cannot be the rule for discussion. In this respect, WG leaders will be required to define deadlines and to promote discussions in *Albertiana*, and they will be made keenly aware that due to the shortage of funds, the organization of meetings and workshops specifically dedicated to the eventual definition of GSSPs is becoming more and more complex.

It pleases me to announce that there is also some good news regarding future activities of the Subcommission. Next year STRATI 2015, the 2nd international symposium on Stratigraphy, will be held in Graz (Austria) from July 19-23 (see the 1st circular at the end of this issue). This event follows the 1st international symposium held in Lisbon in 2013, and it is now the official reference symposium of the International Commission of Stratigraphy. The Organizing Committee together with the ICS is actively planning for the event and sessions and excursions devoted to Triassic topics will be included. The ICS, in particular, is showing an active interest and is providing support for the event. All Subcommissions have been invited to organize activities and discussions in the form of scientific sessions and/or in business meetings. In line with these suggestions and in cooperation with WG leaders, we will define and set goals with deadlines for 2015 for each WG. These deadlines will not necessarily pertain to final decisions for GSSPs, but they at least will include balloting for sections and possible primary marker events. The WGs from which results are expected include the base Olenekian (chair Y. Zakharov), base Norian (chair W. Kürschner) and base Rhaetian (chair M. Balini).

Thanks to the efforts of Leo Krystyn and his colleagues, the WG that is probably closest to final GSSP determination is the base Rhaetian. In December 2013 Krystyn asked me to take his place as WG leader because of the possible conflict created by his direct involvment with the Steinbergkogel proposal. The final proposal is nearly ready and the WG should initiate the final discussion. The next issue of *Albertiana* would be an ideal opportunity to publish the final proposal as well as any other comments, discussions and proposals for auxiliary/additional sections for this important boundary of the Upper Triassic Series.

The base Norian WG is also quite close to the final round of discussions. Important data from North America will probably be published this summer, and hopefully, the WG will be able to agree on a recommendation by the end of 2015. Nevertheless, the amount of data published for this boundary during the past four years is quite impressive.

A huge amount of data has also been published by members of the base Olenekian WG. This group is not far from a final conclusion of its activities, even though some data have not yet been published, namely the revision of the conodont *Neospathodus waageni.* Hopefully, this deficiency will be rectified in the very near future.

Marco Balini
Chair, Subcommission on Triassic Stratigraphy

Feature Review Article

TRIASSIC TIMESCALE STATUS: A BRIEF OVERVIEW

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Abstract – The Triassic is bounded by two mass extinctions that coincide with vast outpourings of volcanic flood basalts. Ammonoids and conodonts are the main correlation tools for marine deposits, but the precise calibrations of terrestrial animal and plant events to the marine stratigraphy are generally uncertain. The Pangea supercontinent has no known glacial episodes during the Triassic, but the modulation of its monsoonal climate by Milankovitch cycles left sedimentary signatures useful for high-resolution scaling, especially of magnetic polarity zones from terrestrial basins. However, the correlation of those segments of the cycle-scaled magnetic polarity pattern and the associated terrestrial stratigraphy to the marine-based records is ambiguous for most intervals. The age model for Early and Middle Triassic is relatively well constrained by cyclostratigraphy and radio-isotopic dates, but there is a lack of precise biostratigraphic-constrained radio-isotopic dates for the Late Triassic, and two end-member options are possible. In contrast to the rapid evolution and pronounced environmental changes that characterize the Early Triassic through Carnian, it appears that the Norian stage of the Late Triassic was a 20-million-year interval of stability in Earth history.

INTRODUCTION

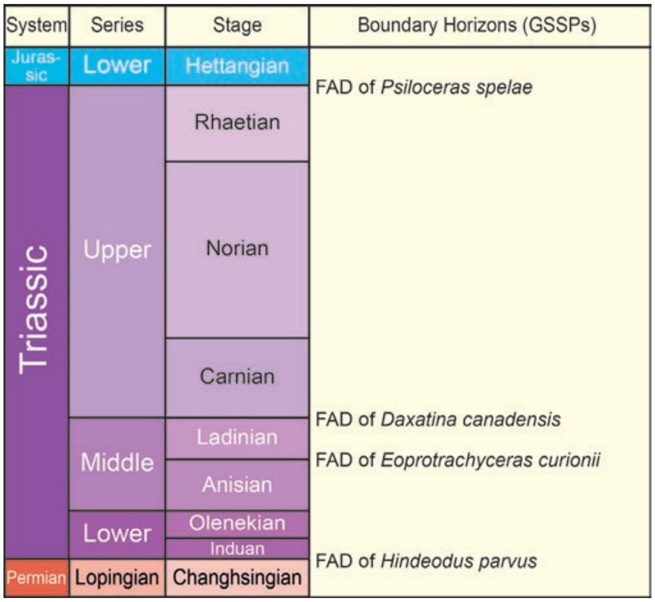
Our understanding of the Triassic underwent a revolution after 2002. Collaborations among geochemists, paleomagnetists, paleontologists and other stratigraphers have concentrated on its exciting boundary intervals, but have also enabled compilation of a comparatively detailed bio-mag-chem-cyclostratigraphy scale for much of the Triassic. Abundant high-precision radio-isotopic dates, coupled with enhanced methods for global correlation and detailed compilations of geochemical oscillations, have revealed a startling inequality in duration of Triassic subdivisions and pacing of evolutionary and environmental change. The Norian of Late Triassic apparently spans nearly three times the duration of the entire Early Triassic (Induan and Olenekian). The early half of that brief Early Triassic has been revealed as an interval of pronounced environmental stress and extraordinarily rapid evolutionary turnover.

This knowledge and the inevitable new questions and debates have been partially summarized in review articles and special volumes. In particular, the book "Triassic Time Scale" (Lucas, 2010a) contains separate papers on every main stratigraphic topic (e.g., history and status of chronostratigraphy, biostratigraphy of different marine and terrestrial groups, magnetic polarity time scale, radio-isotopic age database, etc.). This suite and selected other studies were compiled with potential numerical age models as a Triassic chapter in Geologic Time Scale 2012 (Gradstein et al., 2012).

This article is largely a condensed extract of the status of subdivisions and possible numerical age models from that GTS2012 Triassic chapter, with the inclusion of selected later publications. We highlight aspects where research will establish a more robust international Triassic time scale.

TRIASSIC SUBDIVISIONS

The Trias of Friedrich August von Alberti (1834) united a trio of formations widespread in southern Germany – a lower Buntsandstein ('colored sandstone'), Muschelkalk ('clam limestone') and an upper Keuper (non-marine reddish beds). These continental and shallow-marine formations were difficult to correlate beyond Germany; therefore, most of the traditional stages (Anisian, Ladinian, Carnian, Norian, Rhaetian) were named from ammonoid-rich successions of the Northern Calcareous Alps of Austria. However, the stratigraphy of these Austrian tectonic slices proved unsuitable for establishing formal boundary stratotypes, or even deducing the sequential order of the stages (Tozer, 1984). For example, the Norian was originally considered to underlie the Carnian stage, but after a convolute scientific-political debate (reviewed in Tozer, 1984), the Norian was established as the younger stage. Over 50 different stage names have been proposed for subdividing the Triassic (tabulated in Tozer, 1984).



System	Series	Stage	Boundary Horizons (GSSPs)
Jurassic	Lower	Hettangian	FAD of *Psiloceras spelae*
Triassic	Upper	Rhaetian	
		Norian	
		Carnian	FAD of *Daxatina canadensis*
	Middle	Ladinian	FAD of *Eoprotrachyceras curionii*
		Anisian	
	Lower	Olenekian	
		Induan	FAD of *Hindeodus parvus*
Permian	Lopingian	Changhsingian	

Figure 1 – Summary of Triassic stage nomenclature and status. Stages with ratified GSSPs are indicated by the first-appearance datum (FAD) of the main correlation marker, which are ammonoids except for the conodont Hindeodus parvus at the beginning of the Triassic. Relative durations of stages for this Triassic diagram is "Option 2" (long Rhaetian; shorter Carnian) that was used in GTS2012 Phanerozoic scale, but a modified "Option 1" (a shorter Rhaetian span) is suggested by on-going dating of the Norian-Rhaetian boundary interval (Jörn Wotzlaw, pers. commun.).

The Subcommission on Triassic Stratigraphy (International Commission on Stratigraphy) adopted seven standard Triassic stages in 1991 (Visscher, 1992); but the general lack of unambiguous historical precedents for placement of Triassic stage boundaries slowed the establishment of formal GSSPs (Figure 1). Probably as with many geologic systems, if one could "start over with present knowledge", a more global suite of series and stages could be proposed (see the stimulating discussion and suggestions in Lucas, 2013). However, as with many geologic systems [other than for the international Cambrian and Ordovician, where an entirely new global division and nomenclature was adopted], there is a trend to retain historical usage rather than accept a more "natural" set of semi-equal divisions marked by recognized major global events in Earth's biological and environmental history.

European stratigraphers commonly use substages with geographic names, whereas North American stratigraphers prefer a generic lower/middle/upper nomenclature (e.g., Fassanian substage versus Lower Ladinian). The most common substages are summarized here, these are informal working versions.

Details of the history, definitions and correlation of Triassic subdivisions include the Albertiana newsletters and the annual reports of the Subcommission on Triassic Stratigraphy (ICS). Excellent reviews are in Tozer (1967, 1984) and Lucas (2010b, 2013).

The Permian–Triassic Boundary (base of Induan Stage)

The Paleozoic terminated in a complex environmental catastrophe and mass extinction of life. The latest Permian to earliest Triassic events include the progressive disappearance of up to 80% of marine genera, pronounced negative carbon-isotope and strontium-isotope anomalies, the massive flood basalts of the Siberian Traps, widespread anoxic oceanic conditions, a major sea-level regression and exposure of shelves followed by a major transgression, a "chert gap" and "coal gap", and replacement of reefal ecosystems with microbial-dominated carbonate precipitation (e.g., reviews by Holser and Magaritz, 1987; Erwin, 1993, 2006; Kozur, 1998, 2007; Hallam and Wignall, 1999; Erwin et al., 2002; Wignall, 2007; Knoll et al., 2007; Metcalfe and Isozaki, 2009a; Korte et al., 2010; and many other compilations). The majority of ecosystems did not fully recover until near the end of the Early Triassic. A common hypothesis is that the onset of the enormous Siberian continental flood basalts was the main contributor to the end-Permian wave of extinctions. The dated initiation of the Siberian Traps at 252.28 Ma (Seth Burgess and Samuel Bowring, as reported by Kerr, 2013) is just before or coincides with the onset of the end-Permian mass extinctions at 251.94 ±0.04 Ma (Burgess et al., 2014). Release of aerosols and/or carbon dioxide, coupled with their cooling/warming feedbacks on ocean circulation and stratification and on terrestrial systems, precipitated a progression of environmental and ecological stresses (e.g., Renne et al., 1995; Krull and Retallack, 2000; Wignall, 2001, 2007; Yin et al., 2007; Korte et al., 2010; Isozaki, 2009; Lucas, 2009; Metcalfe and Isozaki, 2009b; Cao et al., 2009; Preto et al., 2010; etc.).

The mass disappearance of the Paleozoic fauna and flora, coupled with the widespread occurrence of a major regression-transgression unconformity in most regions, led to a dilemma. It was easy to recognize the bleak final act of the Permian, but how should the beginning of the Mesozoic be defined? Ammonoids are the common biostratigraphic tool throughout the Mesozoic, and the *Otoceras* ammonoid genus was long considered to be the first 'Triassic' form. Therefore, Griesbach (1880) assigned the Triassic base to the base of the *Otoceras woodwardi* zone in the Himalayan region, but this species is only known from the Peri-Gondwana paleo-margin of eastern Tethys (e.g., Iran to Nepal). The first occurrence of *Otoceras* species in the Arctic realm (*Otoceras concavum* zone) was used by Tozer (1967, 1986, 1994) for a Boreal marker of the base of the Triassic, but is now known to appear significantly prior to *Otoceras woodwardi* in the Tethyan realm (Krystyn and Orchard, 1996). It was realized that the progressive evolution of the conodont *Hindeodus* genera through the Permian–Triassic boundary interval provided global correlation markers with no obvious facies dependence. Therefore, in 2000, the Triassic Subcommission chose the first occurrence of the conodont *Hindeodus parvus* (= *Isarcicella parva* of some earlier conodont studies) within the evolutionary lineage *Hindeodus typicalis–H. latidentatus praeparvus–H. parvus–H. postparvus* as the primary correlation marker for the base of the Mesozoic and Triassic. This biostratigraphic event is the first cosmopolitan correlation level associated with the initial stages of recovery following the end-Permian mass extinctions and environmental changes. Global correlations indicate that this conodont species appears just after the carbon-isotope (δ13C) minimum, although its lowest occurrence may be slightly earlier in some local successions (e.g., Payne et al., 2009). This level is slightly lower than the base of the *Otoceras woodwardi* ammonoid zone of the Himalayas. The revised definition for the base-Triassic assigns the *Otoceras concavum* and lowermost portion of *Otoceras boreale* ammonoid zones of the Arctic (the lower part of the 'Griesbachian' substage of Tozer, 1967) into the Permian (Orchard and Tozer, 1997).

In continental settings, the correlated level to this conodont event is close to the disappearance of typical Permian Dicynodon tetrapods after an interval of co-occurrence with 'Triassic' dicynodont *Lystrosaurus* (Kozur, 1998).

The choice of the first appearance of this conodont to serve as the primary marker for the beginning of the Triassic implies that former traditional concepts of the Permian–Triassic boundary, such as the disappearance of typical Permian marine fauna, rapid facies changes, extensive volcanism and onset of isotope anomalies are now assigned to the latest Permian.

The GSSP for the base of the Mesozoic Erathem, the Triassic System and the Induan Stage is at the base of Bed 27c at a section near Meishan, Zhejiang Province, southern China. This level coincides with the lowest occurrence of conodont *Hindeodus parvus* (Yin et al., 2001, 2005). This Meishan section is now within a special GeoPark that includes a museum of Earth's history. Indeed, the formal park-like setting with sculptures and educational exhibitions is probably the most impressive GSSP-site for the geologic record.

Subdivisions of the Lower Triassic

The Triassic Subcommission adopted the current subdivision into a lower Induan stage and an upper Olenekian stage in 1991. The Induan and Olenekian stages of Kiparisova and Popov (1956, revised in 1964) were named after exposures in the Indus river basin in the Hindustan region of Asia and in the lower reaches of the Olenek river basin of northeast Siberia, respectively.

A suite of four substages is widely used. In an imaginative procedural twist, these Griesbachian, Dienerian, Smithian and Spathian substages are named after exposures along associated small creeks on Ellesmere and Axel Heiberg islands in the Canadian Arctic, which in turn were named after the Triassic paleontologists – Carl L. Griesbach (1847-1907), Carl Diener (1862-1928), James Perrin Smith (1864-1931) and Leon Spath (1888-1957) – who played important roles in Lower Triassic biostratigraphy (Tozer, 1965). These substages were originally defined by grouping of ammonoid zones.

Griesbachian and Dienerian substages of Induan (informal)

The Induan Stage is informally divided into two substages. The lower substage, Griesbachian, is named after Griesbach Creek on northwest Axel Heiberg Island. The definition of the Permian–Triassic boundary implies that the lower portion of the original Griesbachian of Tozer (1965, 1967) is now assigned to the uppermost Permian.

The Dienerian substage is named after Diener Creek of northwest Ellesmere Island. The original placement of the Griesbachian/Dienerian boundary is marked by the appearance of Gyronitidae ammonoids. This substage boundary is recognized in Canada and in the Himalayas as the boundary between *Otoceras* and *Meekoceras* ammonoid-bearing beds of Diener (1912) and in the Salt Range of Pakistan at the base of the Lower Ceratite Limestone (Tozer, 1967).

Olenekian

The Olenekian Stage was originally proposed from sections in Arctic Siberia, whereas the stratotype for the Induan stage was in the Hindustan region of Pakistan-India. Neither region has fossiliferous strata spanning their mutual boundary – the Induan in the Olenek River basin is marginal marine to lagoonal, and ammonoids in the transitional interval in the Hindustan region are rare or absent (Zakharov, 1994). The lower Olenekian is marked by the appearance of a diverse ammonoid assemblage of *Hedenstroemia*, *Meekoceras*, *Juvenites*, *Pseudoprospingites*, *Arctoceras*, *Flemingites* and *Euflemingites*. A sea-level regression caused a scarcity of age-diagnostic conodonts and bivalves during the latest Induan to earliest Olenekian, but the transition seems to be within the lower portion of the *Neospathodus pakistanensis* conodont zone (Zakharov, 1994; Paull, 1997; Orchard and Tozer, 1997). Proposed ammonoid-based biostratigraphic definitions of the stage boundary were the highest occurrence of the ammonoid *Gyronites subdharmus* and the lowest occurrence of the representatives of the *Meekoceras* or *Hedenstroemia* ammonoid genera (Zahkarov et al., 2000, 2002). The base of its lower Smithian substage was originally defined as the base of a broad *Euflemingites romunderi* ammonoid zone (Tozer, 1965, 1967), but this zonation was revised to add a *Hedenstroemia hedenstroemi* ammonoid zone (e.g., Orchard and Tozer, 1997). Conodonts were undergoing a pronounced evolutionary change at the beginning of the Olenekian; and, even though some taxonomic details remain to be resolved, the widespread distribution and resolution of *Neospathodus* species provide the main method for inter-regional correlations (Orchard, 2010).

Therefore, the current working definition selected by the base-Olenekian task group is the lowest occurrence of the conodont *Neospathodus waageni* sensu lato. Correlation of ammonoid and conodont events among paleogeographic provinces indicates equivalence of the first occurrence of *N. waageni* with the lowermost part of the *Rohillites rohilla* ammonoid zone (Spiti region of Tethyan realm), slightly below the lowest occurrence of *Flemingites* and *Euflemingites* ammonoid genera (S. China, Tethyan realm), and lower part of *Lepiskites kolyhmensis* Zone (Siberia, Boreal realm; which is just above the regional *Hedenstroemia hedenstromia* zone) (Zakharov et al., 2009). This level is also just prior to the peak of the first Triassic positive excursion in δ^{13}C, slightly below the top of the second major Triassic reversed-polarity magnetozone (LT2r of Hounslow and Muttoni, 2010), and just above widely recognizable sequence boundary (Subcommission on Triassic Stratigraphy, annual reports of 2008 and 2009; Krystyn et al., 2007a).

Two leading candidate GSSPs for this transition are a roadside outcrop near Chaohu city in the Anhui Province of eastern China (Tong et al., 2004; Sun et al., 2007; Chinese Triassic Working Group, 2007) and Mud (Muth) village in the Spiti Valley of northwest India (Krystyn et al., 2007a, b). A preliminary vote to select Mud as the GSSP was put on hold in 2008 when the desired conodont marker was identified in strata lower than the proposed GSSP level.

Smithian and Spathian substages (informal)

Two informal substages of the Olenekian Stage were named after Smith and Spath creeks on Ellesmere Island of the Canadian Arctic. A major environmental and evolutionary event occurring in their boundary interval (e.g., Payne and Kump, 2007; Galfetti et al., 2007a, b, c) has been termed the "biggest crisis in Triassic conodont history" (Goudemand et al., 2008). A sudden reduction of ammonoid diversity and shift from latitudinal to cosmopolitan distributions (Brayard et al., 2009a) coincides with a major positive peak in Carbon-13 ($\delta^{13}C$) and climatic shift (e.g., Galfetti et al., 2007a). The ammonoids recovered in early Spathian with a dramatic evolutionary radiation accompanied by the development of a pronounced latitudinal gradient of diversity (Brayard et al., 2009a). In the original stratotypes, the Smithian–Spathian boundary was placed at the base of the *Olenekites pilaticus* ammonoid zone, but there appears to be a missing biostratigraphic interval in the type region (Tozer, 1967; Orchard and Tozer, 1997).

The exciting discovery of major global-scale geochemical, climatic and paleontological events that occur within this substage boundary interval should enable precise inter-regional correlations including to terrestrial settings.

Subdivisions of the Middle Triassic

Anisian

The Anisian Stage was named after limestone formations near the Enns (= Anisus) River at Grossreifling, Austria (Waagen and Diener, 1895). The original Anisian stratotype lacks ammonoids in the lower portion, and lower limit was later clarified in the Mediterranean region (Assereto, 1974). The appearance of a number of ammonoid genera, including *Aegeiceras*, *Japonites*, *Paracrochordiceras* and *Paradanubites*, may be used to define the base of the Anisian within different regions (e.g., Gaetani, 1993). However, other markers are suggested that may provide a more global correlation value. The lowest occurrence of the *Chiosella timorensis* conodont slightly precedes the ammonoid level and can be correlated to North American and Asian stratigraphy (Orchard and Tozer, 1997; Orchard, 2010). The boundary interval is also close to a peak in Carbon-13 ($\delta^{13}C$) values. A shift from reversed-polarity- to normal-polarity-dominated magnetostratigraphy (base of normal-polarity magnetozone MT1n of Hounslow and Muttoni, 2010) has been formally proposed as a primary global boundary marker that can be unambiguously correlated between Boreal and Tethyan faunal realms (Hounslow et al., 2007).

A long-standing candidate for the base-Anisian GSSP at Desli Caira Hill in north Dobrogea, Romania (Gradinaru et al., 2007) has been within a condensed Hallstatt limestone facies that may be missing a partial ammonoid zone in the boundary interval (Subcommission on Triassic Stratigraphy annual report, 2009). A potential alternative is a conodont-magnetic-isotope reference section at Guandao in the Nanpanjiang Basin (Guizhou Province, South China) where volcanic ashes within the boundary interval also produced radio-isotopic dates (ca. 247 Ma; e.g., Lehrmann et al., 2006). However, this section lacks a good ammonoid record and the chronostratigraphic reliability of the lowest occurrence of the conodont *Chiosella timorensis* marker is questioned (Ovcharova et al., 2010). Even though the correlations among different stratigraphic methods are fairly well established, no single section spanning the boundary interval has yielded satisfactory records for the main correlation techniques.

Anisian substages (informal)

The Anisian Stage has three to four informal substages. Assereto (1974) proposed a stratotype for a Lower Anisian substage (also called "Aegean" or "Egean") in beds with *Paracrochordiceras* ammonoids at Mount Marathovouno on Chios Island (Aegean Sea, Greece). The Middle Anisian is sometimes subdivided into two substages: a lower "Bithynian", named by Assereto (1974) after the Kocaeli Peninsula (Bithynia) of northwest Turkey, and an upper "Pelsonian", from the Latin name for the region around Lake Balaton in Hungary (Pia, 1930) spanning the *Balatonites balatonicus* ammonoid zone (Assereto, 1974). The Upper Anisian substage is also called "Illyrian" after the Latin term for Bosnia (Pia, 1930).

Ladinian

The Ladinian Stage arose after a heated semantic argument of "Was ist norisch?" (Bittner, 1892), when it was realized that most of the strata that had been assigned to a "pre-Carnian" Norian Stage (Mojsisovics, 1869) were actually deposited after the Carnian (Mojsisovics, 1893). This debate and the emergence of the Ladinian Stage for the actual pre-Carnian strata split the Vienna geological establishment (vividly reviewed by Tozer, 1984). The Ladinian, named after the Ladini inhabitants of the Dolomites region of northern Italy, was assigned to encompass the Wengen and Buchenstein beds (Bittner, 1892).

This historical major revision and even partial inversion of the upper Triassic stratigraphy, coupled with uncertainties about correlation potentials and definition of ammonoid zones, contributed to the problems in assigning a basal limit of the Ladinian Stage (e.g., Gaetani, 1993; Brack and Rieber, 1994, 1996; Mietto and Manfrin, 1995; Brack et al., 1995; Vörös et al., 1996; Muttoni et al., 1996a; Orchard and Tozer, 1997; Pálfy and Vörös, 1998). The ammonoid contenders for the primary correlation markers were distributed over at least two zones; including the lowest occurrence of representatives of the *Kellnerites* genus, of the *Nevadites* genus, of the *Eoprotrachyceras* genus, of the *Reitziites reitzi* species, and of the *Aplococeras avisianum* species. The lowest occurrence of the *Budurovignathus* conodont genus was also considered. The base of *Eoprotrachyceras curionii* zone (lowest occurrence of *Eoprotrachyceras* ammonoid genus, which is the onset of the Trachyceratidae ammonoid family) was eventually preferred. The Bagolino section (eastern Lombardian Alps, Province of Brescia, Northern Italy) was selected for its multiple stratigraphic records, including bracketing of the boundary interval by dated volcanic ashes (Brack et al., 2005).

The Ladinian GSSP at Bagolino is located at the top of a distinct 20-to-25-cm-thick interval of limestone nodules in a shaly matrix ("Chiesense groove"), located at approximately 5 m above the base of the Buchenstein Beds. The *Nevadites secedensis* ammonoid zone of the lowermost Buchenstein Beds, which was historically assigned as Ladinian (e.g., Bittner, 1892), has now become the uppermost zone of the Anisian. Secondary global markers include the lowest occurrence of the conodont *Budurovignathus praehungaricus* and a brief normal-polarity magnetozone (MT8n of Hounslow and Muttoni, 2010) within the uppermost Anisian. The bracketing U-Pb dated volcanic ashes indicate a boundary age of approximately 241 Ma (Brack et al., 2005).

The Ladinian GSSP site is accessible through a geological pathway with explanatory notes and ammonoid casts (Brack, 2010).

Ladinian substages (informal)

Mojsisovics et al. (1895) divided the Ladinian into two substages – Lower or Fassanian (named after Val di Fassa in northern Italy, where it was equated to the Buchenstein Beds and Marmolada Limestone), and Upper or Longobardian (named after the Langobard people of northern Italy, and spanning the Wengen Beds). His substage boundary is approximately at the base of the "*Eoprotrachyceras*" *gredleri* ammonoid zone in the Alpine zonation or the base of *Meginoceras meginae* ammonoid zone in the Canadian zonation.

Subdivisions of the Upper Triassic

The Upper Triassic consists of three stages – Carnian, Norian and Rhaetian – that were originally defined by characteristic ammonoids (Mojsisovics, 1869). However, these units were originally recognized in different locations in the northern Alps of Austria with uncertain stratigraphic relationships. Indeed, until 1892, Norian units were considered to underlie the Carnian, and only after a major geological controversy was the name 'Norian' applied to the same units after recognition that they were younger than Carnian (reviewed in Tozer, 1984).

Carnian

The Carnian stage, named either after localities in the Kärnten (Carinthia) region of Austria, or after the nearby Carnian Alps, was originally applied to Hallstatt Limestone beds bearing ammonoids of *Trachyceras* and *Tropites* (Mojsisovics, 1869: 127). The first occurrence of ammonoid *Trachyceras* (=base of *Trachyceras aon* zone in Tethys or *Trachyceras desatoyense* in Canada) was the traditional base, although it appears that a *Trachyceras* datum would be asynchronous and not cosmopolitan (e.g., Mietto and Manfrin, 1999). Mojsisovics et al. (1895) included the St. Cassian Beds of northern Italy in a revised Carnian subdivision, therefore the level with lowest occurrence of the cosmopolitan ammonoid *Daxatina* at the Prati di Stuores type locality in the Dolomites (northern Italy) was proposed for the base-Carnian GSSP (Broglio Loriga et al., 1998). This section has relatively rapid sedimentation and proved suitable for multiple types of stratigraphy, therefore it was ratified ten years later (2008). Two other reference sections with multiple biostratigraphic successions are in Spiti in Himalaya of northwest India (Balini et al., 1998, 2001) and the New Pass section of Nevada (USA).

The Carnian GSSP at Prati di Stores/Stuores Wiesen is 45 m above the base of the St. Cassian (San Cassiano) Formation. This level is near the lowest occurrence of the ammonoid *Daxatina* (base of *Daxatina canadensis* subzone, lowest subzone of *Trachyceras* zone), of the conodont "*Paragondolella*" *polygnathiformis*, and of the bivalve group of *Halobia* (Mietto et al., 2007). The placement of the base-Carnian at the appearance of *Daxatina* ammonoids implies that the Carnian now begins in the middle of the classical "Ladinian" *Frankites regoledanus* ammonoid zone. This GSSP is just above the base of a normal-polarity magnetic magnetozone (S2n in the local scale of Borglio Loriga et al., 1999; or UT1n in the synthesis scale of Hounslow and Muttoni, 2010), and lies above an interpreted maximum flooding surface within Sequence Lad 3 of Hardenbol et al. (1998).

Carnian substages (informal) and mid-Carnian wet intermezzo

Mojsisovics et al. (1895) subdivided the Carnian into three substages (Cordevolian, Julian and Tuvalian) corresponding to his three ammonoid zones. Cordevolian (=their *Trachyceras aon* zone), from the St. Cassian Beds, was named after the Cordevol people who lived in this area of northern Italy. Julian (=their *Trachyceras aonoides* zone) was based on the Raibl Formation of the Julian Alps in southern Austria. The Tuvalian (=their *Tropites subbullatus* zone) was named after the Tuval Mountains, the Roman term for the region between Berchtesgaden and Hallein near Salzburg, Austria. This trio of original ammonoid zones was later split into additional zones; but these main divisions can be correlated among regions.

Stratigraphers often combine the Cordevolian and Julian into a single Lower Carnian, with the Lower/Upper Carnian substage boundary traditionally assigned as the first occurrence of *Tropites* ammonoids (base of the *Tropites subbullatus* ammonoid zone of Tethys and *Tropites dilleri* zone of Canada). The ammonoid change at this substage boundary is more significant than at the bases of either the Carnian or the Norian stages (Tozer, 1984), conodont diversity may have been reduced to single genus (Mazza et al., 2010), and there were major changes in radiolarians and other faunal groups (Kozur and Bachmann, 2010).

A dramatic event that is considered to be "the most distinctive climate change within the Triassic" (Preto et al., 2010) was a global disruption of the Earth's land-ocean-biological system due to a sudden carbon-dioxide-induced warming and associated increased rainfall on the continents. In the middle of the Carnian stage, tropical carbonate platforms abruptly ended, waves of extinction affected the ocean animals, and engorged river systems left widespread sand-rich layers across coastal regions. This pulse lasted less than a million years. The recovering world saw the first known dinosaurs on land and the emergence of the calcareous nannoplankton in the oceans that now govern Earth's carbon cycle (e.g., Rigo et al., 2007, Dal Corso et al., 2012; Preto et al., 2013, Benton et al., 2014). This unusual climate-oceanographic event in the latest Julian has various regional names – e.g., "Reingraben turnover" (Schlager and Schöllnberger, 1974), "Raibl Event", "Carnian pluvial episode" (Simms and Ruffell, 1989), and "Middle Carnian Wet Intermezzo" (Kozur and Bachmann, 2010). The triggers for both the onset of this "Carnian pluvial episode" and its sudden termination could be a combination of paleogeographic and paleoceanographic factors (e.g., Kozur and Bachmann, 2010), perhaps triggered by volcanic releases during the formation of the former oceanic "Wrangellia" plateau (Greene et al., 2008, 2011; Dal Corso et al., 2012). The distinct fossil assemblages within this "wet intermezzo" interval provide an important means of calibration among terrestrial settings (conchostracans, pollen, ostracod and tetrapod biostratigraphy) from the southwest USA to Germanic Basin and into marine settings (ammonoid, conodont, ostracod and bivalve biostratigraphy) (Roghi et al., 2010; Kozur and Weems, 2010). The abrupt end to this "wet intermezzo" interval in the Germanic-Alpine region coincides with the Lower/Middle Carnian substage boundary as assigned by ammonoid biostratigraphy.

Norian

The Norian derives its name from the Roman province of Noria, south of the Danube and including the area of Hallstatt, Austria (Mojsisovics, 1869). The stratigraphic extent of strata assigned as "Norian" had a contorted history (reviewed in Tozer, 1984).

Ammonoid successions in Nevada and British Columbia led to a proposal that the base of the Norian be assigned to the base of the *Stikinoceras kerri* ammonoid zone, overlying the *Klamathites macrolobatus* zone (Silberling and Tozer, 1968). This level is approximately coeval with a Tethyan placement between the *Anatropites* and *Guembelites jandianus* ammonoid zones (Krystyn, 1980; Orchard et al., 2000). However, early studies had concluded that this ammonoid-based level did not correspond to an unequivocal microfossil signal, whereas the base of the preceding *K. macrolobatus* ammonoid zone is coincident with the first occurrences of conodont *Metapolygnathus communisti* and some radiolarian species (Orchard et al., 2000). But, later examinations of conodont lineages has indicated that the first appearance of *Metapolygnathus* ex gr. *M. echinatus* is at approximately the beginning of the *Stikinoceras kerri* ammonoid zone and coincides with a major faunal turnover (Orchard, 2010).

The leading candidates for placing the Norian GSSP (FAD of *Metapolygnathus echinatus*; or approximately coeval base of *Stikinoceras kerri* ammonoid zone) are Pizzo Mondello in Sicily (Muttoni et al., 2001; Nicora et al., 2007) or Black Bear Ridge on Williston Lake of northeast British Columbia (Orchard et al., 2001; Orchard, 2007; McRoberts, 2007). The section at Black Bear Ridge did not yield a useful magnetostratigraphy; whereas the recommended Norian GSSP level at Pizzo Mondello coincides with the top of a narrow reversed-magnetozone (magnetozone "PM4r" in local terminology; or "UT12r" in the synthesis of Hounslow and Muttoni, 2010) and is just above a positive shift in $\delta^{13}C$ (Nicora et al., 2007).

Norian substages (informal)

The Norian is traditionally subdivided into three substages, following Mojsisovics et al. (1895). The boundary between the lower Norian (or 'Lacian', after the Roman name for the Salzkammergut region of the northern Austrian Alps) and middle Norian (or 'Alaunian', named for the Alauns, who lived in the Hallein region of Austria during Roman times) is the base of the Tethyan *Cyrtopleurites bicrenatus* ammonoid zone. The base of the upper Norian (or 'Sevatian', after the Celtic tribe who lived between the Inn and Enns rivers of Austria) is generally assigned as the base of the North American *Gnomohalorites cordilleranus* ammonoid zone or the Tethyan *Sagenites quinquepunctatus* ammonoid zone; however, there has not been a consistent usage of this Sevatian substage and some include the underlying *Halorites macer* ammonoid zone within it (e.g, Kozur, 1999).

Rhaetian

The Rhaetian was the first Triassic stage to be established, when Carl Wilhelm Ritter von Gümbel (1861) applied the term to strata containing the pteriid bivalve *Rhaetavicula contorta*, such as the Kössen Beds of Austria. This distinction bivalve is found in shallow-marine facies from the western Tethys and across northwestern Europe. His "Rhätische Gebilde" name was derived from either the Rhätische Alpen or the Roman province of Rhaetium. For a while, it appeared that the Rhaetian interval would be incorporated into the Jurassic (and perhaps renamed as a "Bavarian Stage) or incorporated into the Norian Stage (reviewed in Lucas, 2010a). For example, the Rhaetian was eliminated in some Triassic time scales (e.g., Zapfe, 1974; Palmer, 1983; Tozer, 1984, 1990). In 1991, the Subcommission on Triassic Stratigraphy decided to retain the Rhaetian as an independent stage. Many options were considered for the primary biostratigraphic marker for the lower boundary. The bivalve *Monotis* that had been abundant on late Norian shelves nearly vanishes, and low-latitude Tethyan conodonts shift from a dominance by robust *Epigondolella* species to fragile *Misikella* forms (e.g., McRoberts et al., 2008; McRoberts, 2010; Krystyn and Kürschner, 2005).

In 2010, the base of the Rhaetian was placed by the Task Group as the lowest occurrence of the conodont *Misikella posthernsteini* (Krystyn, 2010). This conodont is a phylogenetic descendent of *Misikella hernsteini*, but is very rare at the beginning of its range. Therefore, several secondary markers should be employed to assign the base of the Rhaetian (Krystyn, 2010) including: (1) lowest occurrence of conodont *Epigondolella mosheri* (morphotype B sensu Orchard), (2) lowest occurrence of ammonoid *Paracochloceras suessi* and the closely allied genus *Cochloceras* and other taxa, (3) disappearance of ammonoid genus *Metasibirites*, (4) lowest occurrence of radiolarian *Proparvicingula moniliformis* and other species (Carter and Orchard, 2007), (5) disappearance of *Monotis* bivalves, except for continuation by dwarf *Monotis* species in parts of the Tethys (McRoberts et al., 2008), and (6) just below is a prominent change from an extended normal-polarity magnetozone upward into a reversed-polarity magnetozone (UT23n to UT23r in the tentative Norian-Rhaetian composite scale of Hounslow and Muttoni, 2010).

The leading candidate for the Rhaetian GSSP is the Steinbergkogel section near Hallstatt, Austria (Krystyn et al., 2007c, d). The published magnetostratigraphy from the condensed interval spanning the proposed boundary has been verified; but correlation to the cycle-scaled magnetic polarity scale from non-marine strata (Newark group) is disputed (e.g., Gallet et al., 2007; Muttoni et al., 2010; Hounslow and Muttoni, 2010; Hüsing et al., 2011). Other important reference sections are in British Columbia, Canada and in Turkey.

End-Triassic (base of Jurassic)

The end-Triassic mass extinction terminated many groups of marine life, including the conodonts. After a major international effort to correlate environmental and biostratigraphic events associated with the end-Triassic extinctions and the extensive eruption of the Central Atlantic Magmatic Province at ~201 Ma (e.g., review by Hesselbo et al., 2007), it was decided to utilize the earliest forms of *Psiloceras* ammonites to define the onset of the Jurassic.

The GSSP for the base of the Jurassic (base of Hettangian Stage) was ratified in 2010 as the Kuhjoch section within the Northern Calcareous Alps of Austria (Hillebrandt et al, 2013). The GSSP level, as initially ratified as 5.80 m above the base of the Tiefengraben Member of the Kendelbach Formation, corresponds to the local lowest occurrence of the ammonite *Psiloceras spelae* (new subsp. *tirolicum* Hillebrandt and Krystyn). Other markers include the lowest occurrences of the widely distributed continental palynomorph *Cerebropollenites thiergartii* (Kürschner et al., 2007), of the aragonitic foraminifer *Praegubkinella turgescens* and of the ostracod *Cytherelloidea buisensis* (Hillebrandt et al., 2013). The $\delta^{13}C_{org}$ record shows an initial negative excursion near the boundary between the underlying Koessen and the Kendelbach formations, and a shift to more positive $\delta^{13}C_{org}$ at the GSSP level; and this carbon-isotope signature provides a primary method for high-resolution correlation to other sections (e.g., Ruhl et al., 2009; Deenen et al., 2010b; Ruhl and Kürschner, 2011).

TRIASSIC NUMERICAL AGE MODELS

Ammonoids dominate the historical zonation of the Triassic (reviewed in Balini et al., 2010), but conodonts have become the major tool for global correlation (Orchard, 2010). Thin-shelled bivalves (e.g, *Daonella*, *Halobia*, etc.) provide important regional markers (McRoberts, 2010). During much of the Triassic, the sedimentary record across the Pangea supercontinent was dominated by terrestrial deposits, therefore widespread conchostracan, tetrapod and plant remains are important for global correlation (Kozur and Weems, 2010; .Kürschner and Herngreen, 2010; Lucas, 1998, 1999, 2010d).

Other biostratigraphic, magnetostratigraphic, chemostratigraphic and other events are typically calibrated to these standard ammonoid or conodont zones. Extensive compilations and inter-correlation of Triassic stratigraphy of European basins were coordinated by Hardenbol et al. (1998), and a suite of detailed Triassic reviews and stratigraphic scales are in The Triassic Timescale (Lucas, 2010a) and summarized with composite charts in Geologic Time Scale 2012 (Ogg, 2012).

There is no agreed numerical age model for the majority of the Triassic stages and their component biozones and other events. The numerical age models for the zonations and stage boundaries in the Cenozoic, Cretaceous and a large part of the Jurassic is based on the correlation of the primary biostratigraphic standards (microfossils, ammonite zones) to a verified cycle-scaled magnetic polarity pattern that has partial constraints from radio-isotopic ages (Ar-Ar and UPb). For the majority of the Jurassic through Cenozoic, the cycle-scaled magnetic polarity pattern was obtained from correlation of modeled marine magnetic anomaly patterns to the magnetostratigraphy from multiple overlapping sections of pelagic carbonates that spanned at least one entire stage without a stratigraphic break.

For large portions of the Triassic, there are also cycle-scaled polarity patterns compiled from extended time spans, but these are mainly derived from terrestrial deposits of Upper Triassic lacustrine beds (Newark series of eastern North America) and the major oscillations interpreted as short-eccentricity-induced climatic cycles within the Lower Triassic Buntsandstein of the Germanic Basin. The challenges are (1) to make an unambiguous correlation of these terrestrial cycle-scaled magnetic polarity “floating time scales” to the composite skeleton of magnetic polarity sequences obtained from relatively brief marine strata that contain ammonoids and conodonts of regional importance (Hounslow and Muttoni, 2010), (2) to verify that the terrestrial cycle stratigraphy interpretations are robust, and (3) to confirm that the terrestrial successions do not contain major interruptions or other distortions in their cycle-magnetic patterns. Two additional hurdles are that none of the available radio-isotopic dates are from levels within the cyclic terrestrial deposits and that the dated strata associated with marine fossils are from sections lacking magnetic stratigraphy. Lucas (2013) has suggested that “magnetostratigraphy has been more of a hindrance than a help to timescale definition and correlation” and that “Triassic cyclostratigraphic studies remain far from the goal of developing a reliable, astronomically-calibrated Triassic timescale”. However, we are more confident that the union of these two stratigraphic methods with biostratigraphic constraints provides a powerful tool for global correlation and assigning durations.

The Triassic age models in GTS2012 were an effort to simultaneously merge (1) published cycle-scaled magnetostratigraphy, (2) interpreted correlation of those terrestrial successions to marine-zoned magnetostratigraphy, and (3) guidance from radio-isotopic dates from other marine strata which commonly had uncertainties in their inter-regional correlation. Therefore, the suite of GTS2012 age models represented a temporary working hypothesis that will be revised when additional cycle stratigraphy, magnetostratigraphy, inter-regional biostratigraphic correlations and additional radio-isotopic ages are published. Indeed, since GTS2012 was compiled in 2011, there have been important Triassic studies published and submitted analyses that suggest that the GTS2012 age models require a revised synthesis.

Constraints from Cycle Stratigraphy

The monsoon-dominated climate of the Pangea megacontinent was sensitive to Milankovitch cycles, especially the precession-eccentricity components of these orbital-climate oscillations. The interpretations and controversies concerning these Triassic cyclic deposits are critically examined by Tanner (2010). Extended and quasi-continuous deposits of continental facies having excellent magnetostratigraphy in central Europe and eastern North America are the basis of cycle-scaled polarity patterns for the Early and the Late Triassic. In theory, these successions should be the Rosetta stone to project cycle-scaled durations onto marine sequences for a precise relative time scale, similar to what has been developed for the Cenozoic. In practice, there is a lack of a unique pattern match for correlation of these extended intervals of cycle-scaled magnetostratigraphies with marine-based composite polarity patterns.

Variations in clastic input into the Buntsandstein basins of central Europe during the Early Triassic provide a detailed regional stratigraphy that is applicable to surface exposures and downhole logs (e.g., reviews in Röhling, 1991; Bachmann and Kozur, 2004; Szurlies, 2004; Menning et al., 2005; Feist-Burkhardt et al., 2008). The cycles, spanning about 10-20 meters with sandstones fining upward into more clay-rich sediments, are generally interpreted as oscillations between more arid and more humid conditions. Constraints from terrestrial biostratigraphy (conchostracan, pollen-spores) combined with radio-isotope ages on the span of the Early Triassic indicate that the depositional sequences appear to coincide with the 100 kyr short-eccentricity cycle (e.g., Bachmann and Kozur, 2004; Menning et al., 2005). However, the expected 400 kyr long-eccentricity has not been unambiguously resolved. The magnetostratigraphy from the Buntsandstein, especially within the lower portion, which has relatively longer-duration polarity zones and biostratigraphic constraints, is fairly well correlated to the Early Triassic composite (Szurlies, 2007; Hounslow and Muttoni, 2010). Even though a monotonic 100 kyr periodicity is not expected for short-eccentricity and there is a possibility of "missing beats" at possible exposure horizons within this Buntsandstein succession, the projected cycle-scaling of the marine zonation and associated Early Triassic substages via this magnetostratigraphy is a close fit to radio-isotopic ages and was used in GTS2012 for detailed scaling of the Early Triassic and early Anisian (Figure 2).

Interbedded marls and limestones of shallow-marine origin spanning the Permian–Triassic boundary interval in the Austrian Alps display cycles with ratios matching Milankovitch periodicities, and have been interpreted to imply that the latest Permian extinction and negative carbon-isotope spike spanned less than 30 kyr (Rampino et al., 2000, 2002). However, the entire end-Permian mass extinction interval and initial recovery (defined by Huang et al., 2011, as start of the *Neogondolella meishanensis* conodont zone or *Otoceras* / *Hypophiceras* ammonoid zone at the onset of the negative $\delta^{13}C$ excursion to the base of the *Isarcicella isarcica* conodont zone or *Ophiceras* ammonoid zone and *Claraia wangi* bivalve assemblage zone when $\delta^{13}C$ values again increase) spans approximately 700 kyr according to cycle stratigraphy of sections in China and Austria (Huang et al., 2011).

There is a conflict in interpretation of the cyclostratigraphy through the Induan stage of basal Triassic. Guo et al. (2008) examined the Pingdingshan Section of Chaohu, which contains a candidate for the base-Olenekian GSSP, and concluded that the 56 beds spanning the Induan stage in this section were precession modulated by short eccentricity, therefore the Induan stage spanned 1.1 myr. Unfortunately, neither the basal Induan conodont zone (*Hindeodus parvus*) nor the lower portion of the succeeding conodont zone (*H. typicalis*) is identifiable in this section. An analysis of the cycle-stratigraphy of Induan sections in central China and re-analysis of this Chaohu section (Mingsong Li and Chunju Huang, in prep.) indicated that the Induan stage spanned at least ~1.6 myr (~0.9 myr for Griesbachian, ~0.7 myr for Dienerian), although there may be another 405-kyr cycle in the condensed basal Triassic interval in this sections that would imply a ~2 myr duration for the Induan in China, which is identical to the cyclostratigraphy estimate from the Germanic Basin. Cyclostratigraphy from the Chaohu section suggests a duration of ~4 myr for the Olenekian stage (~1.7 myr for Smithian; ~2.3 myr for Spathian) (Mingsong Li and Chunju Huang, in prep.), although the implied 4 myr Olenekian stage duration is difficult to reconcile with the Germanic basin cyclostratigraphy estimates and the published radio-isotope dates from the Olenekian-Anisian boundary interval (discussed below).

The Latemar massif in the Italian Dolomites was an atoll-like feature with a core of flat-lying Anisian and Ladinian platform carbonates. Oscillations in sea level were created over 500 thin depositional cycles (Goldhammer et al., 1987). Stacking patterns and spectral analysis of the sea-level oscillations had been interpreted as representing precession modulated by short-term (100 kyr) eccentricity, therefore yielding an implication that the Latemar deposit spans approximately 10 myr (Goldhammer et al., 1990; Hinnov and Goldhammer, 1991). In contrast, U-Pb ages from coeval tuff-bearing basinal deposits appear to constrain the Latemar platform to span only a 2 to 4 myr (e.g., Brack et al., 1996, 1997; Mundil et al., 1996; Hardie and Hinnov, 1997; and extended review in Tanner, 2010). A possible solution to this disparity is that an extremely rapid rate of platform construction (ca. 500 m/myr or greater) enabled recording of sub-Milankovitch sea-level oscillations with misleading similarity in ratios to precession-eccentricity (e.g., Kent et al., 2004; Hinnov, 2006; Meyers, 2008). This debate demonstrates that any cycle-stratigraphic analysis based on a single section requires verification from other independent basins and facies.

Radiolarian-rich pelagic chert successions from Japan spanning the Middle Triassic are characterized by ribbon bedding. These chert-clay couplets have been interpreted as productivity fluctuations induced by 20-kyr precession cycles, medium-term variations in bed thickness correspond to 100-kyr and 405-kyr eccentricity cycles, and long-term trends are interpreted as a ~2 myr (Earth-Mars resonance) and ~8 myr eccentricity modulation (Ikeda et al., 2010; Ikeda and Tada, 2013). These cyclostratigraphic interpretations, the tentative correlation of radiolarian taxa to geologic stages, the potential of long-term modulations, and the continuity of the bedded-chert sections await further verification. It would be a major achievement if these radiolarites would yield a reproducible magnetostratigraphy.

Studies of similar oscillating Lofer facies within upper Triassic platform carbonates of the Austrian Alps played an important role in developing fundamental concepts of cyclostratigraphy (e.g., Fischer, 1964), but the reality of regular cyclicity in these deposits has also been debated (e.g., Satterley, 1996, versus Schwarzacher, 2005, and Cozzi et al., 2005; reviewed in Tanner, 2010). There are no published magnetostratigraphies from these extensive deposits.

During the late-Middle Triassic through Early Jurassic, a set of rift basins formed as Pangea underwent an initial phase of breakup. The thick Newark group of lacustrine sediments from these tropical basins are characterized by oscillations between semi-stagnant deep lakes and arid playas as the intensity of monsoonal rains responded to Earth's precession modulated by short-term (ca. 100 kyr) and long-term (ca. 400 kyr) eccentricity cycles. Spectral analysis of sediment facies successions in a series of deep-drilling cores enabled compilation of a cycle-scaled stratigraphic record, including a detailed polarity pattern that is unprecedented in its 30-myr temporal span (e.g., Kent et al., 1995; Olsen et al., 1996; Kent and Olsen, 1999). Uppermost Triassic lacustrine deposits with alternating red-to-green coloration at St. Audrie's Bay have also yielded both a magnetostratigraphy (Hounslow et al., 2004) and an interpreted cyclostratigraphy spanning 3.7 myr (Kemp and Coe, 2007); and its cycle-scaled polarity pattern partially resembles the upper Newark interval of polarity zones E19n-E16n. Unfortunately, as examined below, the comparison of these cycle-scaled terrestrial polarity signature to the un-scaled marine magnetostratigraphy does not provide a unique match owing to the lack of a distinctive "bar code" and the distortion of the relative durations of polarity zones caused by variable sediment accumulation rates in the marine sections.

Constraints from Radio-isotopic Dates

The Triassic and uppermost Permian were the focus of extensive sampling, application of ultra-high-resolution methods and standardization of procedures by different geochronology laboratories. An extensive set of 206Pb/238U CA-TIMS dates from analyses of individual zircons treated by annealing followed by chemical abrasion have replaced the dates derived from multi-grain analyses and K-Ar methods. The new sets of radio-isotopic dates have replaced or called into question nearly all of the Triassic radiogenic isotope ages published before 2004 (reviewed by Mundil et al., 2010). The initiation and termination of the Triassic Period have been constrained by a remarkably extensive suite of ages, implying a span from 252 to 201 Ma (51 myr).

However, nearly all the ages from marine strata having adequate biostratigraphic control are clustered within the early half of the Triassic (ca. 255 to 239 Ma) and within a brief interval spanning the Triassic-Jurassic boundary (ca. 202-200 Ma). In particular, there is a 30-myr gap in reliable dates for the majority of the upper half of the Triassic. Therefore, the Late Triassic remains an interval of controversy in correlation of terrestrial zonations (e.g., dinosaur evolution) to marine stages.

The Permian-Triassic boundary is well constrained as approximately 252 Ma (U-Pb, TIMS) from sets of samples from the Induan GSSP at Meishan, Zhejiang Province and Shangsi section from Sichuan Province in China. Shen et al. (2010, 2011) had used U-Pb (TIMS method) to propose that the late-Permian extinctions peaked at about 252.28 ±0.08 Ma and interpolated the base-Triassic boundary as 252.16 ±0.05 Ma (analytical precision). However, recently, Burgess et al. (2014) constrained the main end-Permian extinction interval as spanning 251.94 ±0.04 to 251.88 ±0.03 Ma, indicating that the largest mass extinction in the Phanerozoic was only 60 ± 48 kyr in duration.

Published dates using the Ar-Ar method are younger – Reichow et al. (2009) obtained an age from sanidines in volcanic-ash Bed 28 about 8 cm above the GSSP at Meishan of 248.25 ±0.14 Ma (based on a monitor standard FCs of 28.02 Ma) which converts to 249.85 ±0.14 Ma using the revised FCs monitor standard of 28.201 Ma. Renne et al. (2010) suggest a "best-fit" (U-Pb plus recalculated Ar-Ar, but using a slightly older FCs assignment of 28.30 Ma) of 252.3 ±0.2 Ma. An FCs standard of 28.20 Ma is used in other GTS2012 radio-isotopic tables. Based on considerations of published (as of 2012) array of dates and external errors, the GTS2012 summary had adopted the P/T age from Shen et al. (2010) of 252.16 ±0.2 Ma. However, a revised and enhanced dating of the Meishan ash beds (Burgess et al., 2014) indicate a slightly younger boundary age of ca. 251.9 Ma.

The age for the base of the Olenekian stage, or rather a candidate level for placing a future GSSP at Chaohu in China, had been considered to be slightly older than sample CHIN-40 that yielded a U-Pb date of 251.2 ±0.2 Ma (Galfetti et al., 2007b). However, that published base-Olenekian date would be difficult to reconcile with the recently-published date of 251.495± 0.064 Ma from a mid-Griesbachian ash bed at Meishan (Burgess et al., 2014). As emphasized by Burgess et al. (2014), if both dates are accepted, then this would imply that the span of the mid-Griesbachian through Dienerian substages would be less than 300 kyr, and that the entire Induan stage was less than 1 myr in duration. Therefore, they advise that it is "unwise to combine/compare dates" until "dates from the Smithian are repeated". In contrast, the cycle stratigraphy of the Induan stage in the Germanic Basin as correlated by magnetostratigraphy to the candidate base-Olenekian GSSP section (e.g., Bachmann and Kozur, 2004; Menning et al., 2005; Szurlies, 2007; Hounslow and Muttoni, 2010) would imply a ~2 myr duration for the Induan. This estimate from the Germanic Basin is consistent with the analysis of the cycle-stratigraphy of Induan sections in central China (Mingsong Li and Chunju Huang, in prep.) which indicates a duration for the Induan stage of ~1.6 myr, or perhaps ~2.0 myr depending upon the 405-kyr tuning of the condensed basal Triassic interval.

The base of the Anisian stage, as potentially recognized by conodont zonation in southern China, was estimated as 247.2 ±0.1 Ma (between samples PGD Tuff-3 and Tuff-2) by Lehrmann et al. (2006). However, U-Pb dates from a nearby ammonoid-bearing basinal section suggest that the ammonoid-defined (top of the regional *haugi* ammonite zone) placement for the base-Anisian may instead be slightly younger than 246.83 ±0.44 Ma (Ovtcharova et al., 2006, 2010).

The base of the Ladinian is constrained to be between

239.3 ±0.2 Ma (sample FP2 of mid-Ladinian; Brühwiler et al., 2007) and 242.1 ±0.6 Ma (sample Mundil MSG.09 at the Grenzbitumen horizon near base of the uppermost Anisian *Nevadites secedensis* ammonoid zone; Mundil et al., 2010). Mundil et al. (2010) estimate the Anisian-Carnian boundary as 242.0 Ma. However, this boundary age would truncate the *Nevadites secedensis* ammonoid zone, and an Ar-Ar measurement on sanadines in MSG.09 from the same Grenzbitumen horizon by Mundil et al. (2010) yielded 240.95 ±0.5 Ma (after adjusting the original 239.5 ±0.5 Ma to an FCs monitor standard of 28.201 Ma). Therefore, until further work enables a convergence of the Ar-Ar and U-Pb ages on that Grenzbitumen horizon, the base-Ladinian was estimated as ca. 241.5 ±1 Ma in GTS2012.

Spanning the Ladinian-Carnian boundary is a gap of about 9 myr in radio-isotopic dates that satisfy both analytical criteria (e.g., suite accepted by Mundil et al., 2010, for their table 3) and biostratigraphic control. However, a U-Pb date of 237.3 Ma (+0.4/-1.0) from the Predazzo granites of northern Italy (Brack et al., 1997) was tentatively correlated to the *Regoledanus* ammonite zone (highest zone of Ladinian) by Pálfy et al. (2003). A volcanic ash from the southern Apennines yielding a date of 230.9 ±0.06 Ma (sample Aglianico; Furin et al., 2006) was tentatively assigned as mid-upper Carnian; and may be near the base of Tuvalian substage (H. Kozur, pers. comm., 2010). The date from this horizon is similar to Ar-Ar ages from strata in Argentina containing some of the earliest dinosaurs (Ischigualasto Formation). If one uses the Predazzo granite as a constraint within the latest Ladinian ammonite zone, then a provisional assignment of 237 ±1 Ma was assigned to the Ladinian-Carnian boundary in GTS2012.

Although no reliable Norian or early Rhaetian radio-isotopic ages have been published, there are suggestions that the Norian may extend to 225 Ma or older. Suites of redeposited zircons within sediments of the southwestern USA that have yield Adamanian and Revueltian tetrapods and early dinosaurs have enabled a temporal framework for that interval of tetrapod evolution. The array of dated horizons suggests that the "Adamanian-Revueltian faunal turn-over occurred between 219.37 and 213.15 Ma." (Ramezani et al., 2009). However, the correlation of the Norian-Carnian stage boundary interval to these deposits is controversial. If the base-Norian is close to 225 Ma, then "A mid-Norian age for the Adamanian to Revueltian land vertebrate faunachron boundary, as suggested by the revised Late Triassic timescale, is no longer compatible with the idea that the faunachron boundary is coincident with the Carnian-Norian Stage boundary" (Ramezani et al., 2010). Alternatively, palynology, vertebrate and conchostracan biostratigraphy correlations from the southwestern USA to the Germanic Basin and European stages are interpreted to imply that the Adamanian is mainly Carnian, and that the redeposited zircon dates are "consistent with the approximately 218 Ma Carnian-Norian boundary in the Newark Supergroup, not a "long Norian" extending to approximately 228 Ma as recently proposed" (Heckert et al., 2009). This ten-million-year divergence in opinion on the placement of the Carnian-Norian boundary requires future acquisition of radio-isotopic dates on marine-zoned lowermost Norian.

There are no published constraints from radio-isotopic dates on the Norian-Rhaetian boundary interval, although groups are actively working on obtaining dates and new results are expected to be published shortly (Christopher McRoberts, pers. commun., March 2014)

In contrast, the Triassic-Jurassic boundary has a precise radio-isotopic age. Schoene et al. (2010) project that T/J boundary age is 201.31 Ma (±0.18/0.38/0.43) based on constraints from ammonoid-bearing strata in Peru (LM4-90 and LM4-100/101) and a similar age from the former GSSP candidate section in New York Canyon, Nevada. They conclude that initiation of the main phase of the Central Atlantic Volcanic Province (CAMP) preceded the Triassic-Jurassic boundary by only ca. 70 kyr (or a maximum of 290 kyr if the extremes on the uncertainties are applied). A proposed significant age difference between these major volcanic eruptions and the marine extinctions (e.g., Pálfy et al., 2000a, b) is now considered to have been an artifact from those multi-grain zircon analysis techniques (reviewed in Mundil et al., 2010). Radio-isotopic ages from CAMP flows in North America and Morocco and cyclostratigraphy of intervening periods of sedimentation within the flow succession indicate that the main phase of eruptions was a brief peak spanning ca. 600 kyr (e.g., Whiteside et al., 2007; Jourdan et al., 2009a; Marzoli et al., 2011). Recent U-Pb dating now indicates an age of 201.546 ±0.015 Ma (analytical uncertainty) for the end-Triassic extinction, and the Triassic-Jurassic boundary is astronomically extrapolated as 100 ±40 kyr after this event (Blackburn et al., 2013).

Early and Middle Triassic age model of GTS2012

The primary method for assigning an age model to the Early Triassic biozones and substage boundaries in GTS2012 is the cycle-scaled magnetostratigraphy from the Germanic Basin (Figure 2). The following constraints and assumptions are made:

(a) The base of the Triassic in GTS2012 was 252.16 ±0.2 Ma [modified from Shen et al., 2010; although revised dating by Burgess et al. (2014) now indicates ca. 251.88 ±0.03 Ma]. The GTS2012 uncertainty of 0.2 myr on that U-Pb isotopic age applies to all other extrapolated numerical ages for Early Triassic zones/events; but not to the cycle-derived durations (e.g., if the base-Triassic is shifted younger by 0.2 myr, then the base-Olenekian and base-Anisian must also be shifted younger by the same 0.2 myr).

(b) The Germanic Basin cycles are a uniform 100-kyr Milankovitch orbital-climate signal with the base of the Triassic at the base of Calvorde cycle s1.2 and the base of the Anisian at the base of Röt cycle s7.1 (Bachmann and Kozur, 2004; Kozur and Bachmann, 2005; Menning et al., 2005). Therefore, the 51 named cycles span 5.1 myr, which was identical to the span of 5.2 myr for the combined Induan and Olenekian stages derived from radio-isotopic dates in GTS2012 (ca. 252.16 to 247 Ma).

(c) The magnetostratigraphy from these cycle-scaled deposits in the Germanic Basin (Szurlies, 2004, 2007) was correlated to the ammonoid-zoned Early Triassic bio-magnetostratigraphy of the Boreal Realm according to Hounslow and Muttoni (2010: fig. 4). Their correlation utilizes the main trends in polarity patterns, although there may be alternative correlations of the

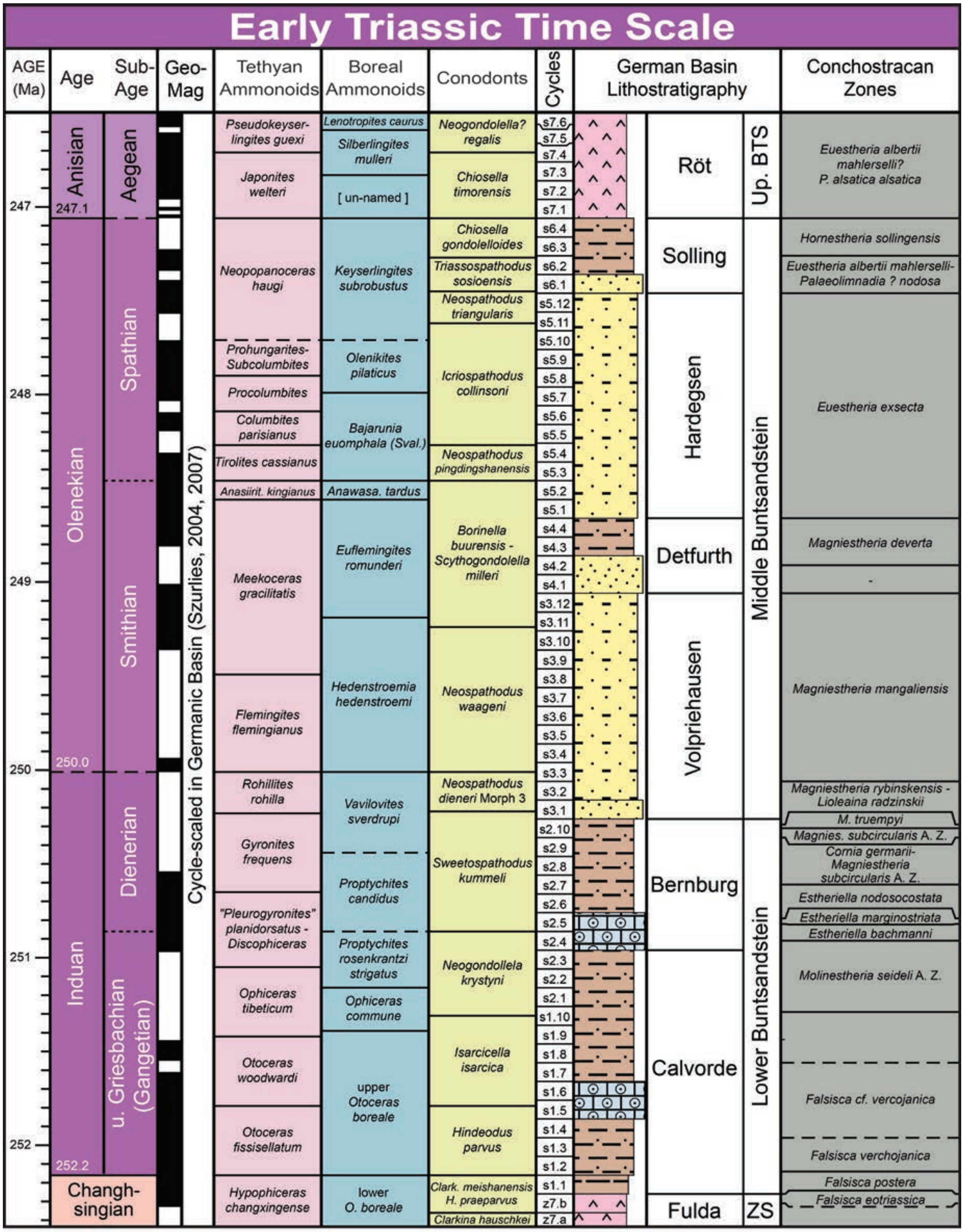


Figure 2 – Early Triassic time scale with magnetic polarity chrons, selected biostratigraphic zonations and Germanic-Basin cyclostratigraphy and main lithostratigraphic units. Working definitions of the Olenekian and Anisian stage boundaries are indicated by dashed lines; but the final definitions will eventually be made by the International Commission on Stratigraphy (see www.stratigraphy.org, or http://stratigraphy.science.purdue.edu). Germanic-Basin cycles are interpreted as eccentricity-induced 100-kyr climatic oscillations (e.g., Szurlies, 2004, 2007; Menning et al., 2005; Kozur and Bachmann, 2005, 2008). Magnetostratigraphy correlated to that cycle-scale is modified from Szurlies (2007) and Hounslow and Muttoni (2010). A selection of marine biostratigraphy relative to the magnetostratigraphy and/or adjacent zonations is represented by generalized ammonoid zones for the Tethyan and Boreal (western North America) realms (e.g., Kozur, 2003 and pers. comm., 2010; Balini et al., 2010; McRoberts, 2010) and by a conodont zonation for Tethyan realm (Kozur, 2003; and pers. comm., 2010). Terrestrial biostratigraphy is represented by conchostracan zones calibrated to the Germanic Basin cycles (Kozur and Weems, 2010, and Kozur, pers. comm., 2010).

details of the meter-scaled Boreal polarity pattern to the cycle-scaled Germanic pattern.

(d) Assignment regional working definitions of stage and sub-stage boundaries are according to their traditional placement relative to Boreal ammonoid zones; with a mean position of each ammonoid zone relative to magnetozones taken as the approximate middle of the uncertainty interval in the summary diagrams of Hounslow and Muttoni (2010). Some of these substage boundary assignments may not correspond to future GSSPs or to current working definitions in other regions (e.g., in China where there are the majority of radio-isotopic dates).

(e) Conodont zones and other stratigraphic scales are placed relative to Boreal ammonoid zones according to selected correlation diagrams of other paleontologists (e.g., charts by Hardenbol et al., 1998; Hounslow et al., 2008b; etc.).

These assumptions yield an age model for the Lower Triassic stages and substages as currently used in the Boreal faunal realm:

Dienerian substage base (base of *Proptychites candidus* ammonoid zone) is estimated by Hounslow and Muttoni (2010) as 25% up in magnetozone LT2n (= magnetozone CG5n of Szurlies, 2007). Therefore, the Dienerian/Griesbachian boundary had a projected age from the cycle-magnetic stratigraphy of 250.9 Ma.

Olenekian stage boundary (base of Smithian substage; base of *Hedenstroemia hedenstroem*i ammonoid zone) is near the base of magnetozone LT3n, which Hounslow and Muttoni (2010) correlate to magnetozone CG6n of Szurlies (2007). This yielded a projected age of 250.0 Ma. This projected age is significantly younger than a radio-isotope-derived estimate from China of ca. 251.2 Ma ±0.2 (Galfetti et al., 2007b), which may indicate different placements of the base- Olenekian between conodont-event versus regional ammonite-zone placements, a problem in radio-isotopic standards (NOTE: see discussion in Burgess et al., 2014, who also identified this problem), a mis-correlation between Boreal and Germanic magnetostratigraphy, and/or a distortion in the cycle stratigraphy. However, the younger age used in GTS2012 was also consistent with preliminary UPb dating of ammonite-zoned strata of Nevada across its regional-ammonite placement of a Smithian/Dienerian boundary (Mark Schmitz, written communications, 2013). It is apparent that a collaborative project and the use of common radio-isotopic and biostratigraphic standards are required.

Spathian substage base (base of *Bajarunia euomphala* ammonoid zone in Svalbard or Siberia zonation) is approximately 70% up in Hounslow and Muttoni's normal-polarity-dominated interval of LT5n-7n of which they correlate to magnetozone CG8n of the Germanic Basin. The implied base-Spathian age was 248.5 Ma in GTS2012.

The relative proportions of these Early Triassic substages as derived from cyclostratigraphy in GTS2012 implies that the first initial stages of recovery (Induan-Smithian) after the end-Permian mass extinctions took slightly longer than estimates based solely on selected U-Pb dates. It is essentially that additional U-Pb dates are acquired from the Induan and that "dates from the Smithian are repeated" (Burgess et al., 2014) to test the cyclostratigraphy scalings.

The "working" base of the Anisian was assigned as the base of Rot formation of Germany and the base of magnetozone MT1n of Hounslow and Muttoni (2010), which is the upper part of magnetozone CG10r of Szurlies (2007). The cycle-stratigraphy age for the base of this Anisian working definition and base of Middle Triassic is 247.06 Ma, which was consistent with published radio-isotopic ages.

The base of the Bithynian substage of the lower Anisian is estimated by Hounslow and Muttoni (2010) as approximately the base of polarity subzone MT3r.3. This subzone spans the upper third of CG11r of Szurlies (2007) in the uppermost Röt Formation; therefore implying a cycle-stratigraphy age of 246.36 Ma. The implied short duration of the underlying Aegean substage is consistent with its compact thickness relative to the Germanic Basin cycle-stratigraphy (Szurlies, 2007) and a radio-isotopic age of 246.3 ±0.07 Ma in early Anisian at Guizhou, China (sample GDGB-0, Ramezani et al., 2007).

There is no verified cyclostratigraphy calibrated to ammonoid/conodont biostratigraphy for the middle and upper Anisian or Ladinian. Therefore, until additional constraints become accepted, a schematic display of ammonite zones within each interval was incorporated in GTS2012, in which the relative duration of ammonite zones was apportioned according to their relative number of ammonite subzones or allocating 1.5 "subzonal units" for undivided zones. The Tethyan ammonite zonal scheme was selected as the standard, therefore all other apparent ages for other biostratigraphic, magnetostratigraphic or chemostratigraphic scales are according to the estimated correlations to this Tethyan scale. This scaling was done for the Bithynian, Pelsonian and Illyrian substages relative to the U-Pb-derived age of 242.1 Ma for the base of the uppermost Anisian *Nevadites secedensis* ammonoid zone. A similar scaling was applied for the Ladinian from the 241 ±1 Ma for the lower boundary relative to the interim assigned age of ~237 Ma for the base-Carnian.

Therefore, this Anisian through lowermost Carnian interval awaits a CONOP-type compilation of biostratigraphic sections to achieve a more realistic scaling of biozones, a verifiable cycle stratigraphy and the acquisition of additional biostratigraphic-constrained radio-isotopic dates. This interval requires a group effort of biostratigraphers, cycle-stratigraphy workers and radio-isotopic labs.

Late Triassic age model options

The relative durations of the Carnian, Norian and Rhaetian stages and the assignment of numerical ages to events within them has been a debated topic with extreme divergence of models. When GTS2012 was prepared (March, 2011), there was a lack of any reliable published radio-isotopic dates within the latest Carnian through early Rhaetian constrained by marine-based biostratigraphy. There is a high-resolution magnetostratigraphy scaled to Milankovitch cycles from lacustrine strata in the Newark Basin that spanned much of the Norian and Carnian (and maybe Rhaetian). However, this pattern lacked an adequate "fingerprint" to correlate with compilations of magnetostratigraphy of marine-zoned strata (e.g., two options of Muttoni et al., 2004b, and in Ogg et al., 2008; three options discussed in detail within

Hounslow and Muttoni, 2010). We present two end-member options.

The "puzzle" of how-to-correlate-the-polarity-zones is illustrated in Figure 3a, which assumed an arbitrary Rhaetian duration of 3 myr and assigned the Carnian-Norian boundary as 223 Ma. In this initial scale, the ammonoid zones (and their magnetic polarity patterns) within each stage have been uniformly scaled by allocating equal durations for each ammonoid subzone and 1.5 subzonal equivalents for those ammonoid zones that have no subzonal divisions. It is obvious that there are many options for visually correlating between the Newark cycle-magnetostratigraphy and the Late Triassic outcrop-based polarity patterns. Once such a correlation is attained, then the duration of each Late Triassic ammonoid zone would be known, plus estimates of sediment accumulation rate changes within the reference sections.

However, in addition to ambiguous matching of magnetic polarity patterns, there are at least four main factors in inter-regional correlation, each of which is disputed:

(1) Whether the published correlation of terrestrial-based biostratigraphy (conchostracans, palynology, tetrapods) from the Germanic Basin and the Southwest USA to the stratigraphic sequences in the Newark basins and to marine-based stages and substages is valid.

(2) Whether the Newark lacustrine cycle succession (the standard for the scaling of magnetostratigraphy) is continuous, and whether the overlying basalts dated at 201 Ma are conformably overlying the highest lacustrine deposits without a significant break in deposition. These factors determine whether numerical ages can be reliably assigned to the magnetozones. For example, some paleontologists have interpreted a major stratigraphic hiatus omitted at least part of the Rhaetian stage below the basalts (e.g., Cirilli et al., 2009; Kozur and Weems, 2005), and a comparison of cycle-magnetostratigraphy below the CAMP volcanics in Morocco suggested a ca. 1-myr hiatus that shortened a major normal-magnetozone (E22n) in the Newark reference succession about 1.8 myr below its CAMP volcanics (Deenen et al., 2010a; in Deenen, 2010: 60).

(3) Deciding on the temporal proximity of the upper-mid Carnian U-Pb date of 230.9 ±0.1 Ma (Aglianico date in Phanerozoic table in Chapter 6 GTS2012) relative to the base of the Norian, and whether a poorly documented date of 225 ±3 Ma (Gehrels et al., 1987) is a reliable constraint on base of the early Norian.

(4) Selecting an appropriate correlation of Rhaetian magnetostratigraphy to the Newark succession, thereby constraining the upper limit of the Norian relative to Newark cyclostratigraphy (e.g., Hüsing et al., 2011, compared to other options in Hounslow and Muttoni, 2010)

Therefore, the two end-members that represent current (2013) published views will be summarized and diagrammed in this review.

Option #1 – Long-duration Tuvalian substage and absence of Rhaetian in Newark cycle-magnetostratigraphy (Left column in Figure 3b)

One fit of this model (modified after Lucas et al., 2012, and Kozur and Weems, 2010) incorporates six main paleontological and stratigraphic conclusions:

(1) The upper-mid Carnian U-Pb date of 230.9 ±0.1 Ma is above the Carnian pluvial event and just below lowest occurrence of the conodont *P. carpathicus* (same as *M. carpathicus,* because genera assignment of *carpathicus* is not yet established). This *M. carpathicus* zone begins below the base of the *T. subbullatus* ammonoid zone, therefore this radio-isotopic age is assigned to the middle of the underlying *T. dilleri* ammonoid zone of lowest Tuvalian substage.

(2) The upper Stockton Formation of the Newark Group has conchostracans of the lower Tuvalian *Gregoriusella* n. sp. Zone (Kozur and Weems, 2010). Therefore, Newark magnetozones E8 or E7 are in the lowermost Tuvalian. The estimated age of ca. 237.0 Ma for the base of the Carnian implies that the four main magnetozone pairs and three subzones (UT1n-UT4r of Hounslow and Muttoni, 2010) are compacted into approximately 5 myr, therefore should correlate to a relatively high-frequency interval in the older portion of the Newark magnetic polarity pattern, hence potentially within the E1-E6 interval.

(3) Newark magnetozone E11r (a relatively long reversed-polarity interval in the middle of Lockatong Formation) correlates with the upper-Lower Tuvalian (upper mid-Carnian). Common taxa indicate that the conchostracan *Laxitextella seegisi* zone of the Germanic Basin is coeval with the *Howellisaura princetonensis* conchostracan zone of Newark succession in this interval and with the *Anyuanestheria wingatella* conchostracan zone of southwest USA within the lower Adamanian land vertebrate faunal chron (e.g., Kozur and Weems, 2010). This zone in the Lehrberg Beds of the Weser Formation in the Germanic Basin (following the Stuttgart Formation of Schilfsandstein deposited during the "mid-Carnian pluvial episode") contains ostracod *Simeonella nostorica*, which is common in the marine lower Turvalian of Hungary and Austria (Kozur and Weems, 2010: 332). Therefore, Newark magnetozone E11r is correlated with the *T. subbullatus* ammonoid zone and its relatively long reversed-magnetozone "Subb-R" ("UT10r" of Hounslow and Muttoni, 2010).

(4) The *Tropites subbullatus* ammonoid zone of the Tuvalian usually encompasses a relatively thicker lithostratigraphic interval than most Carnian-Norian ammonoid zones; therefore, it conceivably spans a correspondingly greater interval of time (H. Kozur, pers. comm., 2010).

(5) Palynostratigraphy had placed the Carnian-Norian boundary in the Newark Supergroup succession near the base of the Passaic Formation (e.g., Cornet and Olsen, 1985) or within Newark magnetozone E13 (as used in Kent and Olsen, 1999). Magnetostratigraphy of the proposed base-Norian GSSP at Pizzo Mondello (Muttoni et al., 2001, 2004a) places the boundary horizon at the top of a relatively narrow reversed-magnetozone (PM4r) between two relatively longer normal-magnetozones. One interpretation is that this Carnian-Norian boundary level corresponds to the top of Newark magnetozone E13r. [NOTE: In contrast, Muttoni et al. (2004a) prefer a correlation to the top of magnetozone E7; which is ca. 10-myr older.]

(6) The Rhaetian stage is not represented in the uppermost Newark succession. In sections of the upper Passaic Formation which have yielded conchostracans, the fauna represent the *Shipingia olseni* Zone of uppermost Norian (no well-dated

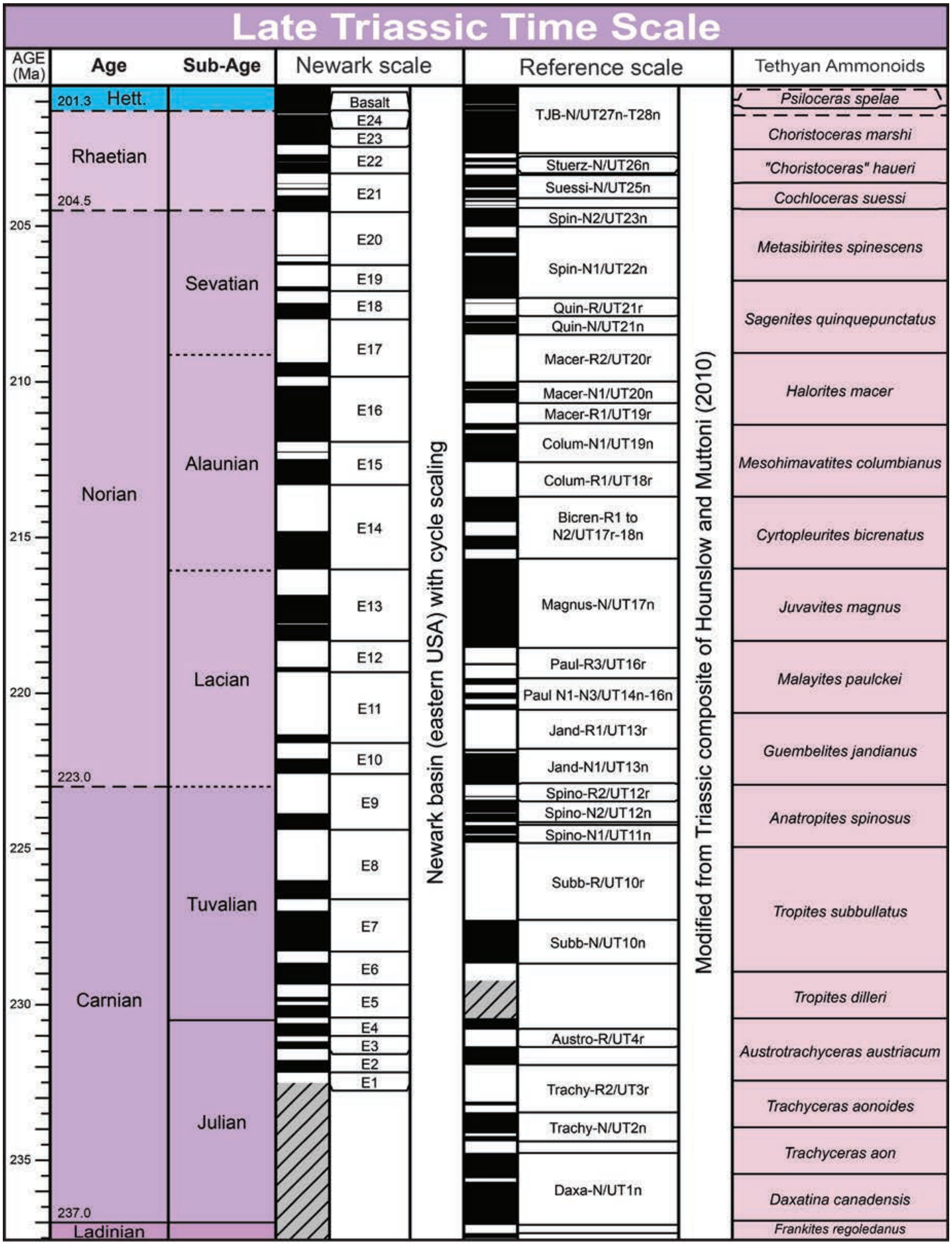


Figure 3 – The Late Triassic Magnetic Correlation Puzzle. (a) The ambiguity in correlating Upper Triassic magnetic polarity scales derived from two independent sources. Lacustrine basins of the Newark Supergroup (eastern USA) have yielded a high-resolution magnetic polarity pattern with durations derived from Milankovitch cycles (Kent et al., 1995), but lack direct calibrations to marine stratigraphy. Magnetostratigraphy from ammonite- or conodont-zoned marine sections have been assembled into a composite bio-magnetostratigraphy scale (modified from Hounslow and Muttoni (2010) by adding stage-based abbreviations for major polarity zones to their "UT" numbering), but lack cycle stratigraphy to estimate elapsed durations. This initial bio-magnetostratigraphy reference pattern is scaled by assigning equal durations to ammonite subzones. Several possible correlations are possible due to: (1) the lack of a distinctive "fingerprint" to correlate cycle-scaled polarity zones to marine sections that have uncertain continuity in sedimentation rates, (2) uncertainties in the correlation of terrestrial biostratigraphy (Newark) to marine biostratigraphy,

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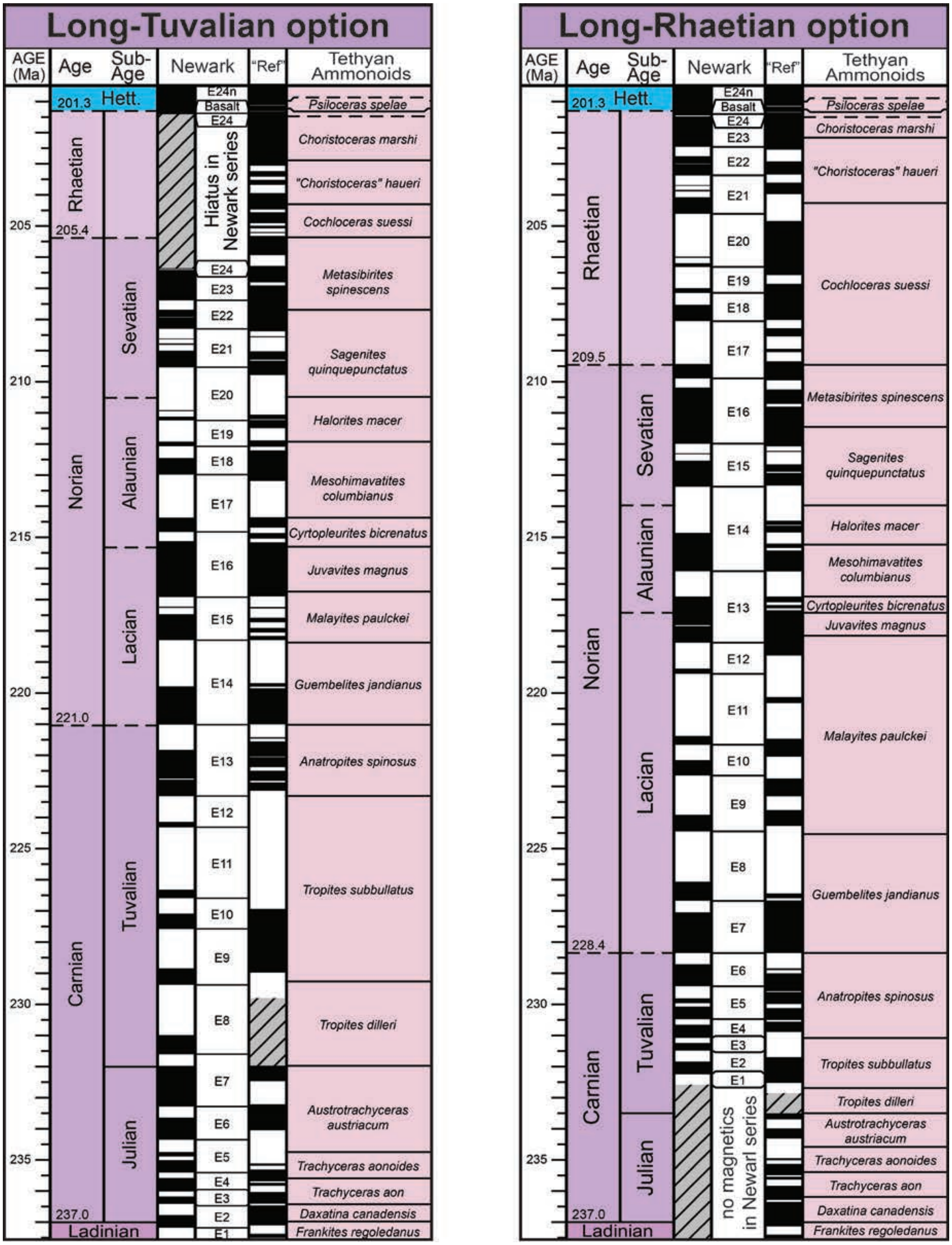


and (3) possible significant gaps in both records. (b) Examples of two suggested end-member correlations are shown: (Left) an Option 1 "Long-Tuvalian" and absence of Rhaetian in the Newark cycle-magnetostratigraphy (modified after Lucas et al., submitted, and others), and (Right) an Option 2 "Long-Rhaetian" spanning the upper Newark cycle-magnetostratigraphy that would imply a short-duration Carnian (modified after Muttoni et al., 2010; Hüsing et al., 2011; and others). In each case, the ages for the top of the Triassic (201.3 Ma) and base of the Carnian (237.0 Ma) are the same. See text for details. In each option, the potential definitions of the Norian and Rhaetian stage boundaries are indicated by dashed lines; but the final decisions will be made by the International Commission on Stratigraphy (see www.stratigraphy.org, or http://stratigraphy.science.purdue.edu). For GTS2012, the age model of Option 2 ("Long-Rhaetian") was selected for scaling the upper Triassic in other diagrams.

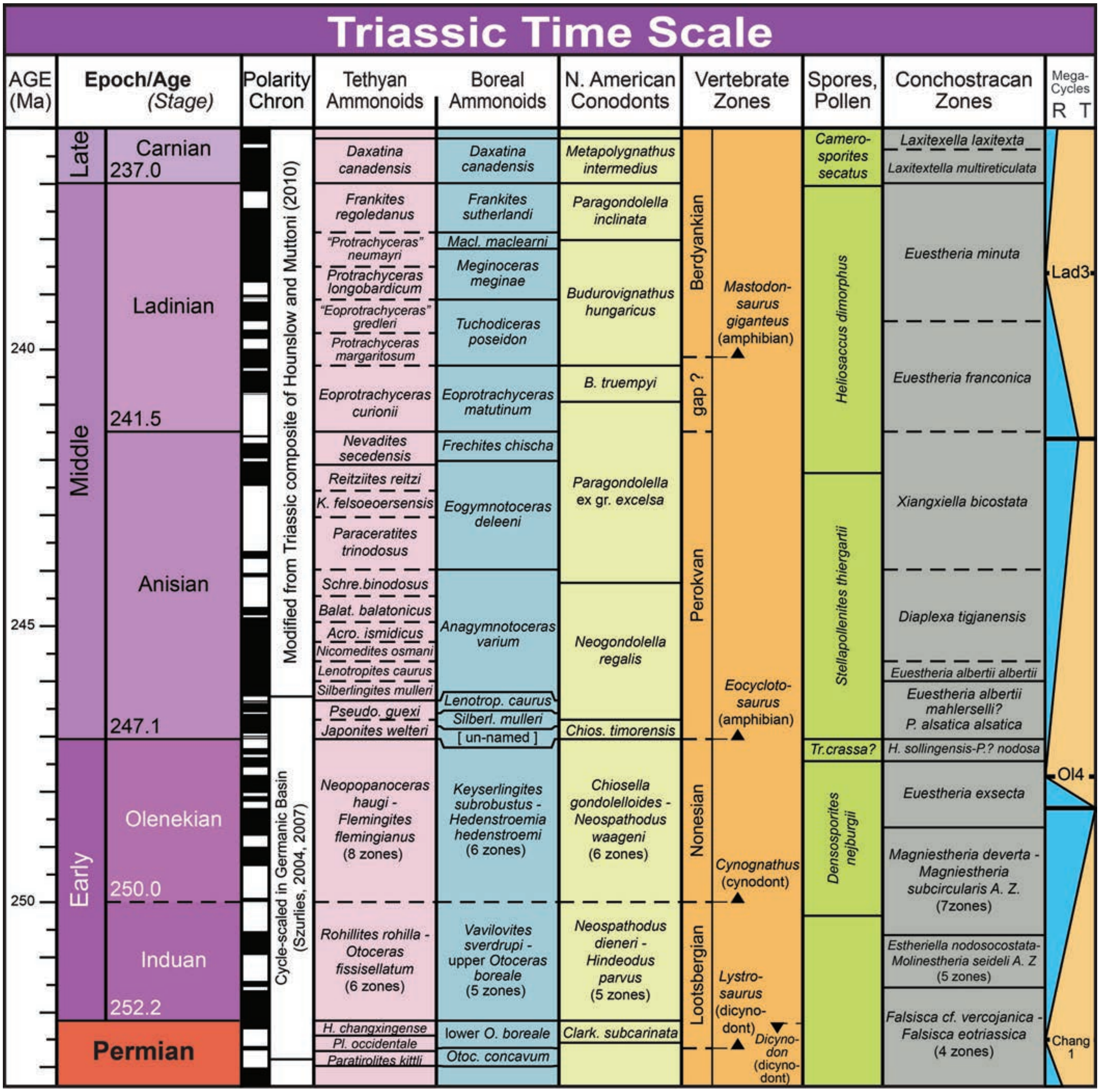
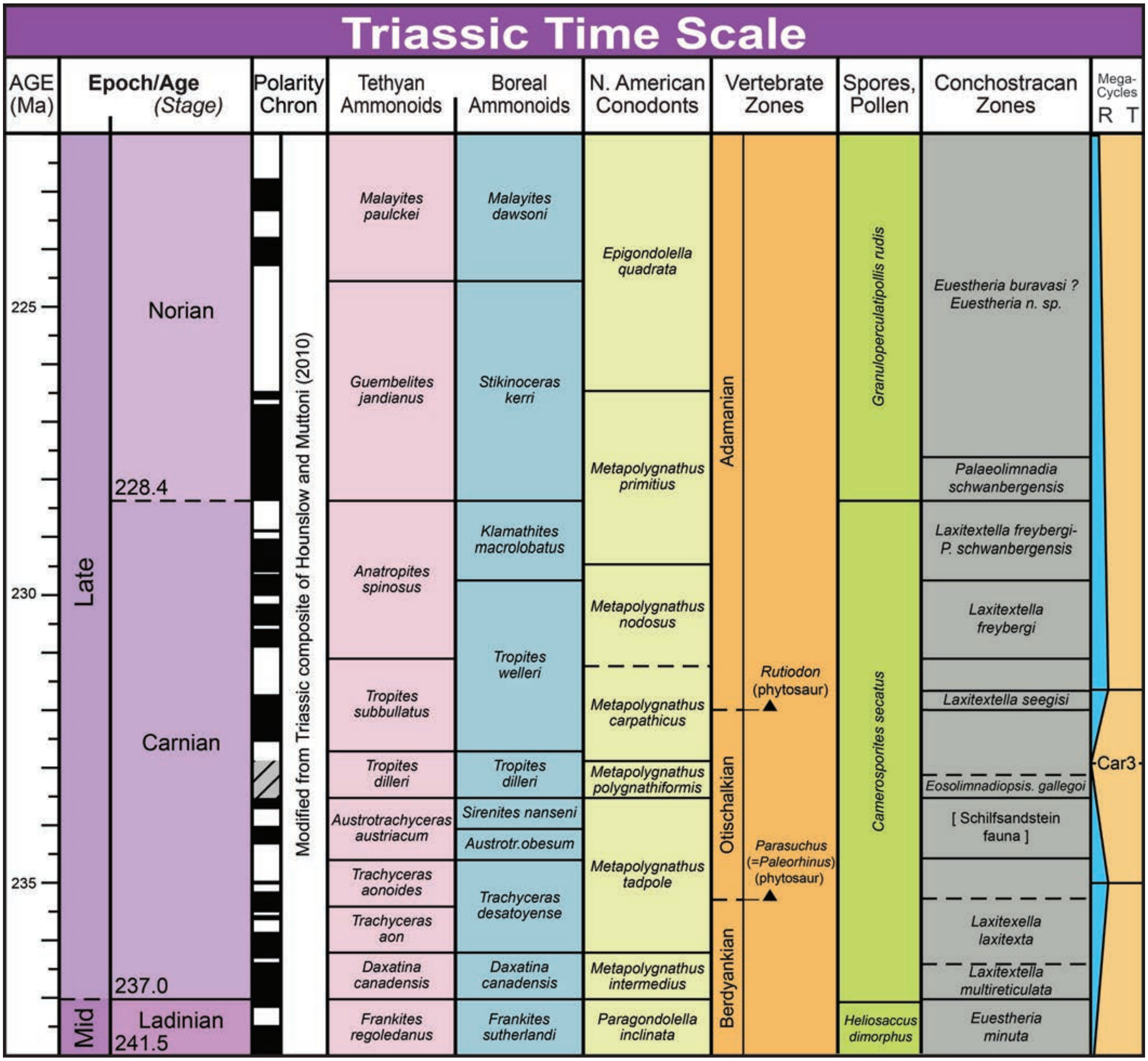


Figure 4 – Summary of a possible age model for epoch/series and age/stage boundaries of the Triassic with selected marine biostratigraphic zonations and principle trends in sea level. ["Age" is the term for the time equivalent of the rock-record "stage".]. Potential definitions of the Olenekian, Anisian, Norian and Rhaetian are indicated by dashed lines; but the final decisions will be made by the International Commission on Stratigraphy (see www.stratigraphy.org, or http://stratigraphy.science.purdue.edu). For GTS2012, the age model of Option 2 ("Long-Rhaetian and Short-Carnian") was selected for scaling the upper Triassic. Magnetic polarity pattern is modified from Hounslow and Muttoni (2010). Marine biostratigraphy are representative ammonoid zones for the Tethyan and Boreal (western North America) realms (e.g., Kozur, 2003 and pers. comm., 2010; Balini et al., 2010; McRoberts, 2010) and conodont zonation for North American realm (e.g., Orchard and Tozer, 1997; Orchard, 2010). Terrestrial biostratigraphy is represented tetrapod "faunachrons" with defining first appearances (Lucas, 2010d), generalized spore-pollen zones (Kürschner and Herngreen, 2010) and Conchostracan zones (Kozur and Weems, 2010; Kozur, pers. comm., 2010). The major sequences are from Jacquin and Vail (1998, as inter-calibrated in Hardenbol et al., 1998). For details in Early Triassic, see expanded scale in Figure 2. Additional Triassic zonations, geochemical trends, sea-level curves, etc. are compiled in the internal datasets within TimeScale Creator (www.tscreator.org).



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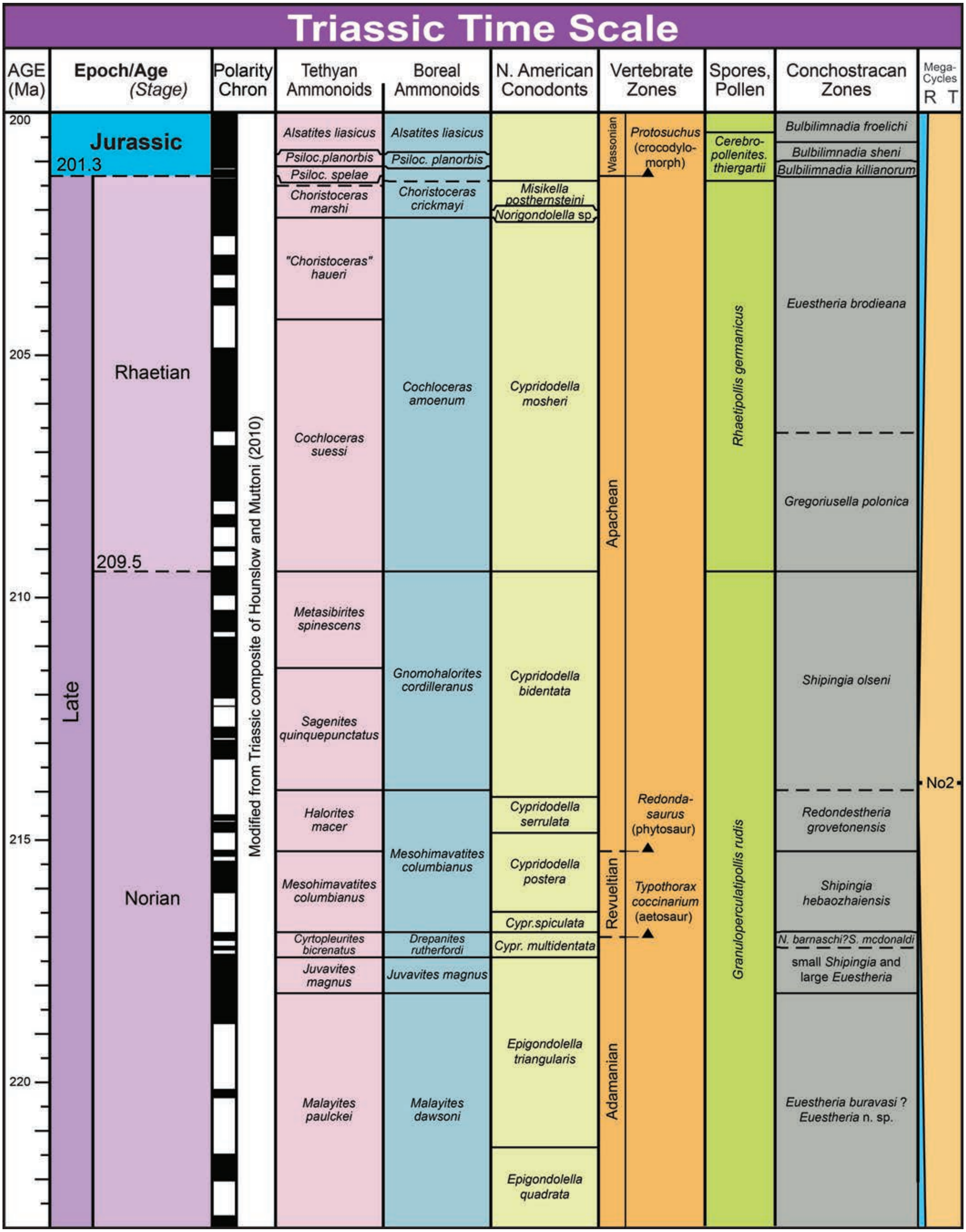

Figure 4 (Continued)

Rhaetian section in any part of the world has yielded any *Shipingia*) overlain locally by a very short interval of the uppermost *E. brodieana* Zone of latest Rhaetian (Kozur and Weems, 2005, 2010). The uppermost Sevatian, lower Rhaetian and part of the upper Rhaetian are not present. Therefore, under this Option 1, then the numerical ages of the magnetozones of the underlying Newark Supergroup cannot be assigned using cycle-stratigraphy "downward" from the overlying basalts that are dated as 201 Ma.

These constraints imply a "Long Tuvalian" with Newark magnetozone E7 near the base of Tuvalian, the 230.9 Ma radio-isotopic date in the middle of *T. dilleri* ammonoid zone, the Newark magnetozone E11r in the middle of the *T. subbullatus* ammonoid zone, and the top of Newark magnetozone E13r (ca. 4-myr later) marking the base of the Norian.

A conservative estimate is to assign the base of the Tuvalian (base of *T. dilleri* ammonoid zone) as 232 Ma and to position this boundary at the base of E7r. Then, assuming that the Newark cycle-magnetic sequence is complete, an age can be assigned to each magnetozone progressively upward and downward from this E7r control age. This implies that the age of the top of magnetozone E13r, which was interpreted as the Carnian-Norian boundary (item #5 above), is ca. 221.9 Ma. The uppermost portion of the preserved Newark magnetostratigraphy, the lower portion of magnetozone E24n of the uppermost Norian, is projected as 206.5 Ma. The Norian-Rhaetian stage boundary would be slightly younger than this level, hence about 205.5 Ma. The age of the Triassic-Jurassic boundary at 201.3 Ma would imply that the Rhaetian was 4 myr in duration, which would be essentially the time-span for the interpreted hiatus in the Newark succession.

If the base of the Carnian is assigned as exactly 237 Ma, then the age assignments to Newark magnetozones imply that the basal Carnian reversed-polarity zone Daxa-R corresponds to Newark magnetozone E2r.

One can propose a suite of possible correlations of the magnetostratigraphy patterns of the other ammonoid zones of the Carnian and Norian to this model of the age-assigned Newark magnetic pattern. One set of possible Newark-to-ammonoid zone correlations has partially used the relative number of ammonoid subzones per zone as an approximate guide to relative durations for adjacent zones. The scaling of polarity patterns within individual ammonite zones are according to magnetostratigraphy reference sections (e.g., Hounslow and Muttoni, 2010), and only the placement of ammonite zonal boundaries have been adjusted for the potential fit to the Newark cycle-scaled polarity pattern. There is the caveat that portions of these composite polarity patterns are not well calibrated to ammonoid (or conodont) zones. Such a model could be tested in different ways, such as obtaining cycle-stratigraphy from the ammonite-zoned reference sections or clarifying the magnetostratigraphy within middle Carnian ammonoid zones (e.g., *T. dilleri*) to ascertain the predicted presence of a long reversed-polarity interval (E8r) from the Newark succession.

In the illustrated Option 1 age model that attempts to match major magnetic polarity characteristics, the 36-myr span of the Late Triassic is distributed as sub-equal ~16-myr durations for the Carnian and Norian, and a 4-myr "short" Rhaetian.

Option #2 – Short-duration Carnian and presence of a long Rhaetian in Newark cycle-magnetostratigraphy (Right column in Figure 3b)

At the other end of the spectrum of models, the suite of biostratigraphic interpretations is relaxed in favor of a hiatus-free Newark succession that is continuous into the CAMP basalts of 201.4 Ma. This assumption is combined with additional interpretations from magnetostratigraphy patterns and radio-isotopic ages:

(1) The ages of all Newark magnetozones are computed downward from the CAMP age of 201.4 Ma.

(2) The Rhaetian is fully present in the uppermost Newark magnetostratigraphy. There is no lithostratigraphic evidence for the interpreted major biostratigraphic gap in the uppermost Newark lacustrine cycles (P. Olsen, pers. comm., 2010), and studies of cycle-magnetostratigraphy of coeval deposits in other basins indicates a nearly identical time span (within 20 kyr) for the uppermost magnetozones to the onset of CAMP volcanics (Deenen, 2010; Deenen et al., 2010b). Therefore, the narrow UT27r of the latest Hettangian in the composite by Hounslow and Muttoni (2010) is correlated with magnetozone E23r of the uppermost Newark. The underlying upper and middle Rhaetian magnetozones (BIT5r to BIT1r/UT24r) are progressively correlated to Newark magnetozones through E22r (Muttoni et al., 2010).

(3) The cluster of reversed-polarity-dominated magnetozones in the lower Rhaetian is underlain by a relatively thick normal-polarity magnetozone UT22n. This may imply that this lowermost Rhaetian interval is interpreted as condensed in the Austrian reference section; therefore this suite corresponds to the expanded set of reversed-polarity dominated E20r-E17r underlain by normal-polarity magnetozone E16n-E17n in the Newark succession (Option A of Hounslow and Muttoni, 2010, or similar model by Hüsing et al., 2011). The Norian-Rhaetian boundary is assigned to just above the base of E17r with an age of 209.5 Ma. A similar "8-myr Rhaetian" model was proposed by McArthur (2008, 2010) upon applying a uniform rate-of-change to the declining 87Sr/86Sr ratios from latest Norian through Sinemurian.

(4) The polarity change at the Carnian-Norian boundary at the candidate GSSP of Pizzo Mondello corresponds to the base of E7n (Muttoni et al., 2004a) with an age projected from the Newark cycle-magnetostratigraphy of ca. 228.5 Ma. This is consistent with reported ages of ca. 225 Ma for lower Norian strata (e.g., Gehrels et al., 1987).

(5) Given these correlations for the top and base of the Norian, then the general trends in polarity dominance would project the base of the Alaunian stage (base of UT17r, above a relatively thick normal-polarity Magnus-N/UT17n) to the base of Newark magnetozone E13r, and the base of the Sevatian (base of Quin-N/UT21n) to perhaps the base of Newark magnetozone E15n (Option A of Hounslow and Muttoni, 2010). One problem is that the outcrop-derived magnetostratigraphy within the mid-Norian Alaunian substage has more interpreted magnetozones than the Newark cycle-magnetostratigraphy; and this apparent inconsistency was noted by Hounslow and Muttoni (2010) in

their similar Option A for Norian correlations.

(6) Correlations within the Carnian proceed downward from the assigned base-Norian at E7r. This would imply that the *A. spinosus* ammonite zone may be slightly longer than the preceding *T. subbullatus* zone, and that the apparently simple polarity pattern of that *T. subbullatus* zone requires further resolution. The duration of the Carnian is much shorter than the Norian, with the Julian-Tuvalian substage boundary projected as approximately midway at 233.5 Ma.

In this model, the 36-myr span of the Late Triassic is apportioned among a "long" 8-myr Rhaetian, a 19-myr Norian, and a ~10-myr Carnian.

We had selected the Option #2 (Short-duration Carnian and a longer Rhaetian) for the Triassic summary figures in GTS2012. This choice was partly influenced by reported radio-isotopic dates of 223-225 Ma (223.81 ±0.78 Ma and 224.52 ±0.22 Ma) derived by U-Pb CA-TIMS methods from single zircons from volcanic tuffs in the Nicola Group of British Columbia that are constrained by conodont assemblages to bracket the lower/middle Triassic boundary interval as used in North America (Diakow et al., 2011, abstract). If confirmed, then those dates were only consistent with the "long-Carnian" aspects of Option #2. The choice between a "long" (ca. 7 myr) versus "short" (ca. 4 myr) Rhaetian is a separate issue, but its resolution from additional radio-isotopic dating and cyclostratigraphy will require also satisfactory correlation of the polarity patterns magnetostratigraphic reference sections.

SUMMARY

During the past decade, Triassic workers have defined most of the stages, greatly enhanced the inter-correlation of biostratigraphic zones, enabled compilation of a nearly complete magnetic polarity pattern calibrated to marine biostratigraphic datums, discovered major excursions in stable isotopes (especially carbon isotope excursions within the lower Triassic), and achieved or rejected cycle-stratigraphic scaling of several intervals. A generalized synthesis of selected Triassic stratigraphic scales is compiled in Figure 4.

Extensive radio-isotopic dating with advanced techniques replaced nearly the entire radiometric dataset used in GTS2004 and established well-constrained dates for the bases of the Early Triassic (Induan Stage), of both Middle Triassic stages (Anisian, Ladinian) and top of the Triassic (base of Hettangian Stage). Unfortunately, there are lingering major uncertainties on the age models and durations for most of the Triassic stages. In particular, establishing a robust Late Triassic time scale requires definitive radio-isotopic dates and cyclostratigraphy on marine sections that have standard biostratigraphy.

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Research Note

THE PERMIAN AND TRIASSIC IN THE ALBANIAN ALPS: PRELIMINARY NOTE

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The Albanian Alps is a tectonic unit, together with Gashi, Cukali, and Kruja units, lying to the NW of the Shkodra-Pes transverse zone (Auboin & Ndojaj, 1964), forming a part of the Adria Mesozoic margin (Fig. 1). Albanian Alps are the only unit in which Permian rocks crop out and the Triassic succession is relatively well exposed. Their knowledge is still preliminary (Meco & Aliaj, 2000), but it represent a significant section, linking Dinarides with Hellenides.

A more detailed report is submitted elsewhere (Gaetani et al., submitted) and an oral presentation is scheduled for the next Karpatho-Balkan Association meeting, to be held in Tirana, September 24-26, 2014.

The Albanian Alps consists of several (at least five) stacked thrust sheets with an internal stratigraphic succession spanning from the Permian to Triassic or from Triassic to Cretaceous, verging to the south-east and thrusted on the Cukali Zone (ISPGJ-IGJN 1983, 1999; Xhomo et al. 2002) (Fig. 1). The complex is subdivided in the Valbona Sub-Zone, forming the lower part of the edifice and the Malsia e Madhe Sub-Zone overlying the previous one. The basal stack may be analyzed along the Kir, Shala, and Curraj valleys, where the thrust-fault system bringing the Albanian Alps to override the flyschoid Cretaceous-Eocene sediments capping the Cukali Zone, is complicated by decoupling of the sole of the Albanian Alps. They are here made up of Permian rocks, in which slivers of Cretaceous flyschoid sediments pertaining to the Cukali Zone are also included.

In the Valbona sub-zone two major stacks are recognized (Fig. 2).

The Bishkaz-Shale Block (Xhomo et al. 2002), forms the first thick stack, with a succession spanning from the Middle Permian to the Upper Triassic. Internal folds and thrusts complicate the stratigraphic succession.

The Permian part consists of a mixed carbonatic/fine clastic succession, more massive and calcarenitic to the west and with thinner beds and finer calcarenite (packstone) to the east. A carbonate ramp deepening towards NE in present co-ordinates developed during the Middle Permian. This unit is sealed by carbonatic breccia bodies, linked significant block faulting, and by fine mature clastics. The position of the Permian/Triassic boundary is not yet constrained.

The Lower Triassic and the lower Anisian were characterized

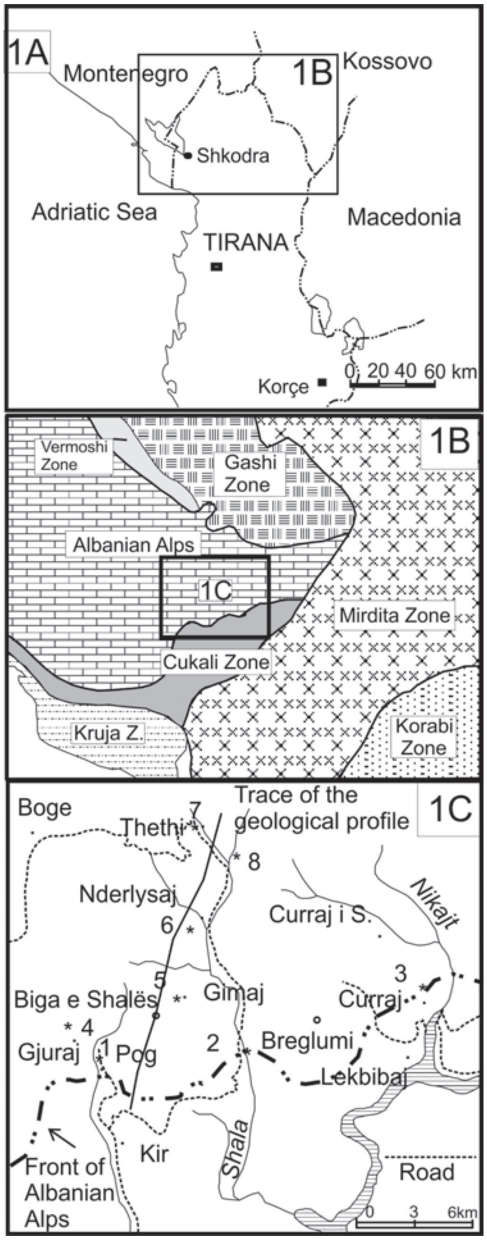

Figure 1 – The Albanian Alps, with position of the studied sections and the trace of the geological cross-section.

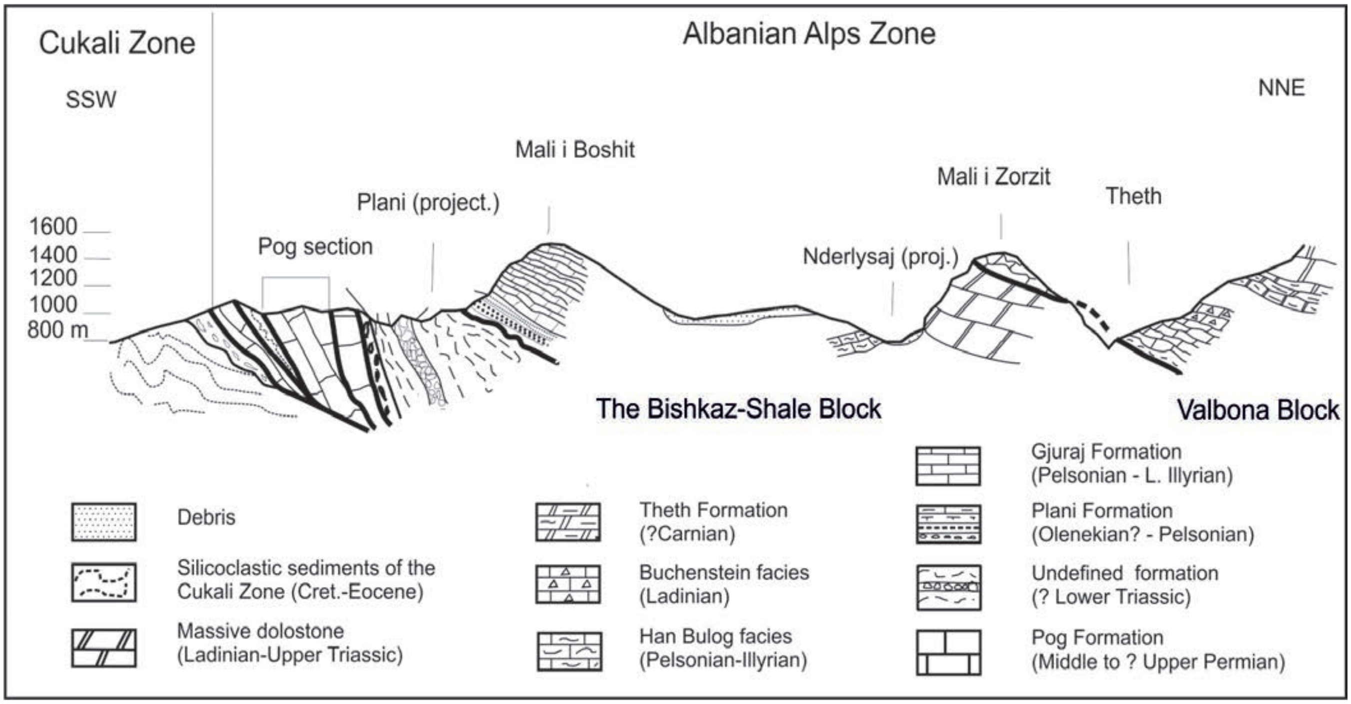

Figure 2 – Cross-section through the lower part of the Albanian Alps edifice.

by very thick terrigenous deposition with cobble conglomerate levels up to 80 m-thick, linking this area with the equivalent area in southern Montenegro. Gradually the clastic deposition was over during the Pelsonian and a wide calcarenitic ramp occupied the area.

The tectonic repetitions allow to observe a facies trend from south to north on the right side of the Shala valley, along the transect Gimaj - Nderlysaj. More to southwest (present co-ordinates) lies the important and well exposed section of Gjuraj. The succession is mostly calcarenitic to the south, where carbonate banks produced abundant skeletal debris, and progressively became more pelagic northwards (present direction), with increasing thickness of red nodular wackestones of the Han Bulog Fm. This facies is overlain by grey, cherty, well bedded nodular limestones. The succession is closed by thick bedded light carbonates, peritidal in the upper part, referred to the upper Ladinian.

The second major stacked thrust, named Valbona Block, with a minor subdivision forming the Theth Block (Xhomo et al. 2002), is only Triassic in age. The basal part is composed of poorly exposed terrigenous clastics mixed with carbonates, followed by nodular limestones of Anisian age, overlain by cherty nodular limestones with tuffs recalling the Buchenstein Fm. of the Southern Alps in Italy. The succession is closed by the black limestone and dolostone of Theth Fm., partly interfingering and eventually capped by thick bedded peritidal dolostones. Conodonts indicate a late Ladinian age for the lower part of the Theth Formation.

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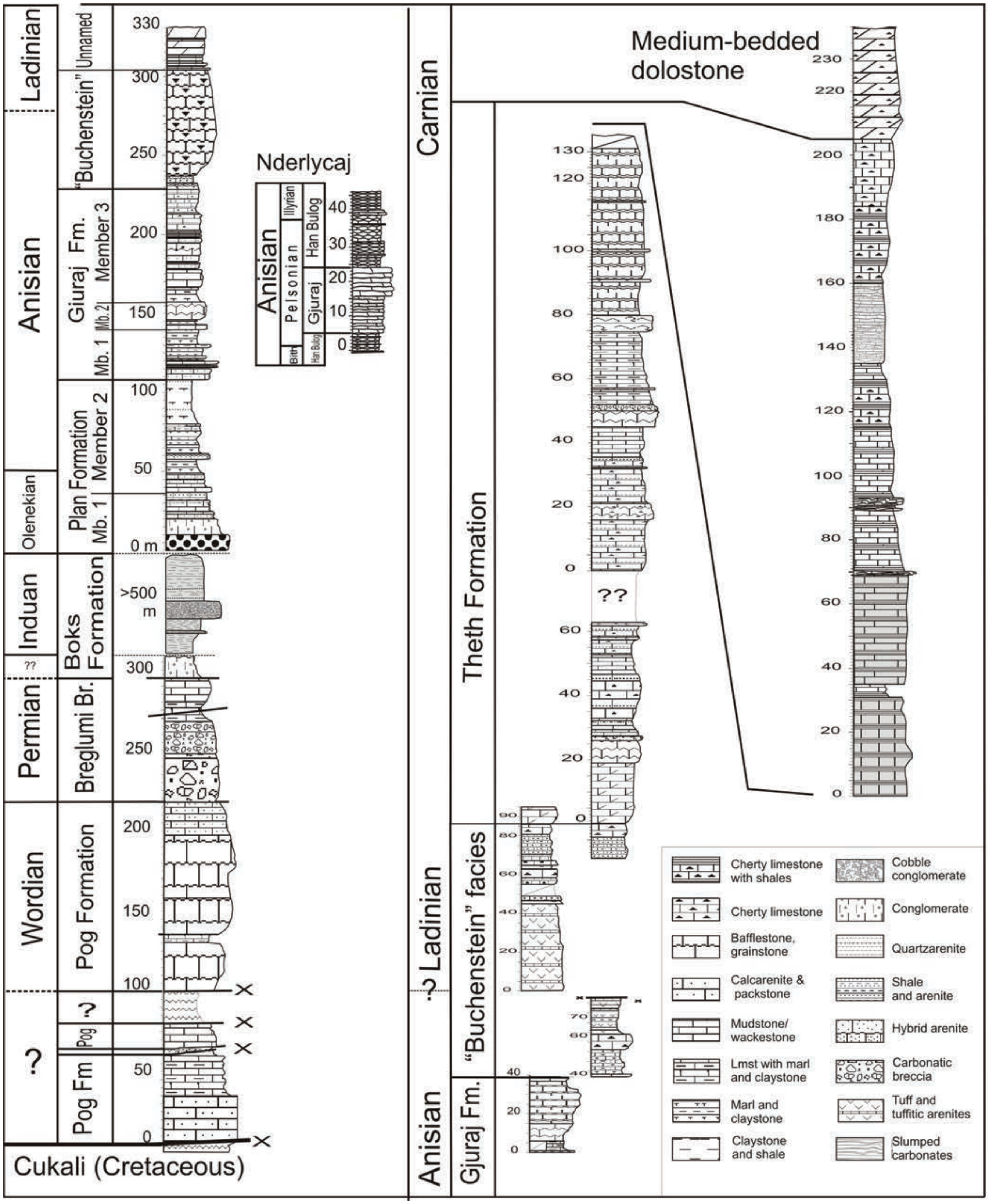

Figure 3 – To the left, the synthetic log of the Bishkaz Shala Block and to the right the synthetic log of the Valbona Block.

Research Note

THE FIRST FIND OF WELL-PRESERVED FORAMINIFERA IN THE LOWER TRIASSIC OF RUSSIAN FAR EAST

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Abstract – The first information on well-preserved Foraminifera from the Lower Triassic of South Primorye (Russian Far East) is given. Foraminifera preliminarily identified as *Ammodiscus* sp. were found in the upper Smithian of the Smolyaninovo section in a member characterized by the occurrence of ammonoid *Churkites syaskoi* Zakharov & Shigeta.

INTRODUCTION

Lower Triassic deposits of Russian Far East are characterized mainly by bryozoans, brachiopods, mollusks, crinoids, ostracods, fishes, amphibians and conodonts, which were mostly investigated in South Primorye (e.g., Diener, 1895; Kiparisova, 1938, 1961, 1972; Shishkin, 1964; Zakharov, 1968, 1978, 1997; Buryi, 1979; Burij & Zharnikova, 1980; Shigeta et al., 2009; Bondarenko et al., 2013; Zakharov & Moussavi Abnavi, 2013). However, information on undetermined Early Triassic Foraminifera from South Primorye found in thin sections of limestones (Korzh, 1959) are restricted. Korzh recognized small Foraminifera shells in limestones from the so-called "*Meekoceras* horizon" of Russian Island (Fig. 1). It is impossible to determine a stratigraphical position of the undetermined Foraminifera found by Korzh, because he did not indicated the sampled locality on Russian Island. Following Burij (1959), he considered that the *Meekoceras* horizon" of Russian Island consisted of mainly sandy sediments, located between Induan basal conglomerates and the Zhitkov Formation, characterized by the dominance of mudstones and siltstones. According to recent data (Zakharov & Moussavi Abnavi, 2013), the "*Meekoceras* horizon" of Russian Island, sensu Korzh, corresponds to Smithian (*Mesohedenstroemia bosphorensis* and *Anasibirites nevolini* zones) and lower Spathian (*Tirolites-Amphistephanites* Zone) beds. We assume that the undetermined Foraminifera may have been found in one of the lower Spathian limestone lenses.

The aim of this paper is to highlight the occurrence of well-preserved Foraminifera (*Ammodiscus* sp.), in eastern South Primorye, and to show their palaeobiogeographical significance. Selected test samples were examined with a scanning electron microscope (SEM, EVO 50XVIP) at the Analytical Center of the Far Eastern Geological Institute (FEGI). The studied Foraminifera collection is kept at the FEGI (Vladivostok) under number 12.

GEOLOGICAL SETTING

Five tests, preliminarily determined as *Ammodiscus* sp., were found in the upper Smithian sediments (*Churkites syaskoi* Beds of the *Anasibirites nevolini* Zone) of the Smolyaninovo section (Fig. 1). *Churkites syaskoi* Beds (68 m thick) exposed in the quarry near village of Smolyaninovo, are represented mainly of mudstones with calcareous-marl concretions and lenses, and sandstone layers (Figs. 2-4).

Ammodiscus sp. occurs in Member 7 (20.2 m thick), consisting of grey mudstones with large (20-50 cm) calcareous nodules, characterized by ammonoids *Churkites syaskoi* Zakharov & Shigeta (dominant), *Mianwalites* sp., Prionitidae gen. and sp. indet., *Preflorianites*? sp., *Juvenites* sp., *Clypeoceras*? sp. and *Hanielites*? sp.

SYSTEMATIC PALAEONTOLOGY
(PRELIMINARY DESCRIPTION)

In this work, the used Foraminifera systematics is adapted from Mikhalevich (2000).

Phylum Foraminifera d'Orbigny, 1826
Class Spirillinata Maslakova, 1990
Subclass Ammodiscana Mikhalevich, 1980
Order Ammodiscida Mikhalevich, 1980
Family Ammodiscidae Reuss, 1862
Genus *Ammodiscus* Reuss, 1862
Ammodiscus sp.
(Fig. 4)

Material. Five specimens in the sample 745-Sm12/5.

Description. The two-chambered test, consisting of 6-7 almost complete whorls, is planispiral, slightly curved discoid; periphery

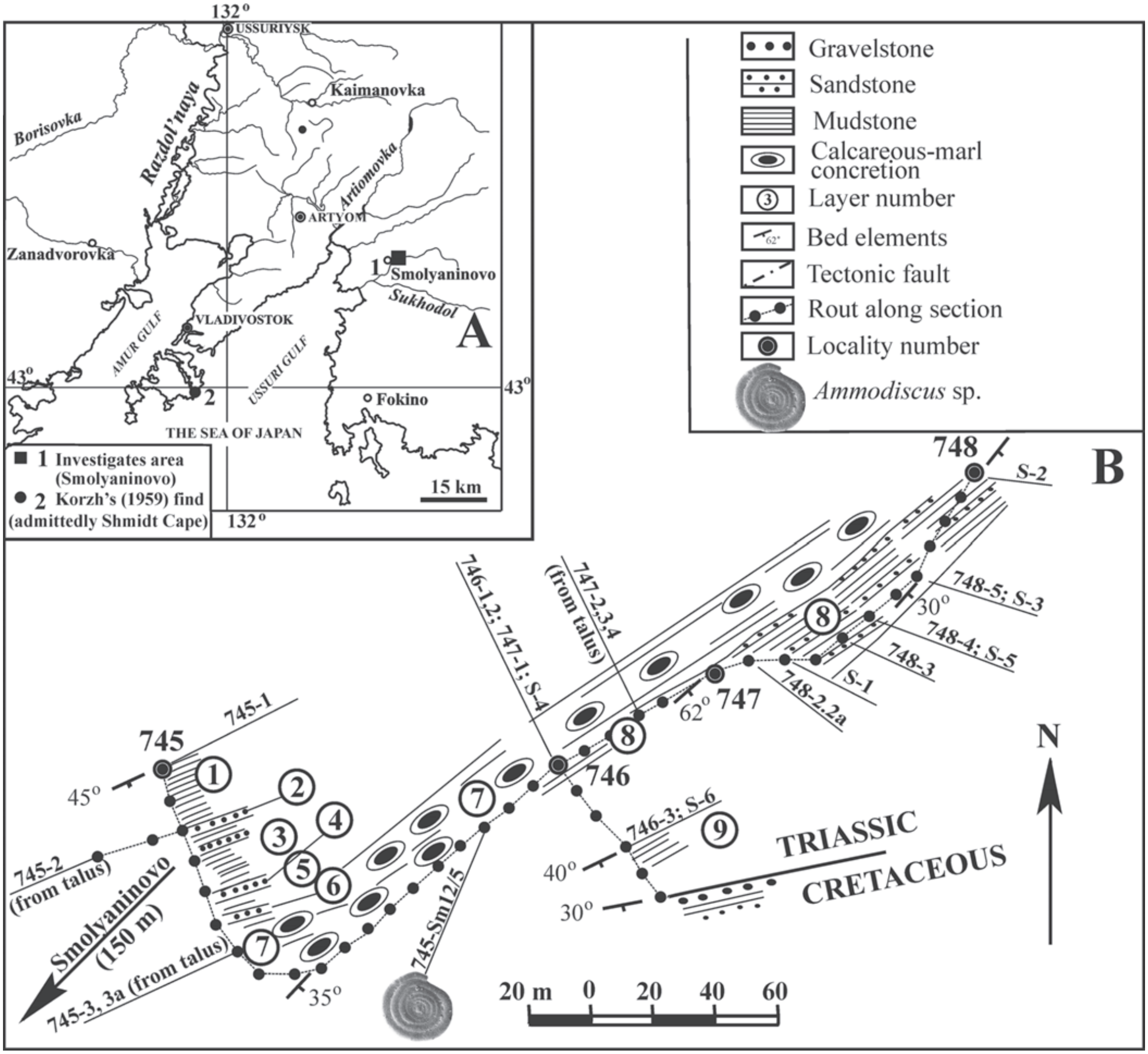

Figure 1 – (A) Map showing location of investigated areas in South Primorye (Smolyaninovo and Russian Island) and (B) Sketch map locating the Smolyaninovo section.

rounded, bent on both sides. The spherical proloculus, about 20 µm in diameter, is followed by a tubular second chamber with the planispiral winding, gradually increasing in height from center to periphery, from 7.5 µm to 25 µm; the tube in cross section is nearly roundish. The wall is agglutinated, microgranular, up to 4 µm thick. The aperture is terminal representing the open end of the tubular chamber.

Comparison. *Ammodiscus* sp. from South Primorye differs from the Lower Triassic species of *Ammodiscus minutus* Efimova by its larger size, number of whorls, and the slowly increasing height of the second chamber. It can be distinguished from Triassic *Ammodiscus parapriscus* Ho by its higher number of whorls and a higher tubular second chamber.

Stratigraphic and geographic occurrence. Upper Smithian (*Churkites syasko*i Beds, *Anasibirites nevolini* Zone) of South Primorye.

CONCLUSIONS

Since the pioneering study of Reuss (1862), who originally described *Ammodiscus*, this genus is known to occur in many Phanerozoic (Silurian – Recent) formations (e.g., Gaździcki et al., 1975; Alekseychik-Mitsckewich et al., 1981; Kolar-Jurkovšek et al., 2013). However, only some species of this genus were discovered in the Lower Triassic (Efimova, 1974, 1991; Vuks, 2007).

Among them, *Ammodiscus paraprіcus* Ho is the most widely

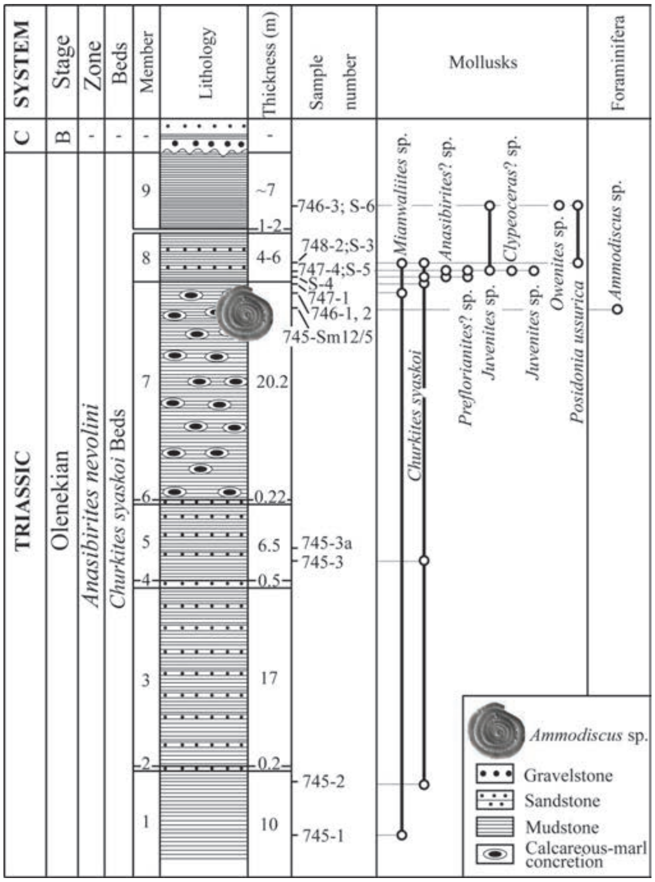

Figure 2 – Distribution of late Smithian ammonoids and Foraminifera in the Smolyaninovo quarry section. Abbreviations: C, Cretaceous, B, Barremian.

Figure 3 – *Ammodiscus* sp. site– Smolyaninovo quarry (photo courtesy of A.M. Popov).

Figure 4 – *Ammodiscus* sp. from the Lower Triassic (*Churkites syaskoi* Beds, *Anasibirites nevolini* Zone) of Smolyaninovo quarry section (scale bar is 100 µm): 1, DVGI 4–2/12, 2, DVGI 4-1/12, 3, DVGI 4–3/12, 4-6, DVGI 4-4/12.

TABLE 1 – Measurements of *Ammodiscus* sp. from the Lower Triassic of South Primorye.

Specimens	Diameter (mm)		Thickness (mm)		Whorl height (mm)		Whorl numbers
	Large	Small	Peripheral part	Central part	First	Last	
1, DVGI 4–2/12	0.26	0.27	-	-	0.008	0.027	6
2, DVGI 4-1/12	0.33	-	-	-	-	-	7
3, DVGI 4–3/12	0.31	0.29	-	-	0.008	0.038	6
4-6, DVGI 4-4/12	-	-	0.03	0.01	0.011	0.029	7

distributed in the Lower Triassic, but it is known only in the Tethys: South China, Himalaya, Germany, France, Spain, Albania, Hungary, Bulgaria, Greece, Turkey, Iran, Slovenia and the Carpathian area (e.g., Ho, 1959; Goel et al., 1981; Salaj et al., 1983; Blau et al., 1995; Fréchengues et al., 1990; Kolar-Jurkovšek et al., 2013). In the Lower Triassic of the Boreal realm, representatives of the genus *Ammodiscus* (*Ammodiscus* sp.; *A.* cf. *filliformis* (Reuss)) seem to be especially rare (Gerke, 1961; Kasatkina et a1., 1985). The occurrences of representative specimens in both the eastern and the western parts of the Tethys apparently indicate that long-distance dispersal was effective in this basin during the Early Triassic. However, the studied late Smithian *Ammodiscus* sp., here discovered in the western circum-Pacific differs from all other Early Triassic taxa and is therefore probably a new species.

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NEW EVIDENCE ON EARLY OLENEKIAN BIOSTRATIGRAPHY IN NEVADA, SALT RANGE, AND SOUTH PRIMORYE (REPORT ON THE IOBWG ACTIVITY IN 2013)

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MAIN RESULTS

1. A new ammonoid genus *Minersvillites* (family Arctoceratidae), 9 new ammonoid species of the genera *Kashmirites*, *Xiaoqiaoceras*?, *Minersvillites*, *Inyoites*, *Meekoceras* and *Vercherites* from the lower and middle Smithian of Utah, USA, have been described (Brayard et al., 2013). Some new subdivisions are recognized in the Smithian of the mentioned area. They are following in descending order: *Vercherites undulates* bed, *Radioceras* aff. *evolvens* beds, *Meekoceras oliveri* beds, *M. millardense* bed, *Preflorianites-Kashmirites* beds, *Inyoites beaverensis* beds, *Owenites* beds (with two horisons), *Anasibirites kingianus* beds, and *Xenoceltitidae* gen. indet. A beds (Brayard et al., 2013).

2. New Triassic ammonoid suborders *Proptychitina* and *Ussuritina* (Zakharov and Moussavi Abnavi, 2013), new Smithian genera *Ussurijuvenites* (family Melagathiceratidae) (Smyshlyaeva and Zakharov, 2012), *Subbalhaeceras* (family Flemingitidae) (Zakharov and Moussavi Abnavi, 2013), and *Ussuriaspenites* (family Aspenitidae) (Zakharov et al., 2013), as well as 18 new species of the genera *Ussurijuvenites*, *Flemingites*, *Euflemingites*, *Subbalhaeceras*, *Monneticeras*, *Brayardites*, *Anasibirites*, *Prionites*, *Anawasatchites*, *Kashmirites*, *Xenoceltites*?, and *Mianwaliites* (with holotypes from the Smithian of South Primorye) have been described.

3. The extensive investigation of Smithian sediments at Artyom area in South Primorye has demonstrated that the upper Smithian (Olenekian) section in the SMID section, encompassing the *Anasibirites nevolini* Zone (45.6 m thick), includes a unique and complete ammonoid succession as well as a nearly complete conodont record (Bondarenko et al., 2013; Zakharov et al., 2013). Judging from data on generic content of ammonoid assemblage of the *Anasibirites nevolini* Zone of the SMID section (*Pseudosageceras*, *Arctoceras*, *Churkites*, *Monneticeras*, *Clypeoceras*, *Brayardites*, *Dieneroceras*, *Juvenites*, *Prosphingitoides*, *Owenites*, *Meekoceras*, *Anasibirites*, *Prionites*, *Anawasatchites*, *Kashmirites*, *Xenoceltites*?, *Mianwaliites*, *Xenodiscoides*?), it is possible to conclude that *Anasibirites* fauna, recognized worldwide, is characterised by far not low-diversity of ammonoids, as it is considered by Brayard ‘s et al. (2013).

4. Ammonoids occurring in the SMID section encompass the genera *Anasibirites* (three species), *Anawasatchites* (one species), Hemiprionites (three species), *Mianwaliites* (one species), *Glyptophiceras* (one species), and *Xenoceltitites*? (one species), known in the upper Smithian of the Central Himalayas and Salt Range (Brühwiler et al., 2010, 2012; Ware et al. 2011). It allows the correlation of the *A. nevolini* Zone in Primorye at least with the *Wasatchites distractus*, *Subvishnuites posterus* and *Glyptophiceras sinuatum* beds, recently documented in Spiti and Nammal.

5. The conodont *Scythogondolella miller*i Zone extends in the SMID Quarry section to the lower part (Member A) of the ammonoid *Anasibirites nevolini* Zone in South Primorye. At the base of Member A, a rich conodont assemblage was found represented by *Ellisonia nevadensis* Müller, *Ellisonia triassica* Müller, *Furnishius triserratus* Clark, *Neospathodus* ex gr. *waageni* Sweet, *Scythogondolella milleri* (Müller) and *Scythogondolella mosheri* (Kozur & Mostler). The top of Member B is characterised by less abundance and less diversity of conodonts that is partially connected, apparently with the degree of their preservation. In this level only *Scythogondolella milleri* (Müller) has been recognized with certainty. Overlying layers of the *Anasibirites nevolini* Zone (the top of Member B, respectively base of Member C), again demonstrates great abundance and diversity of conodonts, which are represented by *Furnishius triserratus* Clark, *Ellisonia triassica* Müller, *Discretella discreta* (Müller), *Neospathodus novaehollandiae* McTavish, *Hadrodontina* sp., and several neogondolellid elements (S3-S4 or possibly S0 posterior processes) formerly identified as “*Hindeodella*” *triassica* Müller. This level is however dominated by an apparently new S – element. Thus, the *Scythogondolella milleri* Zone (Member A) and the “*Hindeodella*” Group B Beds (Members B - base Member C), as the lower and middle parts, respectively, of the *Anasibirites nevolini* Zone, are distinguished in South Primorye.

6. A high-resolution Early Triassic temperature record based on the oxygen isotope composition of pristine apatite from conodonts has been presented for the first time (Romane et al., 2013). This reconstruction shows that the beginning of Smithian was marked by cooler climate, followed by an interval of extreme warmth, lasting until the end of Smithian. Cooler conditions

Figure 1 – *Field*

resumed in the Spathian. It is suggested that climate upheaval and carbon-cycle perturbations due to volcanic outgassing were important drivers of Early Triassic biotic recovery.

Field-work results

Churkites cf. syaskoi-bearing sediments, possible equivalent of the *Anasibirites nevolini* Zone, have been discovered in the upper part of the Tri Kamnya section in South Primorye.

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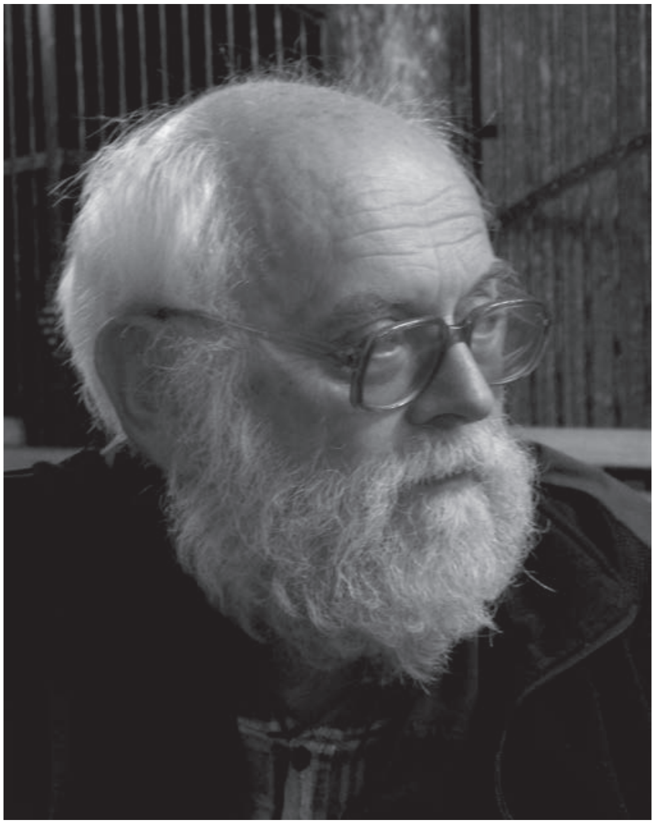
HEINZ W. KOZUR (1942-2013)

On 20 December 2013, Heinz W. Kozur died in Budapest, Hungary, after a long struggle with illness caused by several brain strokes. Born in Hoyerswerda (Sachsen), Germany, on 26 March 1942, Heinz began his studies of geology at the Bergakademie Freiberg/Sachsen in 1961. There, he completed a diploma thesis in 1967 on the conodonts and scolecodonts of the Upper Muschelkalk of Middle Europe under the supervision of Professor Dr. A. H. Müller. For this, and his other student accomplishments, Heinz was awarded the Agricola Medal.

Postgraduate study at Freiberg under the direction of Müller followed. In 1971, Heinz received his doctoral degree (Dr. rer. nat. geol.) for his dissertation (awarded summa cum laude) on the micropaleontology, biostratigraphy and biofacies of the German Middle Triassic. By the time he received this degree, he had begun employment as the Chief of the Department of Natural Science at the Staatliche Museen Meiningen/Thüringen, a position Heinz held until 1981. In 1975, Heinz finished his Habilitation at Freiberg, again under the direction of Prof. Müller, on the biostratigraphy, facies and paleogeography of the Triassic.

Outspoken and headstrong, Heinz came into conflict with the socialist authorities in the former German Democratic Republic (GDR or East Germany). Thus, when the socialist establishment seriously impeded his scientific career in East Germany, he went into exile to Hungary in 1981. Employment at the Geological Survey of Hungary in Budapest followed (1981-1985), which led to Heinz's election to the Hungarian Academy of Science. However, in 1985, political problems resurfaced due to the long arm of the GDR authorities, and Heinz lost his position in Budapest. He was banned from his profession and had his scientific notes, documents and specimens confiscated.

Thus began the remainder of Heinz's professional career, during which regular, full-time employment was replaced by part-time or short-term employment as a visiting professor or by funds supplied by research stipends, grants and professional consulting. Heinz thus undertook most of his professional work and achieved his remarkable and extensive research results of the last three decades as a private citizen without long-term institutional support.



During the 1980s and 1990s, Heinz was a visiting professor at several universities, including Yarmouk University in Jordan, Northern Arizona University in the USA, the University of Palermo in Italy, the University of Lausanne in Switzerland, the University of Salzburg and Innsbruck University, both in Austria, and (after the collapse of the GDR) at the University of Halle in Germany. Long-term research stipends came from Middle East University in Turkey, the Geological Survey of Japan and Innsbruck University. Additionally, Heinz received many research grants from diverse sources.

The research of Heinz Kozur covers a broad range of topics in historical geology, with a strong focus on the Permian and Triassic timescales. To those ends, Heinz served as a voting member of the IUGS Subcommission on Permian Stratigraphy from 1976 to 2007, and remained an honorary member until his death. From 1969 until his death, Heinz was a voting member of the IUGS Subcommission on Triassic Stratigraphy. Within these subcommissions, Heinz participated in the research and deliberations of many of the key working groups devoted to defining geological time boundaries, including the Carboniferous-Permian, the Permian-Triassic and the Triassic-Jurassic boundaries. He was also an integral member of the groups that defined the Guadalupian, that deciphered the Tethyan Triassic and that worked to develop the chronology of nonmarine Triassic strata. He was also active in the Permian-Triassic Subcommission of the German Stratigraphic Commission.

Most of the major advances that have been achieved in refining and defining the Permian and Triassic timescales of the last 30-40 years owe much to Heinz Kozur. As but one example, consider that the defining criterion of the base of the Triassic System (and therefore the base of the Mesozoic Erathem) is the first appearance of the conodont species *Hindeodus parvus*, a species named by Kozur and Pjatkova in 1975.

In his curriculum vitae, Heinz divided his research contributions into six areas: stratigraphy, paleoecology, bioevents, tectonics, paleogeography/paleoclimatology and paleontology/biostratigraphy. In the area of stratigraphy, Heinz contributed much to understanding Cambrian-Devonian marine stratigraphy and both the marine and nonmarine stratigraphy of Carboniferous-Triassic rocks, especially in central Europe. In paleoecology, our understanding of the complex ecosystems of the Permian and Triassic and how they responded to the end-Permian extinctions owes much to Heinz's insight. With regard to bio-events, Heinz contributed much to the analysis and timing of biotic crises, especially at the Permo-Triassic and Triassic-Jurassic boundaries.

All stratigraphic refinement has tectonic implications, and Heinz applied his work to deciphering various tectonic puzzles, particularly of the Variscan and Alpine orogenies in Europe and the Cadomic to Cimmerian orogenies in Turkey. The paleogeography and paleoecology of Pangea, especially the Tethyan realm and the Germanic basin, was one of Heinz's great areas of expertise. However, it is fair to say that it is in paleontology and biostratigraphy that Heinz's greatest contributions were made, as his nearly 600 published articles indicate.

As a paleontologist, Heinz worked on diverse fossil groups. But, perhaps his largest contributions were to the conodonts, radiolarians and conchostracans. In all three groups, many of the new taxa described by Heinz and his collaborators were used to build landmark understandings of the evolution and biostratigraphy (especially during the Triassic) of these groups. Indeed, the work of Heinz Kozur on Triassic conodonts in his doctoral dissertation was the beginning of modern Triassic conodont taxonomy and biostratigraphy. His Muschelkalk conodont zonation is still standard, and many of the key conodont taxa used in Triassic correlations were first identified and analyzed by Kozur. The radiolarians tell a similar story, with Kozur early on the scene to recognize the value of these microfossils to the subdivision of Triassic time; all subsequent work has built on his. And, in the terrestrial Triassic, the last eight years saw Heinz, in collaboration with Rob Weems, elaborate on Heinz's earlier work to present a Triassic conchostracan zonation built largely on the records from the Germanic basin and the Newark Supergroup basins of eastern North America. Among other noteworthy results here is the first demonstration by conchostracan biostratigraphy that the beginning of the Jurassic was in fact during the episode of CAMP volcanism that accompanied the rifting that opened a nascent Atlantic Basin, not prior, as suggested earlier. Truly, it is fair to say that nobody can touch the biostratigraphy and chronology of Triassic Pangea without using the work of Heinz Kozur.

Beyond conodonts, radiolarians and conchostracans, Heinz also made major contributions to other groups of fossils, among them ostracods, holothurian sclerites, scolecodonts, charophytes, megaspores and miospores and the footprints of arthropods and tetrapods.

Throughout much of his career, Heinz was a member of several scientific societies, among them the Deutsche Gesellschaft für Geowissenschaften (since 1990), the Ungarische Geologische Gesellschaft (since 1982), the Deutsche Paläontologische Gesellschaft (since 1990) and he was elected to the Ungarische Akademie der Wissenschaften (in 1984) and the New York Academy of Science (in 1996).

After the collapse of the Soviet Union and the loosening of restrictions on travel by scientists in Eastern Bloc countries, we both met Heinz in the early 1990s. Since then he was a valued collaborator on various projects. To add some personal insight, we can say that Heinz was a person of great energy – a tireless worker on the outcrop, at the museum, in the laboratory as well as behind the microscope and the computer. A polyglot, he moved freely from his native German to fluent English and Russian or on to a working technical knowledge of several other languages, not to forget Hungarian, the language of his adopted country and his wife Dr. jur. Zsuzsánna Tömpe. He never learned how to drive a car, so to drive Heinz to the outcrop was to transport an encyclopedia of Pangea – an earth scientist who had been all over the globe and knew its Triassic outcrops and biostratigraphic problems as well as any and better than most. When other people had to check their notes – Heinz simply knew it. But, listening to Heinz also made it obvious that the conflicts and struggles of bygone years caused many, long open wounds.

When Heinz turned 70, at its Annual Meeting at Hannover in October 2012, the Deutsche Gesellschaft für Geowissenschaften awarded him the Leopold-von-Buch-Plakette to honor his scientific contributions. In 2013, New Mexico Museum of Natural History and Science Bulletin 61, The Triassic System: New developments in stratigraphy and paleontology, was dedicated to Heinz, and his complete scientific bibliography through early 2013 is published there.

With the death of Heinz Kozur we have lost one of the great experts on the geological timescale, particularly of the Permian and the Triassic Periods. Few scientists knew as much about the Triassic System as did Heinz Kozur, and few have ever made such a significant contribution to our understanding of its stratigraphy, paleoecology, bioevents, tectonics, paleogeography/paleoclimatology and paleontology/biostratigraphy. We will miss Heinz, a great geologist and paleontologist, a precious colleague, comrade and friend.

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INNA A. DOBRUSKINA (1933-2014)

Inna Dobruskina, one of the foremost experts on Triassic paleobotany, died peacefully in Jerusalem, Israel, on January 4, 2014; she was 80 years old. Born December 25, 1933 in Moscow, Russia, Inna attended Moscow State University (MSU) from 1952 to 1957 and received a M.Sc. degree in 1957. She then undertook doctoral study at MSU, from 1960 to 1964, and she was awarded the Ph.D. in 1964. She later completed a Dr.Sci. degree (awarded 1977). Inna's first academic position was at MSU, where she sat on the Faculty of Geology from 1957 to 1964. From 1964 to 1989 she worked at the Geological Institute of the Soviet Academy of Sciences. And, after emigrating to Israel, she held positions at the Institute of Earth Sciences of the Hebrew University of Jerusalem from 1990 to 1999.

These are the summary facts of Inna Dobruskina's academic career, so let us provide more perspective on her life, which was one of many challenges and achievements. Inna was born in a "communal apartment" in downtown Moscow. Having nationalized all real estate after the Revolution, the Soviet Government had allotted individual rooms in apartment buildings to unrelated families who were forced to share kitchens and bathrooms in these ad-hoc "communes." (For some residents, these arrangements continued into the late 1980s; indeed, Inna's mother lived in the same communal apartment until her death in 1987).

Inna was 7 years old when Germany invaded the Soviet Union in 1941. There was panic as the Wehrmacht approached Moscow, and Inna's mother, at the time an interpreter with a Comintern publishing house, arranged for Inna to be sent into the country's interior, as one member of a large group of children. Inna lived at the thus created impromptu boarding school until 1943. It so happened that many in the group were the children of foreign communist leaders who were hiding out in Moscow during WWII. After WWII, many of the parents of these children became either government bosses in newly communist countries or the heads of opposition communist parties in the free world. Thus, for example, one of Inna's classmates was Rudolf Slansky, Jr. The older Slansky became secretary general of the Czech Communist Party and wielded great power in that country, until he and 11 other top communists were executed by their own party in 1951 in what became known as the Slansky Trial.

When Inna entered MSU in 1952, science was one of the few careers available that afforded a somewhat comfortable living without having to work for the government politically. In contrast, a career in the humanities meant working for the Party (if one majored in scientific communism, dialectic materialist philosophy, etc.) or the KGB (psychology, foreign languages, foreign relations). Within science, geology was one of the few fields without direct military applications; physics, chemistry, biology and electronics were of interest to the government inasmuch as they assisted the development of new types of weapons. For Inna, non-petroleum geology turned out to be the narrow path between Scylla and Charybdis.

Inna's geological studies included practical field work in the Kola Peninsula, Mangush in the Crimea and along the Cherek River in the Caucasus. Upon earning her M.Sc. in 1957, Inna remained at MSU, joining the newly-formed Amur Expedition. At that time, an urgent project focused on building a joint Sino-Soviet hydroelectric dam on the Amur River, which forms the border between the two countries in the Far East. The scheme required selecting a site for damming the upper Amur River system, possibly as high as the confluence of the Argun and Shilka rivers.

Detailed geological maps were needed along the river system at and around the dam site.

The Expedition's mandate thus was to produce 1:200,000 scale maps of a 1300-km-long stretch of the river, 15 km wide on each bank. Inna and the other young graduates spent three-to-four-month-long summers mapping the area on both sides of the river. Each geologist lead a party of 10 to 15 men into the wilderness, without contact with the outside world for weeks at a time. The conditions were harsh and the equipment basic. Inna recalled how, on one return trip to Moscow, a train conductor neglected to check Inna's tickets, concluding from her clothing and appearance that she was a convict freed under the recent Khrushchev amnesty.

Indeed, a young female academic faced special challenges to her leadership in the wilderness. Inna liked to recount how, early in the expedition, her subordinates challenged her to drink a shot of undiluted alcohol with them (it's not a Russian geological party without a keg of pure alcohol). Convinced that her authority would disintegrate if she refused, Inna upped the challenge to a full glass (250 ml) and drank it in one gulp—the first and the last time in her life she drank more than a glass of wine. She faced no further challenges from her subordinates that year.

Sino-Soviet relations soured as the 1950s wore on, and, in July 1960, the Soviets recalled all scientific advisers from China, cancelling some 200 cooperative scientific projects. The Amur Dam was one of these canceled projects, and 1959 was the Amur Expedition's last field season (Inna participated for all three years: 1957, 1958 and 1959).

Following the cancellation of the Amur Expedition, Inna entered the Ph.D. program at MSU. Her research focused on processing material from the Amur Expedition, and in 1964 she defended her thesis, "Stratigraphy and flora of the Jurassic and Lower Cretaceous of the Amur River." As a teaching assistant during her Ph.D. studies, she returned to Mangush for the 1961 field season, this time as an instructor.

On receiving her Ph.D., Inna took a position at the Paleofloristics Laboratory of the Geological Institute of the Soviet Academy of Sciences (GIN). At GIN, Inna took on the Triassic flora of Eurasia as her subject. She worked on this project for the next 25 years, continuing to travel widely inside the Soviet Union, and conducting field work at Issyk Kul, Madygen, the North Caucasus, Mangyshlak, Pamir, Baskunchak, Bogdo, Rybinsk and at other locales. She received her Dr. Sci. in 1977, for a dissertation titled "Triassic floras of Eurasia (stratigraphic position, systematics, phytogeography)."

In 1965, Inna married Arnold Krupnikov, a mining safety engineer. For their honeymoon, the couple spent four weeks collecting Triassic fossils in the field at Madygen under the direction of Dr. A. G. Sharov; they also visited historic Bukhara and Samarkand on their return journey to Moscow. Inna had worked at the site the previous year and would return the following year, and ultimately again with paleoichthyologists Drs. Maxim and Alla Minich in 1987. Inna and Arnold's marriage produced two children, Irina (b. 1968) and Ari (b. 1977). The couple divorced in 1982.

Although she was the daughter of two Communist Party members, Inna had grown disillusioned with government policy by the time she graduated from the university. She then became an outspoken critic of the regime and helped distribute illicit, often typewritten copies of "samizdat" literature. Despite the persistent threat of prison terms for possession of such subversive material, Inna would often make additional copies for distribution by retyping the text through four or five layers of carbon copy paper. Xerox-style copying technology was understandably unavailable to Soviet citizens.

By the mid-1980s, Inna's frustration with the Soviet authorities grew to a boiling point. She decided that emigration was the only option for her, and with border controls loosening during Perestroyka, she petitioned to renounce her Soviet citizenship and depart the Soviet Union. She settled in Jerusalem, Israel, in 1989, and accepted an adjunct professor position with the Institute of Earth Sciences at the Hebrew University. In Jerusalem, Inna taught undergraduate stratigraphy and continued her research on Triassic floras. Her monograph "Triassic Floras of Eurasia" was published in English in 1994 (it had been published in Russian in 1982).

After leaving the Soviet Union, Inna traveled widely, conducting fieldwork in Austria (with Dr. Harald Lobitzer), France (with Dr. Lea Grauvogel-Stamm), South Africa (with Drs. John and Edith Anderson) and the USA (with Dr. Spencer Lucas). In 1993, she was a Distinguished Visiting Professor at Ohio State University at the invitation of Dr. Thomas Taylor. Inna retired from The Hebrew University in 1999.

In retirement, Inna put much effort into reconciling her knowledge of her family history with the history of the Russian Revolution and civil war. She searched archives as far afield as Stanford, California, and discovered her paternal grandfather's part in establishing communist rule in Siberia and the Caucasus--F. M. Afanasiev had been a colonel in the Imperial Russian Army, wounded in the Russo-Japanese war of 1904-5 and decorated for bravery in that campaign as well as in World War I. In 1918, he chose the Red side in the unfolding civil war, and ultimately rose to Chief of Staff of Soviet forces in Siberia. In this role, he planned and directed military suppression of the numerous peasant uprisings against communist governments in Siberia, as well as oversaw incursions deep into Mongolia to destroy retreating White units.

Inna suffered a stroke in 2011 from which she never fully recovered. She passed away peacefully on January 4 at Shaarey Tzedek hospital in Jerusalem. She is survived by her children Irina and Ari and grandchildren Elisha, Ada and Leah.

With her passing we have lost one of the great students of the Triassic--of its plant fossils, stratigraphy and timescale. Inna's contributions to Triassic paleobotany and stratigraphy were diverse, as her list of published works below demonstrates. Indeed, her monograph on the Triassic floras of Eurasia is one of the most important syntheses of Triassic paleobotany published during the 20th Century. It did much to clarify the complex and diachronous changes from the Paleophytic floras to the Mesophytic floras, most of which took place during the Early to Middle Triassic. Few have ever achieved the knowledge and experience with Triassic paleobotany that came to Inna Dobruskina through her extensive research. She will long be remembered as one of the great students of the Triassic System.

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NEW TRIASSIC LITERATURE

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PART I

New Triassic literature dated pre-2012 but not included in earlier issues of Albertiana.

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Meeting annoucements

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Theme Session 195. Extreme Environmental Conditions and Biotic Responses during the Permian-Triassic Boundary Crisis and Early Triassic Recovery.

Conveners: *Thomas J. Algeo, Hugo Bucher, Peter Roopnarine, Arne M.E. Winguth*

This session will feature new research related to the globally disturbed conditions associated with the end-Permian mass extinction and its aftermath during the early Triassic.

Theme Session 205. Major Evolutionary Events of the Early Mesozoic—Paleontology and Paleoecology from the Middle Triassic to the Late Jurassic

Conveners *Lydia S. Tackett, Rowan C. Martindale, David Bottjer*

The early Mesozoic represents one of the most evolutionarily chaotic intervals of the Phanerozoic. This session encourages paleontological and paleoecological studies from the middle Triassic through the Jurassic (e.g., Mesozoic Marine Revolution, Triassic-Jurassic, Toarcian OAE).

Theme Session 206: Mass Extinctions: Volcanism, Impacts, and Catastrophic Environmental Change

Conveners: *David P.G. Bond, Gerta Keller, Thierry Adatte*

This session explores recent advances in the stratigraphic and geochemical records of mass extinctions and impacts that have seen the impact-kill scenario recede in favor of terrestrial causes that may ultimately derive from massive volcanism.

Theme Session 199: Conodonts as Stratigraphic and Paleoclimatic Tools

Conveners: *Charles M. Henderson, Michael J. Orchard*

This session will focus on the increasing use of conodonts as stratigraphic and paleoclimatic tools and welcomes contributions involving conodont biostratigraphy and isotope geochemistry of conodonts.

Theme Session 243. Road-Testing the Placement of the GSSP Golden Spikes

Conveners: *Lucy E. Edwards, Stanley C. Finney, Brian R. Pratt*

This session is devoted to discussing the utility of GSSP boundary placement from the end-user perspective of geoscientists doing regional mapping and correlations and utilizing outcrop and subsurface data.

Theme Session 206: Mass Extinctions: Volcanism, Impacts, and Catastrophic Environmental Change

Conveners: *David P.G. Bond, Gerta Keller, Thierry Adatte*

This session explores recent advances in the stratigraphic and geochemical records of mass extinctions and impacts that have seen the impact-kill scenario recede in favor of terrestrial causes that may ultimately derive from massive volcanism.

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Meeting annoucements

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Symposium 4: Rapid climate/environmental changes in Mesozoic greenhouse world

Conveners: *Xiumian Hu, Michael Wagreich, Helmut Weissert*

This session is to provide a platform for discussion among sedimentologists interested in Mesozoic rapid climate/ environmental changes, such as oceanic anoxic events, oceanic red beds, carbonate drowning events, other extreme climatic and environmental events. Papers are invited on discussing specific stratigraphic and sedimentological records related to those rapid climate/ environmental events in Mesozoic greenhouse world.

Symposium 31: Triassic to Jurassic basin analysis in the Tethyan realm

Conveners: *Sigrid Missoni, Fabrizio Berra, Tetsuji Onoue*

A substantial lack of knowledge limits our understanding of the north-western Tethys margins during the Triassic-Jurassic and the interplay with (a) the onset of extension in the future Alpine-Atlantic/Alpine-Tethys system, and (b) the closure of the Palaeotethys (early Cimmerian orogeny) and the Neotethys (late Cimmerian orogeny). Open questions include: When and where Tethys related oceans were formed respectively when and where they were consumed?; which intervening continental units, terranes or miroplates were isolated by oceanization processes?.

Field Trip B3: Stratigraphic architecture and facies distribution of high-relief Middle Triassic carbonate platform (Central Southern Alps, Bergamo, Italy

Field Trip Leaders: *Fabrizio Berra, Marco Binda, Flavio Jadoul (University of Milano)*

During the field trip different aspect of a high-relief, flat-topped prograding platform will be observed. In particular, the field trip will focus on the general architecture of a well-preserved carbonate platform (Pegherolo Massif), with the observation of the basinal facies interfingering with the prograding slope breccias and the platform demise, both in the basinal area and on the platform top, where the subaerial exposure of the platform top is spectacularly documented . Visit of the historical Calcare Rosso tepee rich succession