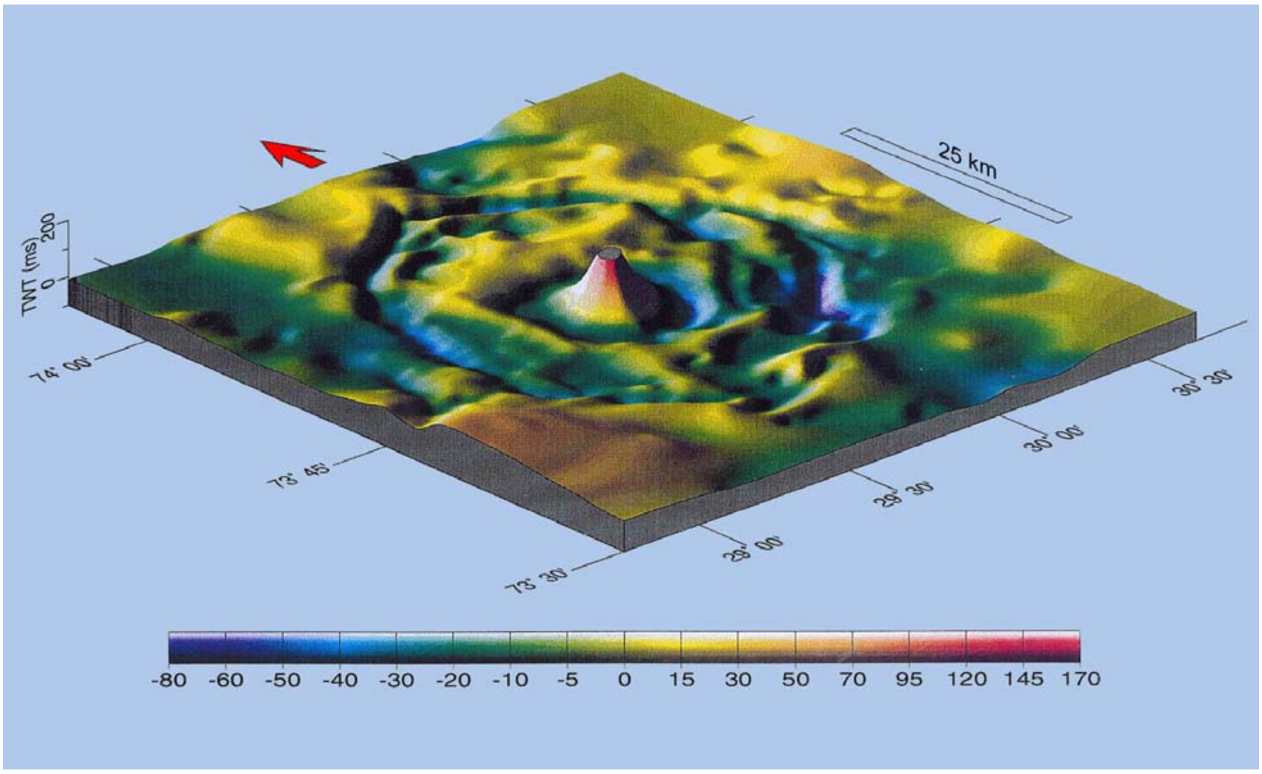
ALBERTIANA



31

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Contents

The primary aim of ALBERTIANA is to promote the interdisciplinary collaboration and understanding among members of the I.U.G.S. Subcommission on Triassic stratigraphy. Within this scope ALBERTIANA serves as the newsletter for the announcement of general information and as a platform for discussion of developments in the field of Triassic stratigraphy. ALBERTIANA thus encourages the publication of anouncements, literature reviews, progress reports, preliminary notes etc. - i. e. those contributions in which information is presented relevant to current interdisciplinary Triassic research. An electronic version of ALBERTIANA is also available in PDF format @ http://www.bio.uu.nl/~palaeo/Albertiana/Albertiana01.htm.

Cover: Illuminated perspective image of residual two-way traveltime to a reflector close to top of the crater fill to illustrate the present structural morphology of the Mjølnir Crater (from Dypvik et al. 1996) see paper by Mork on pages 47-53.

Executive Notes

From the Chair

I've recently returned from a successful International Geological Congress in Florence, Italy. Two events stand out for me. First the workshop on the Upper Triassic (see report and abstracts herein) where an enthusiastic gathering of Triassic workers shared their latest research results aimed at the common goal of arriving at a standard time scale for the interval. Good progress was made and I was pleased to see so much quality work is being done. The second event was the workshop of the International Commission on Stratigraphy, where I briefly summarized the status of the Triassic time scale. At this second meeting, all chairpersons of subcommssions did the same and I was left with an impression of how far advanced a formal standard Phanerozoic scale is. Indeed, some subcommissions have fully agreed GSSPs and are now defining substages. I should add that I was not too alarmed that the Triassic stands out as the one period that lacks any internal GSSP because I am aware how much progress is being made by our task forces charged with defining them. Neverthless we now face a challenge to arrive at agreement on 6 outstanding boundaries within the next few years in order to meet the IUGS requirement. Not for the first time, I urge all of you to become involved in the task groups where you think you can contribute data and energy. Lists are now being complied of all members of these task groups and future decisions will be based on those lists - so act now if you have an interest in contributing to the task of producing a standard Triassic time scale.

Our next formal meeting is planned for Wuhan, China next May. This meeting - which is co-sponsored by STS, SPS, IGCP467, and CHRONOS - is an opportunity to see not only a candidate for the Induan-Olenekian boundary, but also the magnificent site that the P-T boundary (and now base Changxingian) GSSP has become at Meishan. Field trips will also offer the chance to see the entire Lower Triassic and well dated Olenekian-Anisian boundary in Guizhou Province. By then, I hope we will also be able to celebrate final resolution of some new Triassic GSSPs.

From the Secretary

ICS Subcommission on Triassic Stratigraphy

Minutes of joint business meeting of the STS and IGCP Project 467, 32nd International Geological Congress, Florence Italy, 24 August, 2004

Chairman: M. Orchard

Secretary: C. McRoberts

Present

A. Ahluwalia, A. Baud, M. Balini, M. Gaetani, J. Haas, C. Henderson, F. Hirsch, M. Hounslow, T. Klets, H. Kozur, L. Krystyn, W. M. Kürschner, C. McRoberts, A. Nicora, M. Orchard, M. Szurlies, Tong Jinnan, V. Vuks, Yin Hongfu, Y. D. Zacharov

Agenda

1. Welcome and general STS remarks
2. Future Meetings
3. Report of recent Spiti STS and IGCP 467 meeting (by L. Krystyn)
4. Review of present state of Triassic GSSPs
5. Presentation of Induan/Olenekian boundary at Spiti (by L. Krystyn)
6. Closing remarks

Item 1.

Chairman opened the meeting at 17:40 and welcomed participants to the joint STS and IGCP 467 business meeting. Chairman thanks all those who participated in the Workshop DW0-09 as part of the 32nd International Geological Congress. Chairman noted changes in the STS executive following votes from the Dolomite meeting last fall. Included in the changes were Macro Balini as incoming Vice Chairman replacing Y. D. Zacharov and Christopher McRoberts as incoming Secretary replacing G. Warrington.

The chairman announced the forthcoming STS website at http://paleo.cortland.edu/sts/ to be maintained by C. McRoberts which will provide up-to-date information regarding STS activities, memberships, and bulletin board discussion areas for GSSP workgroups. The chairman also mentioned this site will complement and not compete with the very useful *Albertiana* web site run by W. M. Kürschner.

Item 2.

The chairman announced the following future meetings that would be either official STS/IGCP 467 sponsored events or of interest to those working on similar issues. Further details regarding these meetings can be found elsewhere in this issue of Albertiana or from the STS or IGCP 467 websites.

Muscat Oman, January 2005. Elaborated on by A. Baud, this meeting of the 25th IAS Meeting on Sedimentology has an associated field trip of interest to STS and IGCP 467 members entitled "birth and Early Development of the Tethyan Oman Margin from Middle Permian to Middle Triassic: a Geochemical and Sedimentological Approach. Baud distributed hand outs describing the meeting and field trip.

Chaohu, China, May 2005. Elaborated on by Tong Jinnan and Yin Hongfu, this official STS/IGCP467 meeting will involve both field trips and scientific session examining the lower Triassic succession, paleoecology and biotic recovery including candidate Induan/Olenekian boundary and a visit to Meishan Permian/Triassic boundary. A first circular and call for papers was distributed by Tong.

Valencia, Spain, September, 2005.Joint meeting of the XV Congreso Nacional de Sedimentologia and IV Coloquio de Estratigrafia, Paleogeographia del Permico y Triasico.

New Zealand, March, 2006. Circum-Panthalassa Triassic Faunas and Sequences. Wellington, New Zealand. A joint meeting InterRad XI and STS and IGCP 467, he focus of this symposium will be on Triassic stratigraphy and correlations in the circum-Pacific region.

Svalbard, August, 2006. The Boreal Triassic. This symposium will focus on all aspects of the Arctic Triassic and correlation with Tethys.

Belgrade, September 2006. Carpathian/Balkan Geological Association Congress. Elaborated on by J. Haas, who noted the first circular will be forthcoming.

New Mexico, 2007. Final meeting of IGCP 467 and completion and publication of the Triassic timescale.

Item 3.

L. Krystyn made a short report on the recent meeting in Spiti. Krystyn said the organization for the meeting was excellent and thanked his co-organizers, hosts and colleagues, especially members from the Indian Geological Survey and participating Indian universities. Krystyn reported that the program, field guide, and abstracts of the Spiti meeting will be published as a special issue of *Albertiana* (vol. 30).

Item 4.

The Chairman made a brief PowerPoint presentation on the current status of Triassic GSSPs and the recently released ICS timescale. The chairman noted that the STS has only one completed GSSP at the base of the Induan (and therefore Permian/Triassic boundary) and remarked that the STS lagged behind other subcommissions in completing their assigned task. The chairman did report progress on the base Ladinian GSSP, and further stressed the need to complete selection of Triassic GSSPs before the stated ICS goal of having all GSSPs ratified by 2008.

Item 5.

L. Krystyn made a PowerPoint presentation regarding the possibility of a future Induan/Olenekian proposal for the Muth locality in Spiti India as a potential GSSP or auxiliary GSSP. Krystyn outlined recent field-based research activities of 2003 and 2004 in Spiti. Krystyn also noted that, although the section was high (about 4000 meters), it provided excellent stratigraphic exposure, is quite fossiliferous, and exhibits favorable facies with likely continuous and expanded deposition across the boundary. A potential boundary datum is controlled by conodonts and the ammonoid *Flemengites*. Krystyn did note that the rocks have been somewhat heated (C.A.I = 3.5) and no geochemical or paleomagnetic results should be expected. However, Krystyn also noted the section is reasonably accessible and there exists nearby lodging.

Item 6.

Chairman asked if there was any other business to be discussed and no further points were raised. Chairman thanked those present for their participation and declared the meeting closed at 18:45

Duly submitted,

Christopher McRoberts

STS Secretary

Meeting Reports

IGC Workshop DWO-09: Definition, subdivision, and correlation of the Upper Triassic.

Co-sponsored by STS and IGCP 467

The workshop was a most enjoyable event with some 50 participants enjoying lively presentations and discussions of the fruits of our collective scientific labor! Fourteen titles had been submitted as abstracts, although only 12 papers/ posters appeared on the day. All abstracts are reproduced here and can be viewed on-line at the website of IGCP 467 (http://paleo.cortland.edu/IGCP467)

The proceedings began with a brief introduction by Mike Orchard (convenor) laying out the scope of the workshop and the fact that it was dealing with the larger part of the Triassic Period, perhaps 35 of the total ~50 million years. There remained substantial disagreement about the relative lengths of each of the constituent stages - Carnian, Norian, and Rhaetian - and this was unlikely to be fully resolved until we can get an accurate isotopic age from a marine sequence. Present durations are based on astrological calibration of the Newark cycles and divergent views on their magnetostratigraphic correlation with Tethyan marine successions. Whichever correlations prove the more accurate, the Norian or Carnian appear to be the longest Stage in the Phenerozoic so the eventual need for substage definition is evident.

Francis Hirsch presented the first paper in which emphasis was placed on the need for full integration of physical characteristics and various fossil groups in establishing boundaries, and the desirability of auxiliary sections to serve in environments and facies where primary GSSP markers are lacking. This is particularly needed in ancient oceanic environments such as those preserved in tectonic collages. The Middle-Upper Triassic boundary was further discussed by Maurizio Gaetani in his introduction to the Ladinian-Carnian boundary session in which Marco Balini summarised the boundary sections in Spiti, India where his work with Leo Krystyn and Alda Nicora is now concluding. The area provides a rare opportunity to compare the evolution of the ammonoids, conodonts and bivalves and to calibrate an integrated biochronostratigraphic scale. The distinction between key ammonoids and prospective index fossils Daxatina and Trachyceras posed a problem in poorly preserved specimens, whereas the FAD of the prospective conodont species polygnathiformis is associated with typical Ladinian ammonoid species; the bivalve Halobia also appears close to this boundary and affords a further guide fossil. The choice of a GSSP datum awaits comparison with the successions in New Pass, Nevada as well as further consideration of the candidate Prati di Stuores section in northern Italy.

Following a brief introduction to the Carnian-Norian boundary, Mike Orchard presented the details of a new conodont zonation at Black Bear Ridge in western Canada. This succession lies on what was formerly the western edge of Pangea and contains rich and diverse faunas. The need for careful taxonomic work - and standardized views and magnification (x80) in illustrations - was stressed and many new species were shown in several different lineages characterized by, for example, progressively reduced platform lengths, progressively raised anterior platforms, and/or progressively anteriorly shifted pit. These species formed the basis for 2 new zones lying between the samueli interval of the former nodosus Zone and the primitius Zone; these approximate the inappropriately named communisti Zone of former papers. Heinz Kozur also discussed the mozaic evolution of Upper Triassic conodonts and introduced some new concepts relating to lineages through the Norian. As shown also by the British Columbian material, the species formerly combined as ‘primitius’ and ‘abneptis’ conceal several stratigraphically useful homeomorphs and a choice of cosmopolitan guide conodont for the C-N boundary should be possible soon.

Chris McRoberts reviewed the succession of Halobia species across the Carnian-Norian boundary at Black Bear Ridge, on Fredericks Island in the Queen Charlotte Islands, and in the Martin Bridge Limestone in Oregon. He showed the consistent ranges of key species and tied them to the new conodont zones from Black Bear Ridge. In total, the North American successions about this boundary are well integrated and provide a good yardstick for new attempts at correlating with Tehyan successions.

Leopold Krystyn with Wolfram Kürschner presented new data on the Norian-Rhaetian boundary in a 50 m thick boundary interval in the Zlambach Formation in Austria. This included ammonoids, pelagic bivalves, conodonts, radiolarians, palynomorphs and magnetostratigraphy, work he has undertaken with. Integrated ammonoid and palynomorph occurrence. Some of these results were unexpected, including the overlapping ranges of the ammonoids *“Choristoceras” haueri* and *Cochloceras*, and the large time offset between the FOs of *Misikella posthernsteini* and *Cochloceras*. Within a rich palynogical record, a distinct dinoflagellate change occurs midway through the section. This event is widely recognized and could prove invaluable in distinguishing the Norian and Rhaetian in shallow marine and/or high latitude basins. Mark Hounslow reinforced the value of dinoflagellates such as *Rhaetogonyaulux rhaetica* in pinning magnetostratigraphic correlations in his account of the end Triassic successions in the UK.

Beth Carter’s contribution presented and supplemented by Mike Orchard showed that radiolarians appearing at the base of the *Proparvicingula moniliformis* Zone provide the most distinctive faunal change for characterizing the base Rhaetian in the oceanic realm. This level corresponds also to the FAD of the conodont *Epigondolella mosheri* in North America, which is associated with *Cochloceras amoenum* bearing strata at Tyaughton Creek, B.C. and in New York Canyon, Nevada.

Several papers dealt with magnetostratigraphic correlation of the Late Triassic stage boundaries in nonmarine strata. Spencer Lucas highlighted the uncertainty and imprecision of correlating polarity profiles and preferred the traditional correlation of the base Norian that is supported by palynomorphs and terrestrial vertebrates. Based on Newark cyclostratigraphic calibration, this puts the base Norian at about 214 Ma, a number supported by Maureen Steiner's magnetostratigraphic correlation of the Chinle Group with Newark. In contrast, Paul Olsen argued for the unreliablity of the fossil data such as it is and supported a quite different correlation with a base Norian at about 227 Ma, a number supported by other recent publications. Similar disagreements also characterize the base Rhaetian, with published arguments for its duration ranging from 2 - 7 million-years. Apart from the basic uncertainty in the time scale itself and the consequent elusiveness of a common language, these divergent correlations impact also on the recognition and apparent tempo of faunal turnovers and extinction events within and at the end of the Late Triassic. Some isotopic ages from the marine realm would clearly help resolve many problems.

Two contributions from Russia rounded out the workshop. Alena Kopylova and Tatyana Klets presented their work on the Late Triassic of northeastern Asia where significant correlation problems are helped by conodonts. The terrigenous sections of Siberia contain a boreal macrofauna and rather low diveristy conodonts dominated by low diversity *Neogondolella* species. In cherty sequences of the Russian Far East, more diverse faunas include Tethyan elements too and allow correlation of the two successions. Valery Vuks presented a thorough account of the stratigraphy and faunas of the Upper Triassic Sakhray and Khodz groups of the Western Caucasus, and the Chelbasskaya Group and related deposits of the Western Precaucasus. Although sections are incomplete, many species are common throughout the region and correlations are well established. In particular, the foraminiferal assemblages have been useful also in correlating to Europe.

The workshop ended with the convenor stressing the need for sustained progress in Upper Triassic boundary studies. The momentum generated by the workshop will hopeful encourage that.

Mike Orchard

Abstracts

Ladinian/Carnian Boundary Sections in Spiti (Tethys Himalaya, India)

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[2] Palaeontologische Institut der Universitaet Wien

Spiti Valley area (Tethys Himalaya, India) is well known since XIX century for its Lower-Middle Triassic ammonoid rich pelagic succession. The Upper Ladinian/ Lower Carnian consists of Kaga Formation, made of shales with intercalation of distal turbidites, and Chomule Fm., made of well bedded mudstones with marly intercalations. Both the units show an unusually rich record of pelagic bivalves, ammonoids and conodonts that provides the very rare opportunity to compare the evolution of the three groups and to calibrate an integrated bio-chronostratigraphic scale.

Six stratigraphic sections have been sampled in Pin and Lingti Valleys. The sections are arranged into three working areas, roughly aligned from SW to NE. Four sections are located close to Muth village (Muth 1 to 4), one is close to Guling, and one near to Lalung (Lalung 3). Guling section is the most complete and covers the whole Kaga Fm. and the first half of Chomule Fm. It is used as master section, while the other sections cover only the Ladinian/ Carnian boundary interval, located in the lower part of the Chomule Fm.

The correlations of the sections emphasize that:

a) Key beds or distinct lithologic intervals can be correlated and traced for tens of kilometers.

b) Thickness of Kaga Fm. and of marly intercalations in the Chomule Fm. decreases from Muth to Lalung, i.e., from the present SW to the present NE.

c) The distribution of fossils in the studied sections is rather constant, with minor changes from section to section mostly due to local difficulty in sampling (cleavage or unestractability).

d) From the biostratigraphic point of view the Upper Ladinian is quite well documented by the occurrence of the ammonoids *Meginoceras meginae*, *Maclearnoceras* sp. and *Frankites*. *Frankites* also overlaps with *Daxatina*, but the first occurrence of typical Carnian ammonoid

Trachyceras is of difficult location due to rather poor preservation of the specimens.

e) The first occurrence of the *Paragondolella*/ *Metapolygnathus polygnathiformis* is recorded at the middle of the range of *Frankites*, i.e. together with what are normally regarded as Ladinian ammonoids.

f) *Halobia* seems to overlaps the range of *Daxatina*, and possibly also the range of *Frankites*.

The correlation of the studied sections with the GSSP candidate Prati di Stuores is discussed. Preliminary ammonoid data from South Canyon (Nevada, USA) are also compared.

A Norian-Rhaetian boundary at Kennecott Point (Queen Charlotte Islands, Canada) defined by radiolarians and conodonts

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Major changes in radiolarians and conodonts occur about 10m above the base of the Sandilands Formation at Kennecott Point, Queen Charlotte Islands. For each group, these changes mark the transition from faunas associated with upper Norian *Monotis*-bearing strata of the Peril and basal Sandilands formation (= Cordilleranus Zone) to distinctive new faunas equivalent to the Amoenum and Crickmayi zones. These changes are believed consistent with the transition from Norian to Rhaetian.

Radiolarians of the *Betraccium deweveri* Zone (upper Norian) are recognized around the world and their indices are well known. Conodonts from these levels are assigned to the *Epigondolella bidentata* Zone. The top of the Norian is marked most importantly by the disappearance of the radiolarians *B. deweveri*, *Gorgansium richardsoni*, *Phylostephanidium ankaraense*, *Kozurastrum pseudokahleri*, *Citriduma* sp. A (Carter 1993) and all species of *Ferresium* having a rounded shell. In Queen Charlotte Islands, the *B. deweveri* fauna is succeeded by radiolarians of the *Proparvicingula moniliformis* Zone, which are associated with the conodont *Epigondolella mosheri*. Elsewhere, e.g. Tyaughton Creek, B.C. and New York Canyon, Nevada, this conodont species is associated with ammonoids of the Amoenum Zone. These faunas undergo significant radiation in the Rhaetian and many new species arise. The most distinctive of those associated with the appearance of *E. mosheri* include *P. moniliformis*, *Deflandrecyrtium nobense*, *Ferresium triquetrum*, *Icrioma cistella* and *Squinabolella trispinosa*.

The Philosophy of Boundary Stratotypes: The Upper Triassic Example

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Assereto (1973) mentioned "tradition" as a factor to be dealt with when dealing with the definition of some stratigraphic stages and substages. We should have this in mind when asking "What is Carnian, Norian or Rhaetian". The establishment of these stages goes back to the XIXth century and the use of these names have gone through several redefinitions. However, e.g. in the case of the Carnian, the different views held about the attribution of the Cordevolian sub-stage either to the Middle or the Upper Triassic is still debated. First came facies as the answer, but the development of these boundary beds differ whether in the Northern or Southern Alps, the SA St. Cassian Formation having no clear match in the NA. But before opening the biostragraphic debate, let us remember that Spath (1934) proposed his so called **Protrachyceratan** for the Ladinian and **Trachyceratan** for the Carnian. We would very much like to follow this procedure if we could clarifie the ammonoid questions, possibly including corresponding radiolarians, conodonts, palynomorphs and also tetrapods.

The democratically adopted IUGS policy of one single stratotype that imposes its features for global stratigraphic correlation is merely virtual, since it extends boundary lines from a well defined locality through others that may be well defined by other tools at a level that does not necessarily correspond with "the" level in question.

In other words, if we certainly can adopt a fair ammonoid boundary, match it with conodonts, radiolarians, palynomorphs and tetrapods, we still need to consider isotopic and radiometric data, a task that is far from being possible unless we would consider next to an adopted holo-stratotype, several regional para-stratotypes. This more philosophical approach of electing a string of several representative sections, could efficiently answer the basic question, as an example, of "what happened at the M/U Triassic boundary ?"

Among the physical factors we have a drop of sealevel that generated the notorious Carnian salinity crisis; this is accompanied by emersions, felt worldwide from the Neotethys to the Izanagi Plate (Paleo-Pacific) (Hirsch and Ishida, 2002).

Among living organisms we have a number of changes, particularly in ammonoids and conodonts. Among the latter the disappearance of Neogondolellid- is followed by the appearance of Metapolygnathid conodonts. Can we thus propose the last appearance of *Sephardiella diebeli* as upper limit of the Ladinian, or take the first appearance of *Metapolygnathus polygnathiformis* as base of the Carnian? From the Iberic Peninsula to the Middle East, where this boundary proposal can be applied, the palynomorph *Patinosporites densus* enables correlation with a large world of semi-marine deposits.

Before thus making the choice of the boundary-stratotype, to be marked with fanfare, a golden spike, a bronze plaque or a monument, one must keep in mind that nature is versatile and that one single "ideal" locality is only virtual.

We definitely need to make clear that if we e.g. adopt the classical Alpine region for the holo-stratotypes, a proposal we advocate, a number of additional para-type-sections from circum-pacific oceanic to continental localities in Africa, Asia or the Americas should also be considered.

Rhaetian and Late Norian Magnetostratigraphy and its Relationship to Biostratigraphic Zonations in NW Europe

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The magnetostratigraphy through the Penarth Group, commonly considered to be entirely Rhaetian, is summarized, using a composite of data from the sections at St Audrie's Bay, and Lavernock Point in the UK. The relationships of this magnetostratigraphy to the dinoflagellate and miospore zonations are also examined, in the prospect of finding common tie points to the Rhaetian and late Norian from the northern Alps. This approach produces a magnetostratigraphy, which is pinned to the biostratigraphy most satisfactorily by constraints near the top of the Rhaetian. The late Norian and Rhaetian magnetostratigraphies from open marine successions are reviewed, in order to provide a summary of a fully marine-based magnetostratigraphy and its biostratigraphic constraints. This is most satisfactorily constrained by the Sevatian biostratigraphy (i.e pinned at the base). The links between these top-down, and bottom-up approaches to the magnetostratigraphy of the Rhaetian are provided by the Newark Supergroup magnetostratigraphy and the occurrence of the dinoflagellate cyst *Rhaetogonyaulux rhaetica*. In the light of this collation it is concluded that in the UK, the Sevatian is partly represented by the Williton Member (Mercia Mudstone Group), and the lower part of the Westbury Formation (Penarth Group), although disconformities fragment the UK stratigraphy. In the light of these findings the distinctiveness of the magnetostratigraphic polarity pattern is considered as a possible constraint on defining the base of the Rhaetian.

Late Triassic Conodontophorids from NE Asia (Systematic Composition, Biostratigraphy, Correlation)

T.V. Klets and A.V. Kopylova

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Triassic deposits occupy a vast territory in northeastern Russia and are made of exceptionally terrigene rocks such as sandstones, siltstones, and mudstones. They deposited in single boreal basin as evidenced by monotypic and abundant organic remains: bivalves, cephalopods, and brachiopods. Triassic rocks of diverse composition with tropic fauna are known from western coast of the Pacific Ocean (Bychkov, Dagis, 1984; Dagis et al., 1989). In Koryak region, Sikhote Alin, South Sakhalin, and Japan recognized among these rocks are cherty complex strata with terrigenous pelitomorphic interbeds (from several mm to 1-2 cm) and volcanites. Permanent lithologic composition, considerable stratigraphic interval and small thickness (Triassic section near Khabarovsk city is 50-60 m) are indicative of their deposition under steady relatively deep-water conditions. Cherty rocks contain in abundance microfossils with cherty (radiolarians) and phosphate (conodontophorids) skeleton and lack the remains of benthonic organisms and carbonaceous shells of plankton (Bragin, 1991; Klets, 1995). The second type of the section is represented by terrigenous-volcanic rocks with reef bodies containing tropical fauna.

The problem of correlation of cherty sequences containing no macrofauna and terrigenous sections with boreal fauna is one of the outstanding questions in stratigraphy of northeastern Asia. Microfauna analysis is virtually the only instrument for solving the problem. The findings of conodontophorids in the Upper Triassic of the Kotelny island (Novosibirsk islands) and in the basin of the Zyryanka river (Omulevsky Uplift) are of prime interest and of great importance for placing the boundary between the Carnian and Norian Stages and in addition they provide the possibility to solve the problem of Boreal-Tethys correlation (Fig. 1).

The source material in the study were the collections of conodontophorids assembled by the authors and A.V. Yadrenkin (Institute of Petroleum Geology, Siberian Branch of the RAS, Novosibirsk) in cabornaceous rocks. The sections in the basin of the Zyryanka river are described based on the data by A.G.Konstantinov (Konstantinov et al., 1997) and those of the Kotelny island with the use of materials collected by A.Yu. Egorov (Egorov et al., 1987).

Taking an opportunity, we would like to thank B.N. Shurygin for constructive and helpful discussion of the global problem of Boreal-Tethys correlation.

Stratigraphic range of the Late Triassic conodontophorids in northern Siberia.

Omulevsky Uplift

The lower part of the Carnian Stage in headstream of the Zyryanka river is represented by dark-grey, black, micro-and medium crystalline massive pyritized arenaceous limestones with coquina interbeds (0.15-0.35 m) and lenses (0.3-0.4 m). Bivalves, brachiopods, ammonoids, coleoids, ostracodes, anaptychi and acanthodians were found at different stratigraphic levels in the tenuis zone (exposure M2). Twelve meters from the base of the member 1 there were found conodontophorids *Paragondolella foliata* Budurov (sample M2-1-12p).

Deposits on the left side of the creek Saryn' in the omkutchanicum zone contain bivalves, brachiopods, ammonoids, ostracodes, and foraminifera. Conodontophorids *Paragondolella foliata* Budurov were found in limestones some 6-8 m from the base of the member 3 (exposure M6, member 3, sample M6-3-6p and M6-3-8p). In the seimkanensis zone similar assemblage was found at 1m from the base of the member 5(exposure M6, member 5, sample M6-5-1p).

Novosibirsk islands

On the Kotelny island the Lower Carnian Substage is represented by flyschoid-like alternation of black schistous mudstone-like clays, light-gray nonschistous clays and siltstones. The lenses of dark-grey bituminous limestones occur throughout the thickness of the member. Clay rocks contain numerous remains of bivalves and ammonoids.

In the omkutchanicum zone (exposure 195), the limestone lense (18 m from the base) yielded *Paragondolella foliata* Budurov, *Pa*.sp. and two specimens of ramous elements (exposure 195, member 16, sample 195-11-18p) (Klets, 1996).

The Norian Stage on the Kotelny island is exposed in the basin of lower reaches of the Tikhaya river and is represented by dark-grey, mudstone-like, pelitomorphous clay, without bedding, with rare thin (0.1 m) interbeds of clayey limestones with concretions. The clay yielded numerous remains of bivalves and ammonoids. Conodontophorids *Norigondolella "navicula"* (Huckriede) (exposure 190, member 8, sample 190-1-2p) were found in the concretion of clayey limestones at 2 m from the base of the member 8. In the verchojanicum zone at 4 m from the base of the member 10 occur conodontophorids *Norigondolella "navicula"* (Huckriede) (sample 190-3-4p).In the scutiformis zone at 9 m from the base of the member 12 (exposure 192) occur conodontophorids *Norigondolella steinbergensis* (Mosher) and *N. navicula* (Huckriede) (sample 192-1-9p).The assemblage with *Norigondolella steinbergensis* (Mosher) was found in the base of the member 14 (sample 192-7) and at 40 m from the base of member 16 (sample 180-1-40p).

Biostratigraphy and correlation

The analysis of the range of the Late Triassic conodontophorids in Siberian sections allowed us to establish a number of specific assemblages characteristic of definite intervals. These assemblages permitted the biostratigraphic scale in rank of beds with conodontophorods (chart) to be proposed for the territory under discussion.

Carnian Stage

Lower Carnian Substage

Paragondolella foliata beds

These beds are recognized in the basin of the Tikhaya river (exposure 195, member 16), in head water of the Zyryanka river (exposure M2, member 1) and on the left side of the Saryn' creek (exposure M6, member 3 and 5) based on the occurrence of the assemblage with *Paragondolella foliata* Budurov, *Paragondolella* sp. 2 and others.

<u>*Correlation.*</u> The species *Paragondolella foliata* as suggested by S.Kovacs makes its first appearance at the base of the Carnian and is distributed only in Cordevolian-Julian (Kovacs, 1983). The correlation of beds under discussion with foliata zone by conodonts of the Russian Far East is beyond the question due to the presence of index-species (Buriy, 1989; Klets, 1995). The Lower Carnian cherty deep-sea series of the region has yielded *Paragondolella polygnathiformis, Paragondolella inlinata, Gladigondolella tethydis, Metapolygnathus mungoensis, M. mostleri.* In standard chart of X.Kozur, conodont-based diebeli and tethydis zones (Cordevol-Jul) are contemporaneous and characterized by the species *Paragondolella polygnathiformis, Paragondolella tadpole, Gladigondolella tethydis, Metapolygnathus mostleri* (Kozur, 1980). Similar assemblage was recognized in ammonoid-based aonoides and austricum zones (Julian) in Austria by L. Krystyn (Krystyn, 1980). The beds with *Paragondolella foliata* Budurov, *Paragondolella* sp. 2 from northern Siberia can be dated as Early Carnian and compared to the foliata zone of Far Eastern Russia (cherty sequences) and diebeli and tethydis zones of conodont standard (chart).

Norian Stage

Lower Norian Substage

Norigondolella "navicula" beds

The beds were established in the basin of the Tikhaya river (exposure 190, member 8 and 10) due to the presence of index-species.

<u>*Correlation*</u>**.** According to L.Krystyn's data, the species *Norigondolella navicula* is distributed in Austria in the zones of jandianus, paulckei, magnus, bicrenatus and columbianus (Lower – Middle Norian), which are compared to the conodont zones of primitia-Z., spatulata-Z.,

uppermost postera-A.Z. and lower part of the bidentata-Z. zone (Krystyn, 1980). In cherty sequences in Far East of Russia, *Norigondolella "navicula"* is known from the abneptis conodont zone (Lower Norian). *Epigondolella primitia*, *Mockina* aff. *postera* are also frequent to occur here (Klets, 1995). In British Columbia the species was encountered at the base of the kerri zone (Mosher, 1973).The navicula subzone in conodont standard was recognized by H.Kozur in Lower Norian (Kozur, 1980). Consequently, in north of Siberia *Norigondolella "navicula"* beds can be dated by conodonts as Early Norian and compared to the abneptis zone of Far Eastern Russia (cherty sequences) and the navicula zone of conodont standard of H.Kozur (chart).

Norian – Rhaetian Stages

Middle Norian Substage – Rhaetian Stage

Norigondolella steinbergensis beds

They were recognized in the basin of lower reaches of the Tikhaya river (exposure 192, members 12, 14 and exposure 180, member 16) by presence of index-species and *Norigondolella steinbergensis*.

Correlation. L.Krystyn has established in the sections of East Alps complex conodont zone steinbergensis – A.Z. with index-species *Gondolella (=Norigondolella) steinbergensis* (Krystyn, 1980) as an age equivalent of ammonoid subzone Choristoceras marshi – I. This zone contains no platform conodontophorids of the genera *Epigondolella* and *Mockina* which are common in underlying beds. The range of *Norigondolella steinbergensis* in the region under discussion comprises conodont-bearing zones postera, bidentata and steinbergensis (Middle – Upper Norian Substages, lowermost Rhaetian Stage). In British Columbia the above species along with *Mockina postera* characterizes postera conodont zone and is close age equivalent of the Middle Norian columbianis-II subzone (Orchard, 1991). G.I. Burii has recognized the studied species in Middle Norian limestones of reef massifs in Primoriye (Burii, 1989). In the north of Siberia *Norigondolella steinbergensis* beds can be dated by conodonts as Middle Norian – Rhaetian and compared to the upper part of the postera zone and the bidentata and hernsteini zones of Russian Far East (cherty sequences) as well as to navicula, multidentata, bidentatus, andrusovi, hernsteini zones in H. Kozur conodont standard (Kozur, 1980).

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References

Bragin N.Yu. Radiolaria and Lower Mesozoic strata in East USSR. Trans. of Geol.Inst. of the USSR AS, vol. 469, Moscow, Nauka Pub.House, 1991, 124 pp.

Burii G.I. Triassic conodonts and stratigraphy of Sikhote-Alin'. Geol. Inst., Far Eastern Branch of the USSR AS, Vladivostok, 1989, 136 pp.

Bychkov Yu.M., Dagis A.S. Late Triassic fauna of Koryak highland and its significance for paleogeographic and paleotectonic constructions. In: Triassic stratigraphy, fauna and flora of Siberia. Moscow, Nauka Pub.House, 1984. P.8-18.

Dagis A.S., Dagis A.A., Klets T.V. Problems of Triassic biostratigraphy and paleobiogeography of exotic block of northwestern Pacific. In: Stage and zonal scales for boreal Mesozoic in the USSR. Moscow, Nauka Pub.House, 1989. P. 52-60.

Egorov A.Yu., Bogomolov Yu.A., Konstantinov A.G et al. Stratigraphy of the Triassic deposits of the Kotelny island (Novosibirsk islands). In: Boreal Triassic. Moscow, Nauka Pub.House, 1987. P. 66-80.

Klets T.V. Triassic biostratigraphy and conodonts of Central Sikhote-Alin'. Novosibirsk, 1995. 118 pp.

Klets T.V. First findings of conodonts in Upper Triassic deposits of the Kotelny island. In: Startigraphy. Geological correlation. 1996. Vol. 4, no. 6. P. 96-98.

Klets T.V. Upper Triassic conodonts of North-East Asia (composition, biostratigraphy, correlation). In: Materials of Regional Conference for geologists of Siberia, Far East and North-East Russia. Tomsk. 2000. P. 328-331.

Konstantinov A.G. et al. Zonal subdivision of Triassic deposits of the Omulev Uplift (Kolyma river's basin). In: Russian Geology and Geophysics. 1997. Vol. 38, no. 10. P. 1653-1699.

Kovacs S. On the evolution excelsa-stock in the Upper Ladinian-Carnian (Conodonta, genus *Gondolella*, Triassic)// Ostern.Akad.Wissn.Erdwiss. Komm.1983. Bd. 5. P. 107-119.

Evolutionary Lineages in Upper Triassic Platform Conodonts and their Importance for the Definition of the Carnian-Norian Boundary

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A development from smooth gondolellids with subterminal pit to taxa with nodose and denticulated platform and strongly forward-shifted pit occurred twice during the Middle and Upper Triassic in a *Neogondolella*-based stock and in a *Paragondolella* based stock. In the *Paragondolella*-based evolutionary stock a mosaic morphogenetic pattern can be observed in different lineages during the middle Carnian to Rhaetian. In different lineages partly the same evolutionary succession of introduction of morphologic features can be observed as in the *Neogondolella-Budurovignathus* stock, partly the evolutionary succession of these features was reversed. By this several homoeomorphic forms developed, and lineages which are very different in the early stages of development become very similar in later stages of development.

In the upper Tuvalian to Rhaetian *Metapolygnathus-Orchardella* lineage at first the pit is forward-shifted in a central position and later nodes and denticles developed on the platform margin (as in the Longobardian-Cordevolian *Neogondolella-Budurovignathus* stock), and the posterior end of the keel get pointed. All members of this lineage have a relatively long posterior carina after the cusp. In the Julian to Sevatian *Carnepigondolella-Epigondolella-Mockina* lineage at first nodes and denticles developed at the platform, but the pit remains subterminal (*Carnepigondolella* n. gen.), later the pit is forward shifted in a central position (*Epigondolella* Mosher) and finally the posterior end of the keel get pointed (*Mockina* Kozur). A carina after the pit is missing or very short.

In the previous systematics the genera are polyphyletic units of different lineages. Even in some species, taxa of different genera were united, e.g. the North American *Metapolygnathus primitius* (Mosher) contains different species from which in the northern Tethys no one belongs to *M. primitius*, but mostly to *Epigondolella orchardi* n. sp. Best suitable for the definition of the Norian base is the FAD of *M. pimitius*, the first species of the *Metapolygnathus-Orchardella*, in which the platform has always distinct nodes. *M. primitius* is not present in the northern Tethys, but in the Neotethys it occurs, and begins there together with *E. orchardi*, the first species of the *Carnepigondolella-Epigondolella-Mockina* lineage, in which the pit is forward-shifted to central position.

The Norian-Rhaetian Boundary – New Data From A Tethyan Key Section in Austria

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Preliminary data from an integrated shelly fauna (ammonoids, pelagic bivalves), micropalaeontological (conodonts, radiolarians), palynological and magnetostratigraphic study of a 50 m thick boundary interval in the Zlambach Formation (Kleiner Zlambachgraben, Salzkammergut) are presented. The well exposed Western Tethys key section (of alternating deeper water limestones and marls) shows successive FO and LO events of relevant taxa in the following order: 1) closely above base FO of *Misikella posthernsteini*, 2) 27 m a. b. FO of *"Choristoceras" haueri* Mojsisovics, 3) 36 m a. b. FO of Cochloceras, 4) 37 m a. b. LO of Chochloceras, 5) 39 m a. b. FO of *Epigondolella slovakensis*, 6) 41 m a. b. LO of *Epigondolella slovakensis*, 7) 42 m a. b. FO of *Misikella rhaetica*, 8) 43 m a. b. LO of *"Choristoceras" haueri* and 9) 44 m a. b. FO of *Vandaites stuerzenbaumi* Mojsisovics. The overlapping ranges of the ammonoids *"C." haueri* and *Cochloceras* are remarkably and truly unexpected. Another surprise is the large time offset between the FOs of *Misikella posthernsteini* and *Cochloceras.*

Radiolarians have been extracted from the lower 30 m of the section but have yet to be studied. Of specific importance is the rich palynological record with a distinct dinoflagellate change between 26 and 28 m above base – from a Norian to a typically Rhaetian marine microflora (e.g. FO of *Rhaetogonyaulux, Suessia, Dapcodinum*). As this event is currently widely (Australia, Canada) used for the palynological distinction between Norian and Rhaetian in shallow marine and/or high latitude basins and may there remain as the only useful stratigraphic tool, it should be considered whenever a decision on the future Norian – Rhaetian boundary is made.

Recognition of Late Triassic Marine Stage Boundaries in Nonmarine Strata

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Although GSSP's have not been decided for the marine stage boundaries of the Late Triassic timescale (bases of Carnian, Norian, Rhaetian and Hettangian stages), biostratigraphers working in nonmarine Triassic strata have long identified and correlated to these boundaries. Their conclusions rely primarily on palynostratigraphy and vertebrate biostratigraphy and, more recently, on a rapidly growing magnetostratigraphic database. Nevertheless, correlation of all Late Triassic stage boundaries into the nonmarine Triassic section continues to be plagued by uncertainty and imprecision:

1. The Carnian base (~ base desatoyense zone) is particularly difficult to identify in nonmarine strata because of a lack of corresponding palynostratigraphic change, a paucity of vertebrate fossil assemblages that closely bracket this boundary and a lack of magnetostratigraphic data.

2. In contrast, a change in palynofloras and an extensive and closely bracketing vertebrate fossil record allow relatively confident placement of the Norian base (~ base kerri zone), though recent (and arguably unreliable) correlations of Tethyan marine to nonmarine magnetostratigraphy challenge these correlations.

3. The Rhaetian base (however defined) correlates to a palynological turnover in Europe, but is currently invisible to vertebrate biostratigraphy; its published placement in the Newark Supergroup is conjectural, if not demonstrably incorrect, and has been used to argue for a 7-million-year-long Rhaetian.

4. Many workers believe the Hettangian base (~ base planorbis zone) has been approximated by palynostratigraphy and vertebrate biostratigraphy, particularly relying on placement of that boundary in the Newark Supergroup just below the base of the CAMP basalts. However, if the palynological change in the Newark section is equated to the base Rhaetian change in Europe (which it resembles), and the presence of the footprint ichnogenus *Eubrontes* in the Australian Triassic indicates that the LO of *Eubrontes* is not the base of the Jurassic, then the Hettangian base in the Newark section should be moved up to above the base of the CAMP basalts.

A Potential Candidate Section for the Definition of the Carnian/Norian Boundary: The Pignola Section in the Lagonegro Basin (Basilicata, Italy)

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The Lagonegro units form a large part of the Southern Apennines orogenic wedge (Pescatore *et al*., 1999). The Upper Triassic - Jurassic pelagic sediments of the Lagonegro basin are represented by mainly carbonate (*Calcari con selce* Fm) and siliceous (*Scisti silicei* Fm) deposits.

A detailed biostratigraphic analysis of the "*Calcari con selce*" Fm on the basis of conodont associations have been carried out with the aim to recognize in the succession the Carnian/Norian and Norian/Rhaetian boundaries.

Two stratigraphic sections have been investigated: Pignola and Abriola. A total of 53 samples, of about 8 kilograms each, were collected and processed using standard methods. Conodonts, sponge spicules and pyritized radiolarians were found in the residues. The conodonts show a quite good preservation and their Alteration Index (CAI) range from 1.5 to 2.5. The Pignola succession is well exposed and accessible being located along the road connecting Pignola to Abriola Villages.

The Pignola section is about 470 m thick: the lower part is composed of 400 m of calcilutites and calcarenites, locally dolomitized, with cherty lenses and nodules; the section ends with 70 m of calcilutites, silicified shales, marls and radiolarites.

The Abriola section, about 70 m thick, is constituted of mainly calcarenitic beds, with cherty lenses and nodules, interbedded with shales and marls.

The age of the Pignola section ranges from the Lower Carnian (Julian 1-2) up to the Rhaetian as suggested by conodonts among which were recognised some markers of the Triassic Tethyan realm. The following main biostratigraphic data can be underlined:

- the presence of *M. polygnathiformis* (Budurov and Stefanov) and *Gl. tethydis* Huckriede from the sample PG1 to PG10;

- the coexistence of *M. polygnathiformis* (Budurov and Stefanov) and *M. nodosus* (Hayashi) from PG11 to PG12B;

- the first occurrence of *M. pseudodiebeli* (Kozur) in the sample PG13A. This species is associated to *M. nodosus* (Hayashi) up to the sample PG15;

- the first occurrence of *M. communisti* (Hayashi) in the sample PG13B and its last occurrence in the sample PG15B, where it is associated to *M. pseudodiebeli* (Kozur). The specimens of *M. communisti* appears to be morphologically close to *M. communisti* morphotype A *sensu* Krystyn.

- the presence of *E. spatulata* (Hayashi) and *E. triangularis* (Budurov) in the sample PG15D;

- the first occurrence of *E. bidentata* Mosher in the sample PI5;

- the first occurrence of *E. postera* (Kozur and Mostler) in the sample PG16;

- the first occurrence of *M. posthernsteini* Kozur and Mock in the sample PG19.

The Carnian/Norian boundary should fall in the sample PG13B in correspondence of FAD of *M. communisti* A as proposed by Orchard *et al*. (2000). Krystyn *et al*. (2002) suggest the use of *M. communisti* B for its better fitting to the boundary defined by Tozer (1967), but the *M. communisti* morphotype B was not observed in the Pignola section as well as in the Pizzo Mondello section (Muttoni *et al*. 2001). This form is also missing in western North America and seems to be restricted in offshore pelagic environments.

In the Abriola samples conodonts are not significant and their number is very low. Only *Gladigondolella tethydis* Huckriede occurs from the base up to 39 m. The occurrence of *M. tadpole* (Hayashi), at 40 m, indicates a Lower Carnian (Julian 1-2) age.

References

Di Leo, P., Martino, C., Mastandrea, A., Perri, E., 2003, Kübler index and conodont Color Alteration Index as thermal indicators from lower Triassic to Jurassic pelagic successions of the Lucanian Apennine, southern Italy. (in this volume).

Krystyn, L., Gallet, Y., Besse, J. & Marcoux, J., 2002, Integrated Upper Carnian to Lower Norian biocronology and implications for the Upper Triassic magnetic polarity time scale. Earth and Planetary Science Letters, 203, 343-351.

Muttoni, G., Kent, D.V., Di Stefano, P., Gullo, M., Nicora, A., Tait, J., Lowrie W., 2001, Magnetostratigraphy and biostratigraphy of the Carnian/Norian boundary interval from the Pizzo Mondello section (Sicani Mountains, Sicily). Palaeogeography, Palaeoclimatology, Palaeoecology, 166, 383-399.

Orchard, M., Carter, E., Tozer , E.T., 2000, Fossil data and their bearing on defining a Carnian/Norian (Upper Triassic) boundary in Western Canada. Albertiana, 24, 43-50.

Pescatore, T., Renda, P., Schiattarella, M. & Tramutoli, M., 1999, Stratigraphic and structural relationships between MesoCenozoic Lagonegro basin and coeaval carbonate platforms in southern Apennines, Italy. Tectonophysics, 315, 269-286.

Tozer, E.T., 1967, A standard for Triassic time. Geol. Surv. Can. Bull., 156, 1-103.

Halobiid bivalves and the Carnian-Norian Boundary in North America

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Bivalves of the genus *Halobia* (Halobiidae: Pterioida) have long been recognized as important biochronologic indicators from Lower Carnian through Middle Norian strata of the marine Triassic. Given the fact that Mojsisovics named the two stages in the stratigraphically complex Hallstatt facies of Austria and the basal Norian is currently without a GSSP, and an attempt is made better define the boundary on intercallibrated biochronologies utilizing ammonoids, conodonts, and halobiid bivalves. In North America, The Carnian-Norian boundary may be chosen at the first occurance of *Halobia beyrichi* which frequently co-occurs with the ammonoid *Stikinoceras kerri* and species of *Anatropites* above forms referred to as *H. ornatissima* and/or *H. superba*. This bivalve and ammonoid defined boundary occurs within the *Metapolygnathus primitius* conodont zone. The boundary is now known from both allochthonous terranes of the western cordillera (Alexander Terrane, North Slope Terrane, Wallowa Terrane, and possibly Wrangell Terrane) and from craton-bound strata in British Columbia (Pardonet Formation, Williston Lake) and Nevada (Luning sequence of west-central Nevada). In particular, the newly studied section in Keku Strait Alaska is most informative and can easily be correlated with the recently described section at Black Bear Ridge in northeast British Columbia. The first occurrence of *H. beyrichi* in North America likely is slightly older in North America than its appearance in the Tethyan Alpine-Himalayan belt where the boundary may be better delimited by the first occurrence *of H. stryiaca* which is unknown in North America.

Assessment of implications of recent marine magnetostratigraphic correlations for non-marine identification of the Carnian-Norian and Norian-Rhaetian boundaries

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Three recently published Tethyian magnetostratigraphies from Turkey (Krystyn et al., 2001), Slovacia (Channell et al., 2003), and Sicily (Muttoni et al., 2004) are similar to each other and suggest that the conventional identification of the correlative position of the Carnian-Norian boundary within non-marine strata of North and South America is significantly wrong, implying a surprisingly long duration for the Norian (19.5 m.y.). Two of the magnetic polarity stratigraphies (Channell et al,, 2001; Muttoni et al., 2004) suggest that the correlation of the Norian-Rhaetian boundary, at least in the Newark basin of eastern North America is essentially correct and implies that the Rhaetian is of longer duration (6 m.y.) than usually thought. However, the magnetostratigraphy of Krystyn et al., 2001 implies a significantly different correlation for the Norian-Rhaetian boundary and a much-reduced Rhaetian.

The basis for the conventional correlation of the marine Carnian-Norian and Norian-Rhaetian boundaries to non-marine sections is largely a complex correlation web of continental palynomorph taxa (Cornet, 1993; Cornet and Olsen, 1985; Olsen et al., 1996; Litwin andSkog, 1991) and a very few genera of terrestrial vertebrates such as the aetosaurs *Paratypothorax*, *Stagonolepis*, *Aetosaurus* and phytosaurs such as *Paleorhinus* and *Pseudopalatus*, that are known from the Americas and Europe (Hunt and Lucas, 1991; Huber et al., 1993; Lucas and Huber, 2003).. Because the former are subject to significant if not overwhelming climatic influences, and the latter are rare, and at the species level seemingly endemic, these biostratigraphic correlations, although internally consistent and logically robust, have always had the potential to be profoundly inaccurate.

A reassessment of the available biostratigraphic data from the continental strata placed in the Conewagian faunachron of eastern North America (conventionally correlated to the latest Carnian) reveals that they are equally consistent with an early Norian age, as suggested by the recent magnetostratigraphic correlations. Biostratigraphically correlative strata placed in the Adamanian faunachron of Western North America and the Ishugulatian faunachron of South America are [?] thus also of early Norian age. Previous correlations that identified all of these continental strata as Late Carnian also carried the implication that there was relatively minor faunal turnover at the Carnian-Norian boundary. Correlation of these strata with the early Norian, on the other hand, results in a correlation of the much more significant Sanfordian-Conewagian and Otischalkian-Adamanian boundaries with the marine Carnian-Norian boundary allowing synchronous concentrations of marine and continental biotic turnover at the Carnian-Norian boundary.

The implication of a short Rhaetian is that biotic change should be concentrated in multiple episodes before but close to the Triassic-Jurassic boundary, while a long Rhaetian spreads the biotic change out, perhaps to background levels, leaving the significant turnover at the Triassic-Jurassic boundary. In either case, however, there is little indication of significant faunal or floral turnover at the North American equivalent of the Norian-Rhaetian boundary. The hypothesis of a long Rhaetian stage (Channell et al, 2003; Muttoni et al., 2004) based on identification of the Norian-Rhaetian boundaryin the Newark basin, versus the short Rhaetian of Krystyn et al. (2002) should be easily tested by paleomagnetic sampling of actual Rhaetian marine sections; a long Rhaetian should have a relatively large number of polarity zones, while the short Norian hypothesis requires very few.

References

Channell, J.E.T., Kozur, H.W., Sievers, T., Mock, R., and Aubrecht, R., Sykora, M., 2003, Paleogeography, Paleoclimatology, Paleoecology, 191:65-109.

Cornet, B., 1993, New Mexico Museum of Natural History and Science Bulletin, 3:75-93.

Cornet, B., and Olsen, P.E., 1985, in Weber, R. (ed.), Simposio Sobre Floras del Triasico Tardio, su Fitogeografia y Paleoecologia: Memoria, III Congresso Latinoamericano de Paleontologia, Mexico, pp. 67-81.

Huber, P., Lucas, S.G., and Hunt, A.P., 1993, New Mexico Museum of Natural History Science Bulletin, 3:179-186.

Hunt, A.P. and Lucas, S.G., 1991, Palaeontology, 34: 191-198.

Krystyn, L., Gallet, Y., Besse, J., and Marcoux, J., 2002, Earth and Planetary Science Letters, 203:343-351.

Litwin, R.J., Skog, J. E.,1991, Palynology 15: 5-28. Lucas, S.G. and Huber, P., 2003, in LeTourneau, P.M., and Olsen, P.E., eds., The Great Rift Valleys of Pangea in Eastern North America, vol .2: Sedimentology, Stratigraphy, and Paleontology, Volume in press: New York, Columbia University Press, pp. 143-191.

Muttoni, G., Dennis V. Kent., D.V., Olsen, P.E., Stefano, P.D., William. Lowrie, W., Bernasconi, S., Hernández, F.M., 2004, Geological Society of America, in press.

A New Conodont Zonation for the Carnian-Norian Boundary at Black Bear Ridge, NE British Columbia

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Abundant and diverse conodont faunas occur throughout the transitional beds between the Carnian Ludington and Norian Pardonet formations at Black Bear Ridge (BBR) on Williston Lake in northeast British Columbia. The faunas are dominated by species currently assigned to *Metapolygnathus*, here interpreted as a multielement genus possessing a 15-element apparatus that differs from that of *Gondolella*, *Paragondolella*, and *Epigondolella*, genera to which various *Metapolygnathus* species have been formerly assigned. *Metapolygnathus* has the same apparatus as *Neogondolella*, from which it evolved near the Ladinian-Carnian boundary.

Upper Carnian species of *Metapolygnathus* evolved rapidly along several lines from morphotypes combined as *M. polygnathiformis*. The conservative stock *carpathicus-nodosus-?permicus-'primitius' sensu lato* show progressive increase in anterior platform ornament and a progressive migration of the pit towards the centre of the platform. The more strongly ornate forms of the *zoae-samueli* group arise early and undergo a radiation that also involves anterior migration of the pit in tandem with three trends: 1) progressive shortening of the anterior platform and hence a longer blade in the *pseudoechinatus-echinatus-parvus* lineage; 2) an overall shortening of the platform to produce forms similar to the Norian *Epigondolella quadrata*; and 3) lengthening of the posterior platform and a rapid anterior shift in pit position ending in *M. primitius sensu stricto.* A third undescribed group arising form the *polygnathiformis* root stock comprise forms that show both progressive pit migration and relative elevation of one or both anterior platform margins that may be smooth or nodose. Younger forms display high geniculation points, and eventually high parapets. The pit in these younger forms occupies an anterior position like that of *M. communisti,* with which they have formerly been combined. In fact, *M. communisti*, or forms similar to it - including *M. noah* - are a morphologically relatively conservative group in which pit migration was the main trend in the Upper Carnian; this group of metapolygnathids are uncommon in Western Canada.

Numerous closely spaced conodont datums are delineated in the Black Bear Ridge section. Choice of a conodont datum for C-N boundary definition can now be made within the framework of a refined conodont zonation. Three potential levels defined by the successive appearances of *Metapolygnathus* n. sp. A, *M. primitius*, and *M. parvus* are highlighted.

Magnetostratigraphic Correlation and the Late Triassic Timescale

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The magnetic polarity sequences of the Upper Triassic (upper Carnian thru Rhaetian) Chinle Group (western North America) and the approximately coeval Newark Supergroup (eastern NA) are remarkably congruent. The agreement is extraordinary, because the Chinle magnetostrati-graphic record is preserved in only ca. 350 m of dominantly fluvial strata, whereas the Newark record was recorded in ca. 8600 m of mixed fluvial and lacuatrine deposition. Such congruence of magnetostratigraphic records is contrary to the expectations that 1) a fluvial record would contain numerous hiatuses and thus record only a fraction of the geologic time spanned during its deposition, and 2) the probability that a higher sedimentation rate and quieter water sedimentation (lacustrine vs. fluvial) would yield a considerably more complete record. The similarity of Chinle magnetostratigraphy to that of the 25-times-thicker Newark Supergroup appears to suggest, at least in this case, that the hiatuses in fluvial sedimentation can be of short duration, and that a relatively complete stratigraphic record can still result.

The agreement between the Chinle and Newark geomagnetic field polarity records provides for considerable refinement of the Late Triassic Time Scale. The good correlation between the Chinle and Newark Groups permits the rich biostratigraphy of the Chinle Group to place important terrestrial biostratigraphic age calibration on the Late Triassic Magnetic Polarity Time Scale.Further, recent radiochronology in the Chinle Group constrains the Carnian/Norian boundary to be near 214 Ma (which, incidently, is also the age of the Manicougan Impact Stucture). Comparison of the Chinle-Newark terrestrial geomagnetic polarity records with coeval marine Tethyan records indicates that recent Tethyan attempt to define the Carnian/Norian boundary as 227 Ma is seriously in error. The Chinle magnetic polarity and geochronologic record also implies a longer Carnian stage and calls into question the “equal biozone” concept prevalent in Tethyan biostratigraphy.

Upper Triassic of the W Caucasus: Foraminifers, Subdivisions, Correlation

Valery Ja. Vuks

All-Russian Geological Research Institute (VSEGEI), Sredny pr. 74, 199106 Saint-Petersburg, Russia

The Upper Triassic of the Western Caucasus occur in the Laba and Belaya River basins. The upper part of the Caucasus Triassic is represented by the Sakhray and Khodz Groups. The Sakhray Group consists of the terrigenous deposits and overlie the Acheshbok Formation (Middle Anisian) with an erosion. This Group correlate to the Ladinian- Carnian according to foraminifers, ammonites, bivalves, brachiopods. The Khodz Group, represented by diverse types of limestones, overlies the Sakhray Group with an erosion. This Group correlate to the Upper Norian-Rhaetian according to foraminifers, brachiopods and ammonites. The Upper Triassic deposits are unconformably overlain by the Lower Jurassic. In the Sakhray Group there are *Pseudonodosaria obconica-Lenticulina muensteri* local zone (Upper Ladinian) and *Pachyphloides klebelsbergi* local zone (Lower Carnian); the Khodz Group - Aulototrus friedli zone (Upper Norian) and *Involutina liassica* ? local zone (Upper Norian and the lower Rhaetian). There is the ammonite subdivision: the Sakhray Group - *Bugunzhites-Parasturia* local zone, *Proarcestes-Phloioceras* local zone, *Goniojuvavites-Pararcestes* local zone; the Khodz Group - *Placites-Rhacophyllites* local zone, which corresponds to Vandaites stuerzenbaumi. Besides ammonite zones in this Group, there is bivalve local zone - *Monotis* local zone, which good correlate to the Sagenites quinquepunctatus zone. In the Western Precaucasus there are the Upper Triassic deposits which represented by the Chelbasskaya Group (Ladinian-Carnian) and limestone-argillite unit (Norian ?). The Chelbasskaya Group consists of argillites, limestones, volcanic rocks and contains foraminifers and bivalves. The foraminiferal assemblage of the Chelbasskaya Group is in the upper part of this unit and very similar to Carnian foraminiferal assemblage of the Sakhray Group. The uppermost of the Upper Triassic is represented by limestone-argillite unit with fauna like in the middle part of the Khodz Group (*Monotis* assemblage), which correlates to the Sagenites quinquepunctatus zone. According to the ammonite subdivision of the Upper Triassic of the Western Caucasus there is possibilty to find the boundaries of the base of the Carnian and Rhaetian stages, there is not fauna, which occur in the whole stratigraphic interval. In these deposits a lot of foraminifers, but in some intervals there are not typical forms for definition of age. Besides, there is not conodont investigations. So in the Upper Triassic of the Western Caucasus there is the potential for the paleontological and straitigraphical studies of the stage boundaries. The fauna of the mentioned regions are a lot of common species and it allows to correlate these deposit each other. The foraminiferal assemblages of these regions correlate to the coeval associations of the Europe.

Future Meetings

2005

Fieldtrip

For all interested scientists and for those who have not be able to participate in January 2001 to the Permo-Triassic Fieldtrip in Oman, a new and unique opportunity is offer in January 2005, before or after the IAS international meeting January 10-13 in Muscat :

4(BF) - MESOZOIC EVOLUTION OF THE TETHYAN MARGIN OF OMAN: correlations between platform and basin sequences (5 days)

Leaders: Aymon BAUD (Lausanne, Switzerland), Henk DROSTE (Carbonate Centre, Sultan Qaboos University), Cécile ROBIN & François GUILLOCHEAU (Rennes University, France), Philippe RAZIN (Bordeaux III University, France)

The mountain belt of Oman located in the eastern part of the Arabian Peninsula, expose a segment of the Gondwanian Tethyan paleomargin. The aim of this field trip is to study the depositional sequences of Permian to Cretaceous age, from the carbonate platform to the deep-sea plain and to understand the associated tectono-climatic events. The Arabian plaform deposits crop out along the exceptionnally well-preserved wadis of the Jabal Akhdar Mountains, part of the « autochtonous » which are exposed in a large tectonic window. The physiography of the deep-sea part of the margin shows a complex pattern of depositional units located between the slope of the Arabian platform and different seamounts (Kwar Units) : the Sumeini ramp, the Al Aridh slope and the Hamrat Duru deep-sea basin. This trip is focused on the relationship between sedimentary systems, palaeogeography and tectonic and climatic controls. More detailed studies of the turbiditic systems is the topic of Field Trip PF5.

• Duration: 5 days

• Departure: Muscat, Sultan Qaboos University.

• Arrival: Muscat, Sultan Qaboos University.

• Transportation: 4WD Toyota Land Cruiser.

• Physical difficulty: low with short walks and mountain climbings.: SQU

• Participants: minimum 8, maximum 19.

• Cost: 700 USD per person including accommodation (in twin bedrooms), breakfeast, lunch (picnic) and dinner and transportation.

All informations costs and applications are to be found at :

http://www.squ.edu.om/sci/Centers/VR/IAS/home.htm

Second Circular and Registration for The International Symposium on Triassic Chronostratigraphy and Biotic Recovery 23-25 May 2005 (Monday-Wednesday) to be held in Chaohu City, Anhui Province, The People's Republic of China

Objective
This symposium is designed to provide a forum to all kinds of scientists who are interested in the Triassic chronostratigraphy, esp. the Lower Triassic, and the ecosystem reconstruction and biotic recovery in the early Triassic, as well as the related biotic and environmental events following the mass extinction. The symposium will take place at a city where a typical Lower Triassic sequence of good geological and stratigraphical markers is well exposed and a GSSP candidate of the Induan-Olenekian boundary is located. The pre- and post-symposium field excursions will lead you to examine various Upper Permian-Lower Triassic sequences in different paleogeographic facies, including the famous Meishan Section, P-T sections from normal marine to terrestrial via paralic facies, a carbonate P/T sequence with microbialites, a Triassic *Tubiphytes*-reef complex, and Lower-Middle Triassic sections with tuffaceous beds at the boundary, as well as the Guanling Fauna characterized by rich marine reptiles and fully-preserved crinoids.

For further information of the symposium, excursions, accommodation, travel details and payments, please contact:

Dr. Tong Jinnan

Faculty of Earth Sciences, China University of Geosciences, Wuhan 430074, China

Tel: +86-27-6286 7036; Fax: +86-27-8780 1763; E-mail: jntong@cug.edu.cn

Symposium Calendar (2005)

31 September 2004:
Deadline for submission of response to first circular
1 February 2005:
Deadline for submission of abstracts for the proceedings
1 April 2005:
Deadline for submission of pre-registration
21-22 May 2005:
Pre-Symposium Field Excursion from Changxing to Nanjing
23-25 May 2005:
Symposium in Chaohu, Anhui Province
22 May 2005:
Evening: Icebreaker and Registration
23 May 2005:
Morning: Scientific Sessions
Afternoon: Scientific Sessions
Evening: STS, IGCP-467 and IOBWG Workshops
24 May 2005:
Morning: Mid-Symposium Field Excursion in Chaohu
Afternoon: Sight-seeing Tours
Evening: CHRONOS Workshop
25 May 2005:
Morning: Scientific Sessions
Afternoon: Scientific Sessions
26-30 May 2005:
Post-Symposium Field Excursion 1 in Central and Western Guizhou
26-29 May 2005:
Post-Symposium Field Excursion 2 in Southern Guizhou
26 May-1 June 2005:
Post-Symposium Field Excursion 3 in Guizhou

Co-Sponsors

China University of Geosciences
ICS Subcommission on Triassic Stratigraphy

ICS Subcommission on Permian Stratigraphy

IGCP-467 (Triassic Time and trans-Panthalassan Correlation)

National Commission of Stratigraphy of China

National Natural Science Foundation of China

NSF-CHRONOS Project

Task Group on Induan-Olenekian Boundary

Organizer

China University of Geosciences

Office of Land and Resources, Anhui Province

Government of Chaohu City, Anhui Province

Organizing Committee

Chairman:

Orchard, Mike: Chairman of Subcommission on Triassic Stratigraphy, leader of IGCP-467

Vice-chairmen:

Zakharov, Yuri: Leader of Induan-Olenekian Task Force, Vice-Chairman of Subcommission on Triassic Stratigraphy

Yin, Hongfu: Vice-chairman of Subcommission on Triassic Stratigraphy, Vice-Chairman of China National Stratigraphic Commission

Members:

Henderson, Charles: Chairman of Subcommission on Permian Stratigraphy

Lane, Richard: Vice-Chairman of International Commission on Stratigraphy

Ma, Fuchen: Vice-Chairman of National Natural Science Foundation of China

Ogg, Jimes: Secretary General of International Commission on Stratigraphy

Su, Yuguang: Vice-President of Chaohu City, Anhui Province

Yang, Xianjing: Vice-Director of Land and Resources Office of Anhui Province

Wardlaw, Bruce: Co-leader of the CHRONOS Project, NSF

Secretariat:

Tong Jinnan (Correspondence): Professor of China University of Geosciences (Wuhan)

Li Yixiang: Senior Engineer of Land and Resources Office of Anhui Province

Wen Xianhong: Vice-Director of Land and Resources Bureau of Chaohu City

Scientific Programme

Themes:

The symposium will be structured into four main themes:

1. Triassic chronostratigraphy and GSSPs;

2. End-Permian mass extinction and Triassic recovery as well as related events;

3. Triassic paleontology and paleoecology;

4. Correlation between marine and continental Triassic.

Oral Presentations:

20 minutes will be allowed for each oral presentation and 30 minutes for keynote address, plus 5 minutes for questions and discussions.

A computer projector and an overhead projector will be available in the lecture hall. The presentation should be prepared in a Microsoft PowerPoint format (PPT file), but only the PC systems are used and the MacinTosh can not be recognized.

Posters:

Poster presentations are most welcome and will form an important part of the Symposium. The poster room is next to the lecture hall. The size of each display board is 2.0m high and 1.0m wide.

Abstracts:

Deadline for receipt of abstracts is 1 February 2005. The abstract to be presented should be camera-ready and it may be up to three A4 pages in length (both illustrations and references inclusive). Meanwhile, a disc or e-mail of the abstract is required. An Abstract Volume will be published and distributed to all delegates at the beginning of the Symposium.

Pre-symposium Field Excursion

Permian-Triassic boundary sequence in Changxing, Zhejiang Province and Lower Triassic sequence in Nanjing, Jiangsu Province

This two-day field excursion will provide you to view the famous Meishan Section, where the GSSP of the Permian-Triassic boundary, the type section of the Changhsingian Stage and a potential GSSP of the stage are located, and a Lower Triassic sequence of different facies in Nanjing, which was a transitional facies between Meishan and Chaohu. The Induan-Olenekian boundary sequence will be examined as well at the Nanjing Section. Meanwhile, we may make a stop at the Nanjing Institute of Geology and Paleontology to visit the new-built paleontological museum if we have time.

Excursion Leader: Tong Jinnan and Zhao Laishi, China University of Geosciences (Wuhan)

Dates: 21-22 May 2005 (Saturday-Sunday)

Duration: 2 days

Begins: Hangzhou, Zhejiang Province; 8:00 a.m.

Ends: Chaohu, Anhui Province; 5:30 p.m.

Participants: min. 6, max. 30

Cost: Euro€200, including excursion guidebook, 2 breakfasts, 2 lunches, 2 dinners, 1 night hotel accommodation (sharing a double room, for single room add Euro€20)

Remarks: This excursion will starts in Hangzhou City, Zhejiang Province. Please schedule your trip to Hangzhou. Hangzhou is a famous city for tourism and has a very easy travel from Beijing, Shanghai, Hong Kong and most major cities in China. You can also come here a few days early to make a tour of the city and its neighboring cities such as Suzhou and Shanghai.

Mid-symposium Field Excursion

Permian-Triassic boundary and Lower Triassic sequence in Chaohu City, Anhui Province

During the symposium we will spend half a day to visit a Permian-Triassic boundary section in Chaohu, which was formed in a different facies from the Meishan Section, and some Lower Triassic sections, which are the best-studied Lower Triassic sequences in South China. The Changhsingian and Lower Triassic here were formed on deep shelf (or slope), while Meishan was on shallow shelf. The proposed GSSP of the Induan-Olenekian boundary at the West Pingdingshan Section will be closely examined.

This excursion is free to all participants and a lunch provided.

Post-symposium Field Excursion 1

Permian-Triassic boundary sequences across marine and continental facies in Central-Western Guizhou Province

This excursion provides you for a unique chance to trace the Permian-Triassic boundary from marine to continental via paralic facies. Many excellent marine Permian-Triassic boundary sequences have been studied in the central and southern Guizhou while the continental sections are in the western Guizhou and northeastern Yunnan. A marine, a paralic and a continental Permian-Triassic boundary sections are to be visited, respectively. The Zhejue Section, proposed as a candidate of the terrestrial Permian-Triassic boundary stratotype, will be closely examined. During the trip we will have a stay at a locality (a field museum) of the Guanling Fauna, which is a Ladinian-Carnian fossil assemblage typically composed of well-preserved marine reptiles and crinoids.

Excursion Leaders: Yang Fengqing and Yu Jianxin, China University of Geosciences (Wuhan)

Yu Youyi, Guizhou University of Technology

Dates: 26-30 May 2005 (Thursday-Monday)

Duration: 5 days

Begins: Chaohu, Anhui Province; 7:00 a. m.

Ends: Guiyang, Guizhou Province; 5:00 p.m.

Participants: min. 8, max. 25

Cost: Euro €500, including excursion guidebook, 5 breakfasts, 5 lunches, 5 dinners, 4 nights accommodation (sharing a double room, for single room add Euro€80), and 1 air ticket from Nanjing to Guiyang (economic class)

Remarks: The excursion will end in Guiyang, Guizhou Province. Please schedule your back trip from Guiyang. There are daily flights from Guiyang to Beijing and Shanghai.

Post-symposium Field Excursion 2

Permian-Triassic boundary and a Lower-Middle Triassic boundary sequence on the Great Bank of Guizhou in Southern Guizhou Province

This trip is designed to allow you to examine the record of the end-Permian extinction and pattern of biotic recovery in shallow- and deep-marine facies of an isolated carbonate platform, the Great Bank of Guizhou, in southern Guizhou province.

In shallow-marine facies of the platform interior we will examine peculiar but important PT boundary sections containing a microbialite crust deposited in the immediate aftermath of the extinction. The patterns of biotic recovery will be investigated in shallow-marine facies of Lower Triassic sections with low biodiversity, oolites and microbialites and Middle Triassic *Tubiphytes* reefs with greater biodiversity. We will examine the deep-marine record of recovery in the coeval basin-margin facies in a chronostratigraphically constrained Permian through Ladinian section with dated volcanic ash horizons bracketing the Olenekian-Anisian boundary. This section will form an ideal reference section to compliment the O-A GSSP to be designated at the Desli Caira, Romania. These sections are important not only for constraining the timing and environments of biotic recovery but also for pro-

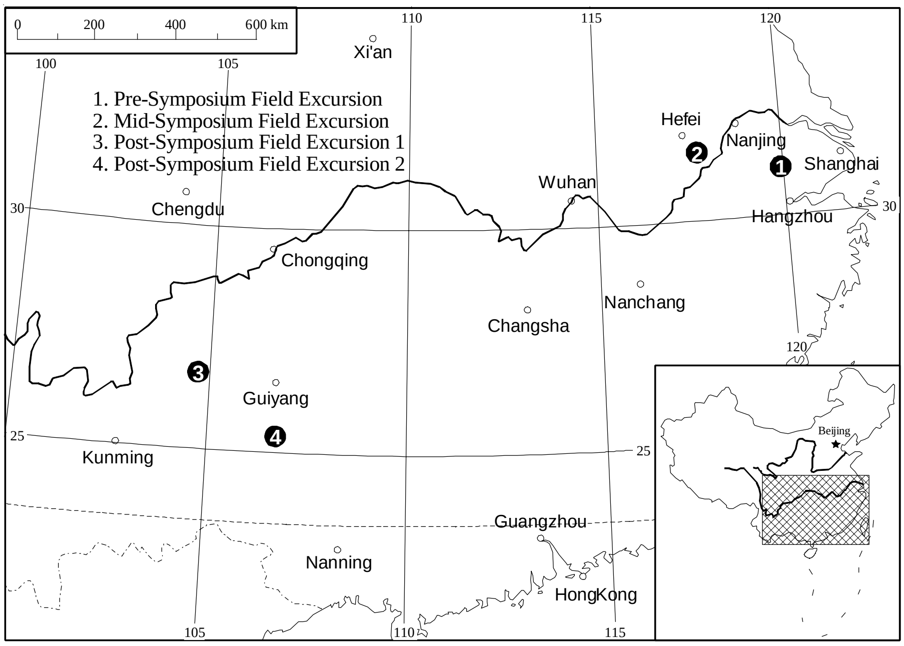

Figure 1: Field excursion map

viding an example of platform evolution entirely different than that of the classic Dolomites platforms of Italy.

Field excursion map

Excursion Leaders: Daniel Lehrmann, University of Wisconsin-Oshkosh

Yu Youyi, Guizhou University of Technology

Dates: 26-29 May 2005 (Thursday-Sunday)

Duration: 4 days

Begins: Chaohu, Anhui Province; 7:00 a. m.

Ends: Guiyang, Guizhou Province; 5:00 p.m.

Participants: min. 8, max. 25

Cost: Euro€450, including excursion guidebook, 4 breakfasts, 4 lunches, 4 dinners, 3 nights accommodation (sharing a double room, for single room add Euro€60), and 1 air ticket from Nanjing to Guiyang (economic class)

Remarks: The excursion will end in Guiyang, Guizhou Province. Please schedule your back trip from Guiyang. There are daily flights from Guiyang to Beijing and Shanghai.

Post-symposium Field Excursion 3

This field excursion is composed of the Post-Symposium Field Excursion 1 and Excursion 2. The first five days it goes the same route as the Excursion 1 to view the various Permian-Triassic boundary sequences and the Guanling Fauna while the last two days we will follow the route of the Excursion 2 to visit the Great Bank of Guizhou.

Excursion Leaders: Yang Fengqing and Yu Jianxin, China University of Geosciences (Wuhan)

Yu Youyi, Guizhou University of Technology

Daniel Lehrmann, University of Wisconsin-Oshkosh

Dates: 26 May-1 June 2005 (Thursday-Wednesday)

Duration: 7 days

Begins: Chaohu, Anhui Province; 7:00 a. m.

Ends: Guiyang, Guizhou Province; 5:00 p.m.

Participants: min. 8, max. 25

Cost: Euro €650, including excursion guidebook, 7 breakfasts, 7 lunches, 7 dinners, 6 nights accommodation (sharing a double room, for single room add Euro€120), and 1 air ticket from Nanjing to Guiyang (economic class)

Remarks: The excursion will end in Guiyang, Guizhou Province. Please schedule your back trip from Guiyang. There are daily flights from Guiyang to Beijing and Shanghai.

Language

English is the official language of the Symposium. All presentations, including registration forms, oral reports, posters, and abstracts should be in English.

Icebreaker Party and Pre-Symposium Reception

The get-together “Icebreaker Party” is planned in the Linhu Hotel, Chaohu on 22 May, starting at 19:00 h. You can register at the same time. There will be a buffet with beverages and food.

Registration

The registration, including the symposium and excursions, should be made to the registration form attached on this circular. All fees are in Euro dollars and all payments must be made in this currency. Payment can be made by

Bank Transfer:

Bank: Bank of China, Wuhan City, Guanggu Sub-branch

Reference: Tong Jinnan

Account No.: 4662102-0188-012796-0

Registration fees:

Before 1 April 2005: Euro€200; After 1 April 2005: Euro€230

The registration fees include: symposium material and activities, icebreaker, morning and afternoon teas, 3 lunches and 3 dinners, the Mid-Symposium Field Excursion, and the Sightseeing Tours on 24 May 2005.

Hotel Accommodation

Several hotels in the downtown of Chaohu City are arranged for participants. But participants are suggested to reside in the Linhu Hotel (Lakeside Hotel), where most Symposium activities will be held. You can also stay in the Wanhu Hotel next to the Linhu Hotel. Both Linhu Hotel and Wanhu Hotel are three-stars hotels. The hotels will provide a preferential price for the participants of the Symposium. One night costs:

Euro€20-30 for a standard double room or a standard single room

Euro€40-50 for a luxurious suite

No deposit is needed for booking the room, but FCFS (First Come, First Served) will be followed.

Weather

The May is the best time for working in Chaohu. The weather is warm but not hot and cool but not cold. The temperature is usually between 10 and 20°C, or slightly over 20°C. The weather for the excursions is also very welcome and comfortable, but it might be a little sunny in field. The excursions are by bus or minibus and only involve short walks. Some quarries and paths may be muddy after rain. Please wear good walking boots.

Transportation

Chaohu is situated in the middle part of the Anhui Province. It is a mid-size city in the southeastern China with very good traffic access, 50 km from Hefei, the capital of the province, and is served by railway and freeway, about an hour to Hefei City by bus. Moreover, it is only 100 km from Chaohu to Nanjing, the capital of the Jiangsu Province. Both freeway and railway connect Chaohu City and Changxing County, where the GSSP of the Permian-Triassic boundary is located; the drive is about three hours.

Some students will meet you in Hefei at the airport or railway station if you let us know your exact arriving time in Hefei. The Hefei Airport has daily flights from Beijing, Shanghai and some other cities in China. The train and bus systems are also very convenient from most cities to Hefei. Also, we will arrange a minibus to meet the participants arriving at the Nanjing Airport on 22 May, but the last bus will leave by 5:00 p.m. The participants of the Pre-Symposium Field Excursion will be gathered in Hangzhou. Hangzhou is a famous tour city and has very good connections with most cities in China by airplane, train and bus. The express train and express bus from Shanghai to Hangzhou are about two hours.

Meanwhile, the Nanjing Institute of Geology and Paleontology and China University of Geosciences would like to provide logistic help for those who intend to visit the institute and the university before or after the symposium.

Insurance

The Symposium organizers cannot be held responsible for any accident of injury or loss or damage of property that may happen to the participants in the Symposium and Excursions. Please make your own insurance arrangements.

Letters of Invitation

A letter of invitation will be sent on request. This letter, however, does not constitute any obligation of the organizing Committee to cover expenses, fees, etc., associated with participation in the Symposium. We will ask the Administration of the Hubei Province to send an official letter or a fax to the Chinese Embassy or Consulate in your country, if requested and necessary, to help you to get your Chinese visa.

If you need an official invitation letter for the visa, please send us your personal data, including your full name (which occurs in your passport), occupation and title, institution, birth date, passport no., a brief experience, etc.

Abstract

The abstract must be in English and may be up to three pages in length.

Please follow instructions below:

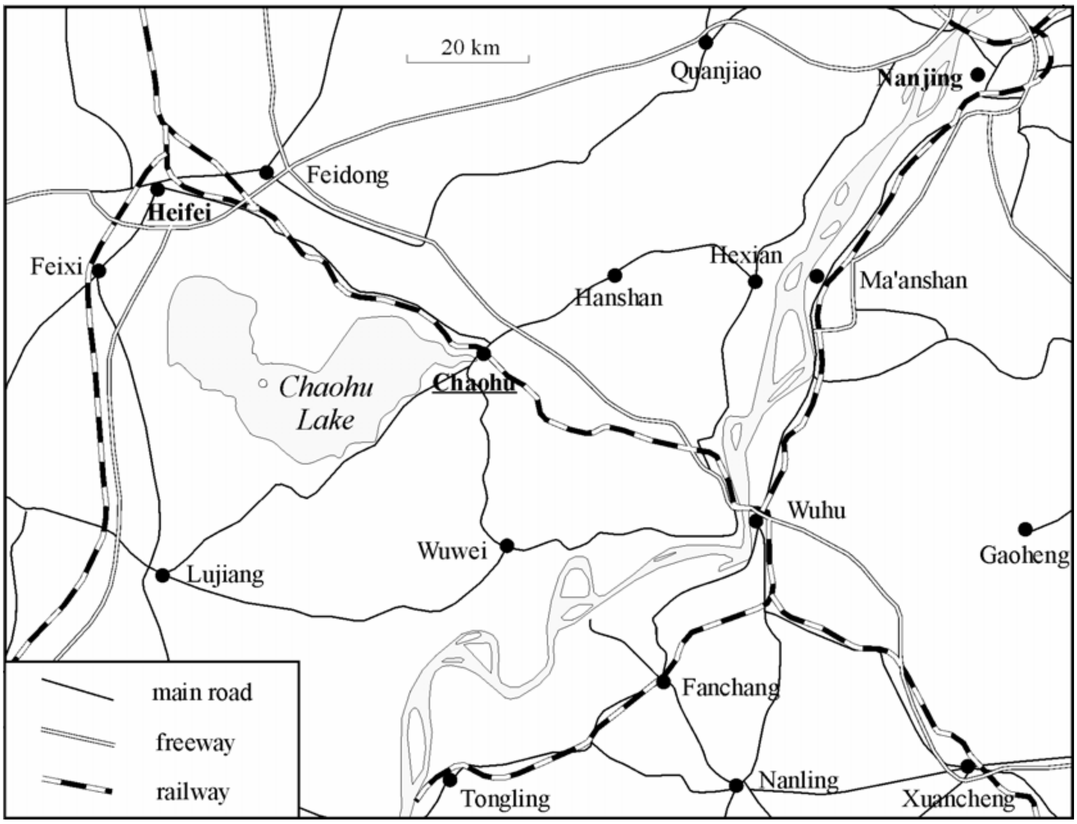

Figure 2: Regional map around Chaohu

Heading: Left justified, bold, 12pts Times New Roman

List of authors: Left justified, 10pts Times New Roman, with first name, then initials and family name, marked by superscripts to identify addresses

List of addresses: Left justified, italics, 10pts Times New Roman, superscripted to correspond to the list of authors, including the e-mail account of the corresponding author, if possible

Please skip one line before the text

Text: 10pts Times New Roman, left justified, single-spaced. Please indent the first line of each paragraph

Reference list: Including only key citations in the text, in alphabetical order

Figures: Line drawings only. Halftone or color photographs are not acceptable. Hand-drawn line figures should be prepared to a professional standard on good quality drafting film or while paper. You are encouraged to send figures in digital versions (CorelDraw and TIFF files only). Please ensure that electronic artwork is prepared such that, after reduction, all lettering will be clear and easy to read.

To help us quickly and accurately process your abstract, please note:

Your abstract should be Camera-Ready. Basically, there will be no editions and corrections.

Your abstract should be each paper only within a space of 16´24 cm. If the abstract exceeds the required format, it might be rejected.

Indent the first line of each paragraph and lines must be single-spaced.

The text should be sent on a 3.5² diskette or by e-mail in MS Word or RTF format, together with a hard copy of the paper.

The deadline for submission of Abstracts is 1 February 2005.

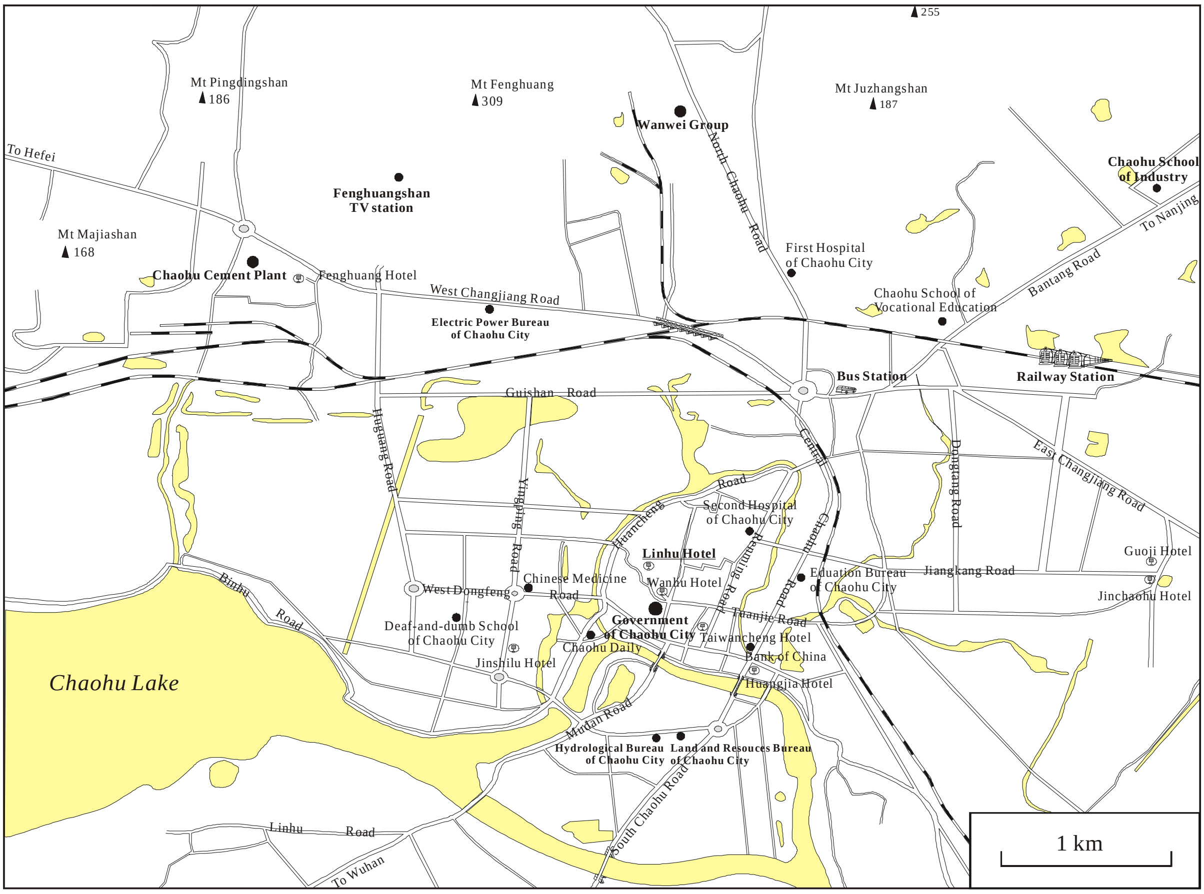

Figure 3: Town map of the Chaohu City

Registration Form for
The International Symposium on

Triassic Chronostratigraphy and Biotic Recovery

23-25 May 2005, Chaohu

Forename: ________________ Initial (S): _____________ Surname: ______________________

Title(s): □ Ms. □ Mr. □ Dr. □ Prof. Sex (M/F): □ Female □ Male

Institution: ____

Mail Address: ____

____ Country: ________________________

Telephone: ________________ Fax: ________________ E-mail: ______________________________

Presentation: □ oral paper □ poster

Title: ____

____

Abstract title: ____

____

Registration Fees: □ Euro€200 Before 1 April 2005 □ Euro€230 After 1 April 2005

Field Excursions: □ Euro€200 Pre-Symposium Field Excursion

□ Euro€500 Post-Symposium Field Excursion 1

□ Euro€450 Post-Symposium Field Excursion 2

□ Euro€650 Post-Symposium Field Excursion 3

Total Amount: Euro€ _____________

Payment (Bank Transfer): I have instructed my bank to transfer the amount of Euro€_________ to:

Bank: Bank of China, Wuhan City, Guanggu Sub-branch

Reference: Tong Jinnan

Account No.: 4662102-0188-012796-0

Accommodation (No pre-payment needed):

Linhu Hotel: □ Single Room □ Double Room □ Suite

Other hotel: ____

Arrival Details: □ airplane □ train □ bus

Station: ___________ Flight/Train No.:__________ Date:_____________ Time: __________

Remarks: ____

____

Signature:______________________ Data:____________________ City: _________________

2006

InterRad XI: Radiolarians in Stratigraphy & Paleoceanography 11th Meeting of the International Association of Radiolarian Paleontologists & Circum-Pacific Triassic Stratigraphy & Correlation

A symposium hosted by IGCP 467 and STS

Wellington, New Zealand, March 2006

~ First Circular ~

This joint conference will be held at *Te Papa Tongarewa*, Museum of New Zealand, in Wellington, March 19-24. The conference is sponsored by InterRad, IGCP Project 467 (Triassic Time and Trans-Panthalassa Correlations), the Subcommission on Triassic Stratigraphy (STS) and the Institute of Geological and Nuclear Sciences (GNS).

Organising committee

Chris Hollis and Hamish Campbell (convenors), Janet Simes (organiser), Yoshiaki Aita, Jack Grant-Mackie, Rie Hori, Barry O'Connor, John Simes, Bernhard Spörli, Percy Strong and Atsushi Takemura

Schedule

March 13-19: Pre-conference excursion 1. Northland and Auckland to Wellington via west coast Triassic localities (1A) or via central North Island volcanic and geothermal areas (1B)

March 19: Conference registration and ice-breaker

March 20-21, 23-24: Conference symposia and general sessions

March 22: Mid-conference Excursion 2. Wellington south coast

March 24-29: Post-conference Excursions 3, 4 and 5. Marlborough-Canterbury, Canterbury-Southland, Nelson

Registration

Discounted registration fees (prior to 30 September 2005) will be approximately ($NZ450 (€225, $US250) for professionals and $NZ250 (€125, $US150) for students, retired/unwaged and accompanying persons.

Funding

Some funding for travel and conference expenses is available through InterRad, IGCP and other sponsors. If your attendance at the conference will depend on partial or complete funding, please contact convenors as soon as possible.

Provisional symposia

The conference will be arranged as a series of symposia, which will begin with plenary talks. Each day will finish with a general talk open to the wider scientific community. Suggestions for additions or changes to symposia are welcome and should be emailed to the convenors.

A. Triassic stratigraphy and biogeography

A1. Triassic catastrophes: P/T, T/J and intra-Triassic boundary events

A2. Paleobiogeography and terrane analysis

A3. Trans-Panthalassan correlation and radiolarian evolution

B. Paleontological and stratigraphic methods and results

B1. Quantitative stratigraphic methods (BIOGRAPH, CONOP, GRAPHCOR, etc.)

B2. Quantitative paleoecological analysis

B3. Advances in processing and examining microfossil samples

C. Correlation and interpretation of Cretaceous-Cenozoic biosiliceous facies

C1. Biostratigraphy of deep-water facies

C2. Paleoenvironmental interpretation of biosiliceous facies

D. Biological indicators of ocean productivity

D1. Climate and ocean productivity interactions in the modern ocean

D2. Interrelations between Quaternary climate cycles and ocean productivity

D3. Plankton response to aberrant climate events in a greenhouse world

E. Plankton biology and phylogenetics

E1. Phylogenetic methods

E2. Advances in plankton classification

Accommodation

Accommodation will be in a central Wellington Hotel, five minute's walk from the conference venue. The hotel offers a wide range of single, twin, double and family rooms as well as budget bunkrooms. Prices (including breakfast) will range from about $US60 to $US20 per night. It also has a cooking, laundry and internet facilities, a restaurant and a large bar.

Excursion

Pre-conference Excursion 1: Northland, March 13-16 (4 days). Return flights: Kerikeri-Auckland. Permian-Triassic oceanic association of basalt, limestone, chert, and argillite (Waipapa Terrane), including fusuline/coral-, conodont- and radiolarian bearing lithologies and Arrow Rocks Permian-Triassic boundary succession. Late Cretaceous-Paleocene oceanic association of basalt and radiolarian bearing-limestone and chert (Tangihua Volcanics). Late Cretaceous-Oligocene allochthonous oceanic succession, including radiolarian-bearing organic shale and siliceous mudstone (Whangai and Waipawa Formations) and micritic limestone (Mahurangi Limestone); the latter formation containing exceptionally well-preserved Oligocene radiolarians. Leaders: Atsushi Takemura, Yoshiaki Aita and Bernhard Spörli. Indicative cost $NZ1000 (€500, $US600)

Pre-conference Excursion 1A: Auckland-Taupo-Wellington (North Island), March 19-20 (3 days). Minivans: Auckland-Wellington. Triassic-Jurassic oceanic association of pillow basalt, chert and argillite, Kawakawa Bay, followed by scenic tour through central North Island, overnighting in the Taupo. Maori cultural experience, thermal pools, geysers, and calc-alkaline volcanoes in central North Island volcanic area. Leaders: Chris Hollis and Yoshiaki Aita. Indicative cost $NZ600 (€300, $US360).

Pre-conference Excursion 1B: Auckland-Waitomo-Wellington, March 19-20 (3 days). Minivans: Auckland-Wellington. Triassic-Jurassic oceanic association of pillow basalt, chert and argillite, Kawakawa Bay, followed by a western North Island excursion to examined late Triassic-earliest Jurassic volcaniclastic sections in Marakopa and Awakino areas (Murihiku Terrane) Visits to a native bird park and Waitomo Caves may be included. Leaders: Hamish Campbell, Rie Hori and Jack Grant-Mackie. Indicative cost $NZ600 (€300, $US360).

Mid-conference Excursion 2 Wellington south coast, March 22. Late Triassic accretionary wedge and associated oceanic sediments (Torlesse Rakaia Terrane) exposed along the Cook Strait coast. Leader: Hamish Campbell. Indicative cost $NZ100 (€50, $US60).

Post-conference Excursion 3 Marlborough-south Canterbury (South Island), March 24-28. Ferry: Wellington to Picton, minivans Picton-Oamaru-Christchurch. Late Cretaceous-middle Eocene hemipelagic-pelagic succession of siliceous mudstone, chert, limestone and marl (Whangai, Mead Hill and Amuri Limestone Formations), including the only global records of radiolarian faunal turnover from Late Cretaceous to Eocene with intact Cretaceous-Tertiary and Paleocene-Eocene boundary intervals. Whale-watching, seal-colonies, radiolarian-bearing Mead Hill Formation in Kaikoura. Radiolarian-rich late Eocene diatomite, pillow basalts and penguins of Oamaru. Leader: Chris Hollis. 5 days. Indicative cost $NZ1000 (€500, $US600).

Post-conference Excursion 4 Southland (South Island), March 23-28. Return flights: Wellington-Dunedin. Early-Late Triassic neritic sequence in Southland Syncline along Otago coast (Kaka Point to Nugget Point) and inland in the Hokonui, Taringatura and Wairaki Hills (Murihiku Terrane). Leader: Hamish Campbell. 4 days. Indicative cost $NZ1200 (€600, $US720).

Post-conference Excursion 5 Nelson (South Island). Return flights: Wellington-Nelson, boat travel to D'Urville Island. Poorly fossiliferous Early Triassic Maitai Group exposed in river sections near Nelson city and on D'Urville Island. Leader: Yoshiaki Aita. 4 days. Indicative cost $NZ1200 (€600, US720).

CONTACT DETAILS

Symposia, themes, funding and excursions

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Registration, accommodation, travel

Janet Simes (conference organiser), janet.simes@conferences.co.nz

Web site

This circular and conference updates will be posted at:

http://www.gns.cri.nz/interrad

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NORIAN – RHAETIAN BOUNDARY TASK FORCE Call for membership

Within the Subcommission on Triassic Stratigraphy (STS) a Norian-Rhaetian boundary working group (now called as task force) has been formed. Scientists working actively on this boundary or are known for their specific interest have been asked for participation. Others have expressed their willing to cooperate during the STS business meeting in Florence (August 2004), and this is another invitation to those who would like to be included in the search for potential GSSP candidates as well as the most appropriate boundary level which should be correlatable both in the marine and continental realm. Researchers in any stratigraphic discipline usable for high-resolution correlation and from as many regions worldwide are highly welcome to become member of the task force.

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INDUAN-OLENEKIAN BOUNDARY TASK FORCE

Open letter to Prof. Jinnan Tong

Dear Jinnan,

You ask me about recent situation on the GSSP of the I/O boundary. As you know, the Indian Spiti section is characterized by well-preserved ammonoids and, according to L. Krystyn's and H. Kozur's data, by abundant well-preserved conodonts. I am fully confident that L. D. Kiparisova and Y. N. Popov, authors of the Induan and Olenekian stages, if they would be alive, would welcome the Leo Krystyn's proposal in this situation. But before evaluation of the Spiti section as a candidate of the GSSP of the I/O boundary I should like to have, as a minimum, full information on the ammonoid and conodont distribution in the I/O boundary interval, where samples recently were collected, but fossils from them have not been determined yet. I hope that it will be done by Leo Krystyn in nearliest feature and necessary additional data will be demonstrated soon. It would be very alluringly to have the IOB stratotype in the Himalayas, stratotype area of the Induan, but I am embarrassed by the negative paleomagnetic results obtained from the Spiti section. The Chaohu section in South China in this respect (excellent paleomagnetic results were recently obtained there by Hans Hansen) profitably differs from both the Abrek (Russian Far East) and the Spiti sections, and therefore it is very important now to fill a small gap in our knowledge on the Chaohu conodont succession (I mean additional data, which you are waiting from Mike Orchard). It will be good, if new results on both the Chaohu and Spiti sections, the main candidates for the GSSP of the I/O boundary in my opinion now, will be demonstrated at the Chaohu meeting. In this case we will have effective discussion in this topic just in the framework of the IOBWG of the nearest meeting.

Yuri Zakharov

(Leader of Induan-Olenekian Task Force)

Scientific Reports

Late Triassic extinction events

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Abstract - Accelerated biotic turnover during the Late Triassic has been misinterpreted as a single, end-Triassic mass extinction event, now regarded as one of the "big five" extinctions. However, careful examination of the fossil record indicates that the groups usually claimed to have suffered a catastrophic extinction at the end of the Triassic, including ammonites, bivalves, conodonts and tetrapods, experienced multiple or prolonged extinctions throughout the Late Triassic, and that other groups were relatively unaffected or subject to only regional effects. Instead of a single mass extinction at the end of the Triassic, the Late Triassic was an interval of elevated extinction rates, encompassing distinct extinction events at the Late Triassic stage boundaries, as well as other, within-stage extinction events.

Introduction

The decline in diversity at the Triassic-Jurassic boundary (TJB) has come to be regarded as one of the "big five" mass extinctions of the Phanerozoic. Attribution of this level of suddenness and severity to the extinction at the TJB followed Sepkoski (1982), who, based on a global compilation of families of marine invertebrates, designated this boundary as one of four mass extinctions events of intermediate magnitude (end-Cretaceous, end-Triassic, Late Devonian, Late Ordovician). Overall, this assumption of intense and sudden biotic decline at the TJB has remained unquestioned, until recently (Hallam, 2002; Tanner et al., 2004).

Here, we reject what we believe is the myth of a catastrophic extinction at the TJB. This myth is largely rooted in poor stratigraphic resolution compounded by a reliance on literature compilations as a method of identifying and gauging mass extinctions. Instead, the Late Triassic was an interval of elevated extinction rates that manifested themselves in a series of discrete extinctions throughout Norian and Rhaetian time. Significantly, no data document Late Triassic mass extinction(s) of many biotic groups, including gastropods, brachiopods, conulariids, foraminiferans, ostracods, fishes and marine reptiles (Hallam, 2002; Tanner et al., 2004). Therefore, we focus our discussion on those groups that have been perceived by some as part of a TJB mass extinction, namely ammonites, bivalves, reef organisms, radiolarians, conodonts, tetrapods and land plants.

The compiled correlation effect

Two methods have been used to analyze the data on extinctions at the TJB: (1) the compilation of global diversity from the published literature; and (2) the study of diversity changes based on the actual stratigraphic distribution of fossils in specific sections. These two methods are not totally disjunct, because the global compilations supposedly reflect the actual stratigraphic distributions of the fossils in all sections. However, the global compilations contain a serious flaw—their stratigraphic imprecision (Teichert, 1988), which Lucas (1994) termed the Compiled Correlation Effect (CCE). This imprecision is largely responsible for the myth of a single, TJB mass extinction.

The CCE refers to the fact that the temporal ranges of taxa in literature compilations are only as precise as the correlations, or relative ages, of the compiled taxa. Because most published correlations are at the stage/age level, the temporal resolution of extinction events within these stages/ages cannot be resolved (Fig. 1). The result is the artificial concentration of extinctions at stage/age boundaries; a complex extinction of significant temporal duration during a stage/age is made to appear as a mass extinction at the end of the stage/age (Fig. 1).

Much of the literature on the TJB extinction fails to consider the CCE. Thus, for example, the supposedly profound extinction of ammonites at the end of the Rhaetian reflects a lack of detailed stratigraphic analysis; literature compilations assumed that any ammonite taxon found in Rhaetian strata has a stratigraphic range throughout the entire Rhaetian (Fig. 1). This gives the appearance of a dramatic ammonite extinction at the end of the Rhaetian, when in fact, there were several ammonite extinction events within the Rhaetian. Furthermore, those who did not recognize a Rhaetian Stage exacerbated the CCE, because they reduced stratigraphic resolution by considering the entire post-Carnian Late Triassic to belong to a single, Norian Stage.

Also note that the Signor-Lipps effect, which recognizes

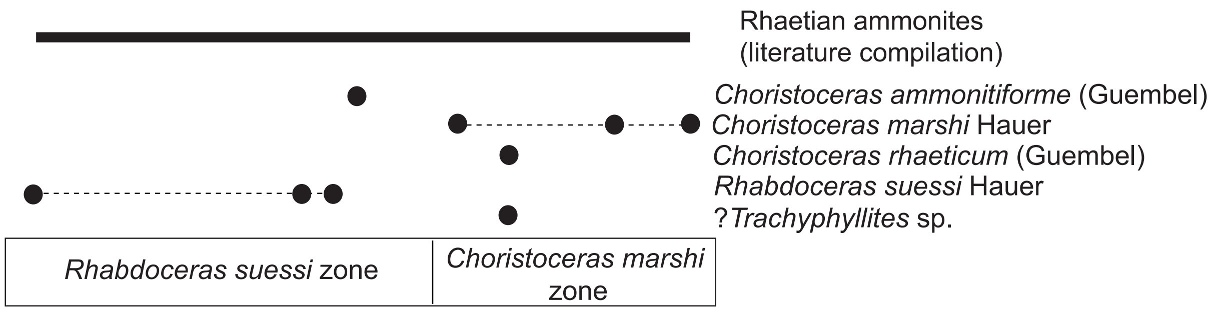

Figure 1. The actual ranges of Rhaetian ammonites in the Weissloferbach section (Austria) of the Kössen Beds (after Mostler et al., 1978) show a low diversity Rhaetian ammonite assemblage with only one taxon (*Choristoceras marshi*) present at the top of the Rhaetian section. In contrast, the low stratigraphic resolution characteristic of literature compilations indicates all ammonite ranges simply truncated at the top of the Rhaetian, a typical example of the CCE.

that in theory some actual stratigraphic ranges in the fossil record are artificially truncated, has been used by some to discount the reliability of actual stratigraphic ranges. Statistical methods even exist to "complete" these supposedly truncated stratigraphic ranges. Howevrer, we regard these methods as little more than assumption-laden ways to invent data, and prefer to rely on the actual stratigraphic ranges of fossils in well-studied sections.

Ammonites

Biostratigraphic recognition (and definition) of the TJB has long been based on a clear change in the ammonite fauna from the ornamented ceratites and their peculiar heteromorphs of the Late Triassic to the smooth psiloceratids of the Early Jurassic. Most workers agree that all but one lineage of ammonites became extinct by the end of the Triassic, and the subsequent Jurassic diversification of ammonites evolved from that lineage.

There is indeed substantial turnover in the ammonites around the TJB, and Early Jurassic ammonite assemblages are qualitatively very different from Late Triassic assemblages. However, Kennedy (1977) and Signor and Lipps (1982) correlated the drop in ammonite diversity at the end of the Triassic with a drop in sedimentary rock area, not with a mass extinction. And, Teichert (1988) listed more than 150 ammonite genera and subgenera during the Carnian, which was reduced to 90 in the Norian, and reduced again to 6 or 7 during the Rhaetian. This indicates that the most significant ammonite extinctions were during or at the end of the Norian, not at the end of the Rhaetian.

The most completely studied and ammonite-rich section in the world that crosses the TJB is in the New York Canyon area of Nevada, USA (Fig. 2). Taylor et al. (2000, 2001) and Guex et al. (2003) plotted ammonite distribution in this section based on decades of collecting and study; of 11 Rhaetian species, 7 extend to the upper Rhaetian (shown in Figure 2), and only 2 are present at the stratigraphically highest Rhaetian ammonite level. Taylor et al. (2000) presented a compelling conclusion from these data: a two-phase latest Triassic ammonite extinction, one in the Norian followed by a low diversity Rhaetian ammonite fauna that becomes extinct at the end of the Triassic.

Another detailed study of latest Triassic ammonite distribution is in the Austrian Kössen Beds (Fig. 1; Ulrichs, 1972; Mostler et al., 1978). The youngest Triassic zone here, the *marshi* zone, has three ammonoid species, two with single level records low in the zone, and only *Choristoceras marshi* is found throughout the zone. This, too, does not indicate a sudden TJB mass extinction of ammonites. Thus, the change in ammonites across the TJB is profound, but it took place as a series of extinction events spread across Norian and Rhaetian time, not as a single mass extinction at the TJB.

Bivalves

The perception of a TJB mass extinction of marine bivalves stems from Hallam (1981), who claimed a 92% extinction of bivalve species at the TJB by combining all Norian (including Rhaetian) marine bivalve taxa, thereby encompassing a stratigraphic interval with a minimum duration of 15 million years. He then compared this to a pool of Hettangian taxa, an outstanding example of the CCE.

Johnson and Simms (1989) pointed out that better much stratigraphic resolution could be achieved on the local scale; in the Kössen beds, for example, Hallam considered all of the bivalve taxa to range throughout the Rhaetian, even though published data (e.g., Morbey, 1975) showed varied highest occurrences throughout the Rhaetian section. Furthermore, Skelton and Benton's (1993) global compilation of bivalve family ranges showed a TJB extinction of 5 families, with 52 families passing through the boundary unscathed, certainly suggesting that there was not a mass extinction of bivalve families. Hallam and Wignall (1997) reexamined the bivalve record for the TJB in northwestern Europe and the northern Calcareous Alps in considerable detail. They found extinction of only 4 out of 27 genera in northwest Europe and 9 of 29 genera in the Calcareous Alps, again, not indicating a mass extinction. Although Hallam (2002) continued to argue for a substantial TJB bivalve extinction, he conceded that the data to demonstrate this are not conclusive. We believe unequivocally that these data do not exist.

Indeed, detailed inspection of the Late Triassic bivalve record suggests that extinctions were episodic throughout this interval, not concentrated at the TJB. A significant extinction of bivalves, including the cosmopolitan and abundant pectinacean *Monotis*, is well documented for the end-Norian (Dagys and Dagys, 1994; Hallam and Wignall, 1997). Detailed studies of Late Triassic bivalve stratigraphic distributions (e.g., Allasinaz, 1992; McRoberts, 1994; McRoberts and Newton, 1995; McRoberts et al., 1995) identify multiple bivalve extinction events within the Norian and Rhaetian Stages. A good example is the New York Canyon section, where bivalve genera disappear at several levels in the Rhaetian, with most bivalve turnover predating the ammonite-based TJB (Fig. 2). The pattern of bivalve extinction during the Late Triassic is thus one of multiple extinction events, not a single mass extinction at the TJB.

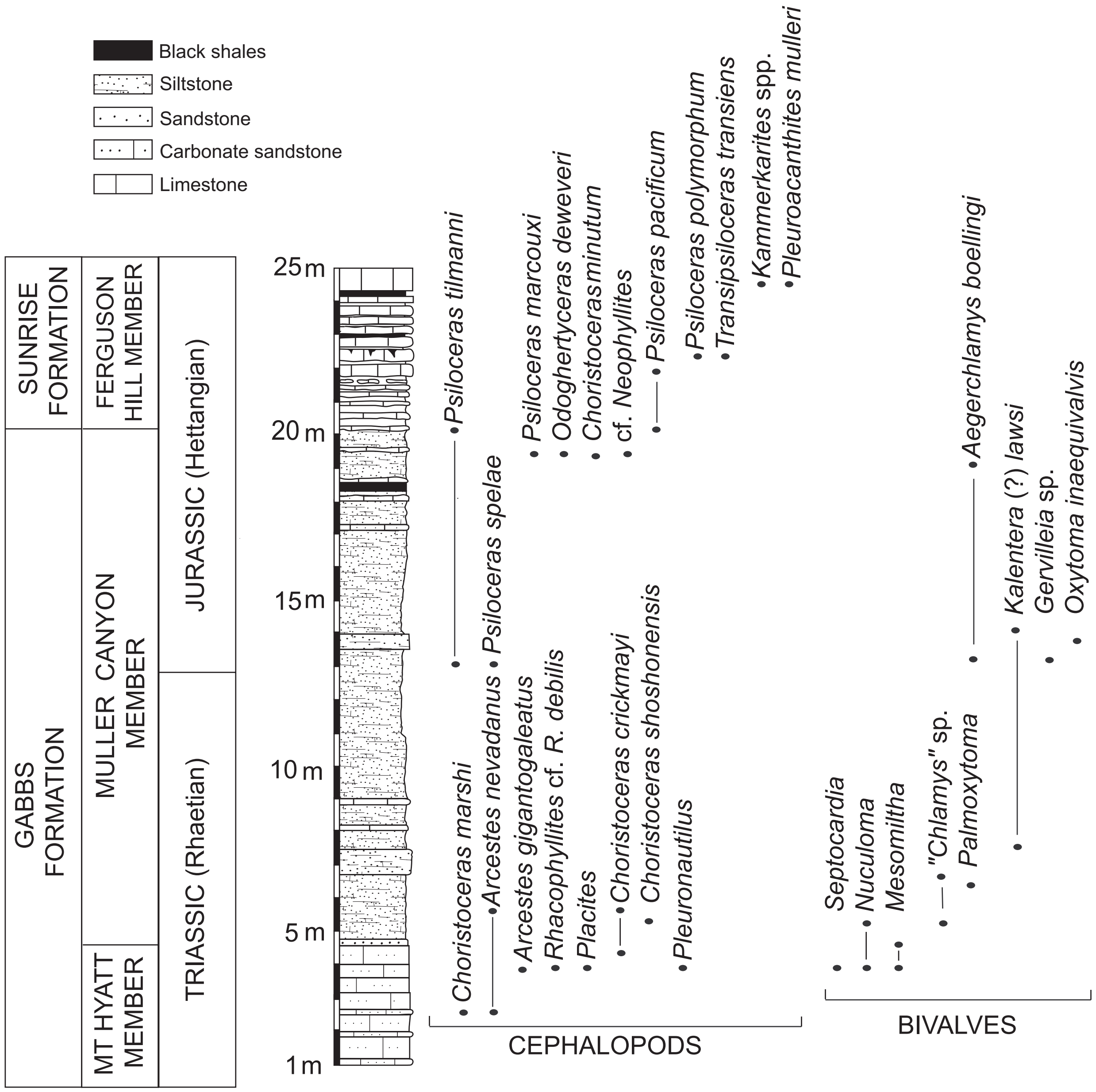

Figure 2. The actual stratigraphic ranges of ammonites and bivalves across the TJB in the New York Canyon section, Nevada (modified from Guex et al., 2003). The TJB is placed here at the lowest occurrence of *Psiloceras tilmanni.*

Reefs

The scleractinian corals, important reef builders during the Triassic, underwent a marked decline at the end of the Triassic that was followed by a "reef gap" during the Hettangian and early Sinemurian, after which corals re-diversified to become the dominant reef builders (Stanley, 1988). The extinctions in the reef community at the end of the Triassic are best documented in Tethys, where the reef ecosystem collapsed, carbonate sedimentation nearly ceased, and earliest Jurassic reefal facies are rare. Those earliest Jurassic reefs that are known (particularly in Morocco) are carbonate mounds produced by spongiomorphs and algae (e.g., Flügel, 1975). However, coral Lazarus taxa have been discovered in Early Jurassic suspect terranes of western North America, indicating the persistence of at least some corals in Panthalassan refugia during the earliest Jurassic reef gap.

Hallam and Goodfellow (1990) argued that sea level change caused the collapse of the reef system, with significant extinctions of calcisponges and scleractinian corals at the TJB. They discounted the possibility of a major drop in productivity as an explanation for the facies change from platform carbonates to siliciclastics. There is indeed a distinct lithofacies change at or near the TJB in many sections, particularly in the Tethyan realm, where facies changes suggest an interval of regression followed by rapid transgression. At the TJB section in western Austria, for example, a shallowing-upward trend from subtidal carbonates to red mudstones, interpreted as mudflat deposits, is succeeded by thin-bedded marl and dark limestone (McRoberts et al., 1997). The boundary in parts of the Austrian Alps displays karstification, suggesting a brief interval of emergence. In the Lombardian Alps the TJB is placed (palynologically) in the uppermost Zu Limestone at a flooding surface that marks the transition from mixed siliclastic-carbonate sedimentation to subtidal micrite deposition (Cirilli et al., 2003). Thus, a change in bathymetry resulted in the extirpation of reefs, which in large part caused the cessation of carbonate sedimentation. However, the evidence that this was a global event is lacking, and can be explained easily as a regional extinction driven by sea level changes.

Kiessling's (2001) compilation indicates that the decline of reefs began during the Late Triassic and that the TJB corresponds to the loss of reefs concentrated around 30^{o}N latitude, although this article is frequently cited as documenting a TJB mass extinction of reef organisms (e.g., Pálfy, 2003). Beauvais (1984) stressed the endemism of scleractinian species during the Liassic, raising the possibility that the apparent TJB extinction of these organisms may be heavily influenced by (Tethyan?) sampling biases. Thus, a sudden extinction of reef organisms at the TJB is limited to Tethys and reflects a regional change in bathymetry, not a global mass extinction of reef organisms.

Radiolarians

At the family level, radiolarians show no decline at the TJB (Hart and Williams, 1993), although significant species turnover is indicated (Vishnevskaya, 1997). Data from the Queen Charlotte Islands in western Canada have been interpreted to indicate a drastic extinction of radiolarians at the TJB (Tipper et al., 1994; Carter, 1994; Ward et al., 2001). Carter (1974) cites the loss of 45 radiolarian species in the top 1.5 m of the *Globolaxtorum tozeri* zone (topmost Rhaetian) on Kunga Island, above which is a low diversity Hettangian fauna in which nasselarians are rare. However, Guex et al. (2002) argue that the radiolarian extinction in the Queen Charlotte Islands section is directly associated with a stratigraphic gap (unconformity), which suggests the extinction is more apparent than real, though E. Carter (personal commun., 2003) believes there is no gap in the section. Regardless, few data indicate that this extinction was anything more than a local event.

Data from other Pacific rim locations suggest that the extinction pattern was not catastrophic. Bedded cherts from Japan, for example, display radiolarian faunas that indicate gradual replacement across the boundary with observable transition groups (Hori, 1992), though Carter and Hori (2003) recently reported a drastic change in the radiolarian fauna across the TJB in one Japanese section. Vishnevskaya (1997) indicates that about 40% of the latest Triassic radiolarian genera survived the TJB. Indeed, the greatest radiolarian extinction of the early Mesozoic occurred during the Early Jurassic (early Toarcian), not at the TJB (Racki, 2003). Moreover, occurrences of bedded cherts show no decrease from the Late Triassic to the Early Jurassic, suggesting that there was no significant radiolarian decline (Kidder and Erwin, 2001).

Conodonts

The Conodonta (a phylum or subphylum) is usually identified as one of the most significant groups to have suffered complete extinction at the end of the Triassic. This is misleading. Detailed reviews of the conodont extinction emphasize that conodonts suffered high rates of extinction throughout the Triassic (e.g., Clark, 1983; Sweet, 1988; Aldridge and Smith, 1993), and maximum conodont extinction took place at the end of the Norian. Indeed, this long appeared to be the final extinction of conodonts in North America, as the youngest conodonts on the continent were from the late Norian *suessi* zone (Clark, 1980, 1981, 1983). Conodonts, however, are now known from the Rhaetian *crickmayi* zone in Canada, though they are known only from terranes and are low in both abundance and diversity (Orchard, 1991, 2003). They are also found in the Rhaetian *marshi* zone in Europe, though diversity is low (4 species) and population sizes (based on sample abundance) also are low (Mostler et al., 1978). Thus, conodonts were mostly extinct by the end of the Norian.

Tetrapods

The idea of a substantial nonmarine tetrapod (amphibian and reptile) extinction at the end of the Triassic began with Colbert (1949, 1958), and has been more recently advocated by Olsen et al. (1987, 1990, 2002a, b), largely

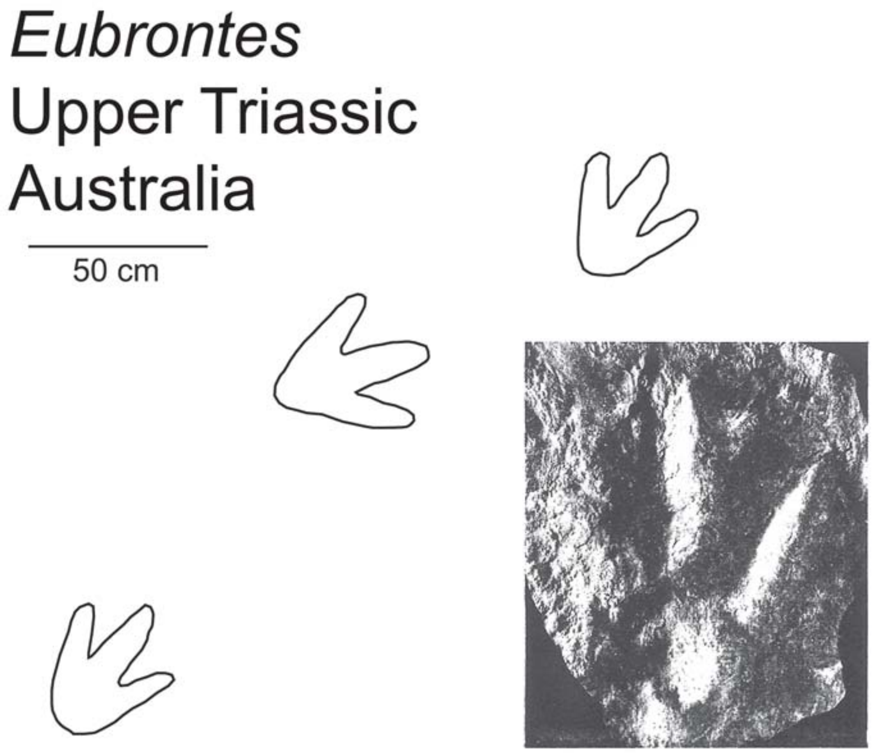

Figure 3. *Eubrontes* footprints from the Upper Triassic of the Sydney basin, Australia. The drawings are of a trackway (after Staines and Woods, 1964), and the photograph of a track is after Batholomai (1966).

based on the tetrapod fossil record of the Newark Supergroup (eastern North America). Benton (1994) and Lucas (1994) rejected this conclusion, both arguing against building a case for extinction on the very incomplete record of the Newark Supergroup. Furthermore, Cuny (1995) saw no evidence of a TJB mass extinction of tetrapods in the western European tetrapod fauna.

Colbert (1958) believed that the temnospondyl amphibians, a significant component of late Paleozoic and Early-Middle Triassic tetrapod assemblages, underwent complete extinction at the TJB. However, more recent discoveries have invalidated that conclusion. Milner (1993) demonstrated a less pronounced extinction of amphibians, with only one family extinct at the end of the Triassic (plagiosaurids); he showed the disappearance of the capitosaurids, metoposaurids and latiscopids at the Norian-Rhaetian boundary. Moreover, these temnospondyls are only a minor component of Late Triassic tetrapod assemblages, being of low diversity and relatively small numbers in many samples (e.g., Hunt, 1993). Temnospondyl extinction thus largely preceded the Rhaetian.

The global compilation of reptile families by Benton (1993) lists the extinction of 11 terrestrial reptile families at the TJB: Proganochelyidae, Kuehneosauridae, Pachystropheidae, Trilophosauridae, Phytosauridae, Stagonolepididae, Rauisuchidae, Ornithosuchidae, Saltoposuchidae, Thecodontosauridae and Traversodontidae. However, only two of these families, Phytosauridae and Procolophonidae, have well established Rhaetian records (Lucas, 1994), especially given that new data indicate that the uppermost Chinle Group in the western United States is pre-Rhaetian. There is thus no evidence that most of the tetrapod families that disappeared during the Late Triassic were present during the Rhaetian; they apparently became extinct sometime earlier, during the Norian.

The Newark Supergroup body fossil record of tetrapods is inadequate to demonstrate a mass extinction of tetrapods at the TJB, so the tetrapod footprint record in the Newark Supergroup has been used to identify a TJB tetrapod extinction (e.g., Olsen and Sues, 1986; Olsen et al., 2002a,b). However, detailed stratigraphic data on the Newark footprint record (e.g., Szajna and Silvestri, 1996) indicate the disappearance of about 4 ichnogenera and appearance of 2 ichnogenera at the palynologically-determined TJB, with four ichnogenera continuing through this boundary; this does not qualify as a sudden mass extinction. Avanzini et al. (1997) described a diverse track assemblage in peritidal sediments of the Southern Alps of Italy of earliest Hettangian age, which negates the idea advocated by some of low tetrapod diversity during the earliest Jurassic.

The discussion of tetrapod footprint evidence of a TJB mass extinction by Olsen et al. (2002a, b) argued that the sudden appearance of large theropod tracks (ichnogenus *Eubrontes*) in the earliest Jurassic strata of the Newark Supergroup indicates a dramatic size increase in theropod dinosaurs at the TJB. They interpreted this as the result of a rapid (thousands of years) evolutionary response by the theropod survivors of a mass extinction and referred to it as "ecological release" (Olsen et al., 2002a, p. 1307). They admitted, however, that this hypothesis can be invalidated by the description of *Dilophosaurus*-sized theropods or diagnostic *Eubrontes giganteus* tracks in verifiably Triassic-age strata.

Indeed, large, *Dilophosaurus*-size theropods have been known from the Late Triassic body-fossil record since the 1930s: *Liliensternus* from the Norian of Germany (estimated length of ~ 5 m) and *Gojirosaurus* from the Norian of the USA (estimated length ~ 5.5 m) (Huene, 1934; Welles, 1984; Carpenter, 1997). *Dilophosaurus* has an estimated length of 6 m, and the foot of *Liliensternus* is 92% (based on maximum length) the size of that of *Dilophosaurus*. Clearly, theropods capable of making *Eubrontes*-size tracks were present during the Norian, and the sudden abundance of these tracks in the Newark Supergroup at the beginning of the Jurassic cannot be explained simply by rapid evolution to large size of small theropods following a mass extinction.

Also, tracks of large theropod dinosaurs (ichnogenus *Eubrontes*) have long been known from the Triassic of Australia (Staines and Woods, 1964; Hill et al., 1965; Bartholomai, 1966; Molnar, 1991; Thulborn, 1998), further invalidating the "ecological release" hypothesis. These tracks (Fig. 3) are from the Blackstone Formation of the Ipswich Coal Measures near Dinmore in southeastern Queensland, a unit of well-established Triassic age (probably late Carnian: Balme and Foster, 1996). The largest tracks are 43 cm long and 38 cm wide (Fig. 3) and closely resemble tracks of *Eubrontes giganteus* from the Newark Supergroup described by Olsen et al. (1998).

Thulborn (2003) argued that the Australian Triassic record of *Eubrontes* refutes the notion that its first occurrence is at the TJB. Olsen et al. (2003), nevertheless, claimed that the Australian *Eubrontes* tracks are actually tridactyl underprints of a pentadactyl chirothere track. However, the footprint of *Eubrontes* is mesaxonic (symmetrical around its long axis), as are the Australian *Eubrontes* tracks (Fig. 3). Tridactyl underprints of chirotheres are paraxonic (asymmetrical around their long axis). Therefore, the *Eubrontes* tracks from the Upper Triassic of Australia are correctly identified. The concept of a sudden appearance of *Eubrontes* tracks due to "ecological release" at the TJB thus was refuted decades before it was proposed by Olsen et al. (2002a, b).

PLANTS

Ash (1986) reviewed the global record of megafossil plants and concluded that changes across the TJB boundary primarily involved seed ferns, in particular, the loss of the families Glossopteridaceae, Peltaspermaceae, and Corystospermaceae (also see Traverse, 1988). The TJB in East Greenland is marked by the transition from the *Lepidopteris* Zone to the *Thaumatopteris* Zone, with few species in common. The former is characterized by the presence of palynomorphs including *Rhaetipollis*, while the latter contains *Heliosporites* (Pedersen and Lund, 1980), and although extinction of some species across the transition between the two zones is evident, many species continue. Thus, no catastrophic extinction is documented. This accords well with the global compilations at the species and family levels that show no substantial extinction at the TJB (Niklas et al., 1983; Knoll, 1984; Edwards, 1993; Cleal, 1993a, b). Nevertheless, McElwain et al. (1999) claimed a 95% extinction of leaf species for northern Europe (East Greenland and Scania) at the TJB, but this supposed extinction has not been confirmed over a wider area.

The palynological record provides no evidence for mass extinction at the TJB. Fisher and Dunay (1981) demonstrated that a significant proportion of the *Rhaetipollis germanicus* assemblage that defines the Rhaetian in Europe (Orbell, 1973; Schuurman, 1979) persists in lowermost Jurassic strata. Indeed, a study of the British Rhaeto-Liassic by Orbell (1973) found that of 22 palynomorphs identified in the *Rhaetipollis* Zone, only 8 disappeared completely in the overlying *Heliosporites* Zone. These authors, as well as Brugman (1983) and Traverse (1988), have concluded that floral turnover across the TJB was gradual, not abrupt. Kelber (1998) also described the megaflora and palynoflora for Central Europe in a single unit he termed "Rhaeto-Liassic," and concluded there was no serious disruption or decline in plant diversity across the TJB.

Nevertheless, profound palynomorph extinction at the TJB has been argued from the Newark Supergroup record (Olsen and Sues, 1986; Olsen et al., 1990; Fowell and Olsen, 1993; Olsen et al., 2002a,b). Notably, the palynomorph taxa used to define the TJB in the European sections (*Rhaetipollis germanicus* and *Heliosporites reissingeri*: Orbell, 1973) are not present in the Newark Supergroup basins, so placement of the palynological TJB in these basins was initially based on a graphic correlation of palynomorph records (Cornet, 1977). More recent work identified the TJB in the Newark by a decrease in diversity of the pollen assemblage, defined by the loss of palynomorphs considered typical of the Late Triassic, and dominance by several species of the genus *Corollina*, especially *C. meyeriana* (Cornet and Olsen, 1985; Olsen et al., 1990; Fowell and Olsen, 1993; Fowell et al., 1994; Fowell and Traverse, 1995).

Nevertheless, this method of defining the system boundary is compromised by regional variations in the timing of the *Corollina* peak. In the classic Kendelbach section, for example, the peak abundance of *C. meyeriania* occurs in beds of Rhaetian and older age (Kössen Formation: Morbey, 1975), as it does in Tibet (Hallam et al., 2000). But, in Australia this peak may not occur until mid-Hettangian (Helby et al., 1987). Thus, abundance patterns of *Corollina* spp. are not a reliable indicator of the TJB. Furthermore, apparent extinction of palynomorphs in the Newark Supergroup basins does not match other megafossil data from the Newark Supergroup, which suggest that any extinction effects represented by these data are strictly local.

Prospectus

Two hundred years of fossil collecting failed to document a global mass extinction at the TJB, yet 20 years of literature compilation and the CCE did. The myth of a single mass extinction at the TJB has led to a search for the cause of the "mass extinction" ("those weapons of mass destruction must be around here somewhere") and drawn attention away from what were actually a series of extinctions that took place throughout the Late Triassic. Research now needs to focus on these multiple extinctions and their causes, not on a single extinction event. Perhaps the most interesting question not yet addressed by most researchers is why this prolonged (at least 20 million years) interval of elevated extinction rates occurred during the Late Triassic?

References

Aldridge, R. J., Smith, M. P. 1993. Conodonta. In: Benton, M. J. (Ed.), The Fossil Record 2. Chapman & Hall, London, pp. 563-572.

Allasinaz, A. 1992. The Late Triassic-Hettangian bivalve turnover in Lombardy (Southern Alps). Rivista Italiana Paleontologia Stratigrafia, 97: 431-454.

Ash, S. 1986. Fossil plants and the Triassic-Jurassic boundary. In: Padian, K. (Ed.), The Beginning of the Age of Dinosaurs. Cambridge Univ. Press, Cambridge, UK, pp. 21-30.

Avanzini, M., Frisia, S., van den Driessche, K., Keppens, E., 1997. A dinosaur tracksite in an early Liassic tidal flat in northern Italy: paleoenvironmental reconstruction from sedimentology and geochemistry. Palaios, 12: 538-551.

Balme, B.F., Foster, C.B., 1996. Triassic (chart 7). In: Young, G.C., Laurie, J.R. (Eds.), An Australian Phanerozoic Timescale. Oxford Univ. Press, Melbourne, pp. 136-147.

Bartholomai, A., 1966. Fossil footprints in Queensland. Australian Natural History, 15: 147-150.

Beauvais, L., 1984. Evolution and diversification of Jurassic Scleractinia. Palaeontographia Americana, 54: 219-224.

Benton, M.J., 1993. Reptilia. In: Benton, M. J. (Ed.), The Fossil Record 2. Chapman & Hall, London, pp. 681-715.

Benton, M.J., 1994. Late Triassic to Middle Jurassic extinctions among continental tetrapods: testing the pattern. In: Fraser, N.C., Sues, H-D. (Eds.), In the Shadow of the Dinosaurs. Cambridge Univ. Press, Cambridge, UK, pp. 366-397.

Brugman, W.A., 1983. Permian-Triassic palynology. Utrecht, State University Utrecht, 121 pp.

Carpenter, K., 1997. A giant coelophysoid (Ceratosauria) theropod from the Upper Triassic of New Mexico, USA. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 205: 189-208.

Carter, E. S., 1994, 1994. Evolutionary trends in latest Norian through Hettangian radiolarians from the Queen Charlotte Islands, British Columbia. Geobios Mémoire Spécial, 17: 111-119.

Carter, E. and Hori, R., 2003. Extinction and recovery of radiolarians at the Triassic-Jurassic boundary in Queen Charlotte Islands: implications for global productivity collapse. Geological Association of Canada, Vancouver 2003 Meeting, Abstracts Volume, 28: CD-ROM.

Cirilli, S., Galli, M.T., and Jadoul, F., 2003. Carbonate platform evolution and sequence stratigraphy at Triassic/Jurassic boundary in the Western Southern Alps of Lombardy (Italy): an integrated approach of litho-palynofacies analysis. Geological Association of Canada, Vancouver 2003 Meeting, Abstracts Volume, 28: CD-ROM.

Clark, D.L., 1980. Rise and fall of Triassic conodonts. American Association of Petroleum Geologists Bulletin, 64: 691.

Clark, D.L., 1981. Extinction of Triassic conodonts. Geologische Bundesanstalt Abhandlungen, 35: 193-195.

Clark, D.L., 1983. Extinction of conodonts. Journal of Paleontology, 57: 652-661.

Cleal, C.J., 1993a. Pteridophyta. In: Benton, M.J. (Ed.), The Fossil Record 2. Chapman & Hall, London, pp. 779-794.

Cleal, C.J., 1993b. Gymnospermophyta; in Benton, M. J., ed., The Fossil Record 2. London, Chapman & Hall, p. 795-808.

Colbert, E.H. 1949. Progressive adaptations as seen in the fossil record. In: Jepsen, G.L., Mayr, E., Simpson, G.G. (Eds.), Genetics, Paleontology and Evolution. Princeton University Press, Princeton, NJ, pp. 390-402.

Colbert, E.H., 1958. Triassic tetrapod extinction at the end of the Triassic Period. Proceedings National Academy Science USA, 44: 973-977.

Cornet, B., 1977. The palynostratigraphy and age of the Newark Supergroup. Ph.D. Thesis. Pennsylvania State University, University Park, PA, 505 pp.

Cornet, B. and Olsen, P.E., 1985. A summary of the biostratigraphy of the Newark Supergroup of eastern North America with comments on provinciality. In: Weber, R. (editor), III Congreso Latinoamericano de Paleontolia Mexico, Simposio Sobre Floras del Triasico Tardio, su Fitogeografia y Palecologia, Memoria. UNAM Instituto de Geologia, Mexico City, pp. 67-81.

Cuny, G., 1995. French vertebrate faunas and the Triassic-Jurassic boundary.

Palaeogeography, Palaeoclimatology, Palaeoecology, 119: 343-358.

Dagys, A.S. and Dagys, A.A., 1994. Global correlation of the terminal Triassic. Mémoire de Géologie (Lausanne), 22: 25-34.

Edwards, D., 1993. Bryophyta. In: Benton, M.J. (Ed.), The Fossil Record 2. Chapman & Hall, London, pp. 775-778.

Fisher, M. J.and Dunay, R.E., 1981. Palynology and the

Triassic/Jurassic boundary. Review of Palaeobotany and Palynology, 34: 129-135.

Flügel, E., 1975. Fossile Hydrozoan—Kenntnisse und Probleme. Paläontologische Zeitschrift, 49: 369-406.

Fowell, S.J. and Olsen, P.E., 1993. Time calibration of Triassic-Jurassic microfloral turnover, eastern North America. Tectonophysics, 222: 361-369.

Fowell, S.J. and Traverse, A., 1995. Palynology and age of the upper Blomidon Formation, Fundy basin, Nova Scotia. Review of Palaeobotany and Palynology, 86: 211-233.

Fowell, S.J., Cornet, B. and Olsen, P.E., 1994. Geologically rapid Late Triassic extinctions: palynological evidence from the Newark Supergroup. Geological Society of America Special Paper, 288: 197-206.

Guex, J., Bartolini, A., Taylor, D., 2002. Discovery of *Neophyllites* (Ammonita, Cephalopoda, early Hettangian) in the New York Canyon sections (Gabbs Valley Range, Nevada) and discussion of the ~^{13}C negative anomalies located around the Triassic-Jurassic boundary. Bulletin Société Vaudoise Sciences Naturelles, 88.2: 247-255.

Guex, J., Bartolini, A., Atudorei, V. and Taylor, D., 2003. Two negative $\delta^{13}C_{org}$ excursions near the Triassic-Jurassic boundary in the New York Canyon area (Gabbs Valley Range, Nevada). Bulletin de Géologie Lausanne, 360: 1-4.

Hallam, A., 1981. The end-Triassic bivalve extinction event. Palaeogeography, Palaeoclimatology, Palaeoecolology, 35: 1-44.

Hallam, A., 2002. How catastrophic was the end-Triassic mass extinction? Lethaia, 35: 147-157

Hallam, A. and Goodfellow, W. D., 1990. Facies and geochemical evidence bearing on the end-Triassic disappearance of the Alpine reef ecosystem. Historical Biology, 4: 131-138.

Hallam, A. and Wignall, P.B., 1997. Mass Extinctions and their Aftermath. Oxford University Press, Oxford, 320 pp.

Hallam, A. and Wignall, P.B., 2000. Facies changes across the Triassic-Jurassic boundary in Nevada, USA. Journal Geological Society (London), 157: 49-54.

Hallam, A., Wignall, P.B., Yin, J. and Riding, J.B., 2000. An investigation into possible facies changes across the Triassic-Jurassic boundary in southern Tibet. Sedimentary Geology, 137: 101-106.

Helby, R.J., Morgan, R. and Partridge, A.D., 1987. A palynological zonation of the Australian Mesozoic: Memoir Assocaiation Australian Paleontology, 4: 1-94.

Hill, D., Playford, G. and Woods, J.T. (Eds.), 1965. Triassic fossils of Queensland. Queensland Palaeontographical Society, Brisbane, 32 pp.

Hori, R., 1992. Radiolarian biostratigraphy at the Triassic/Jurassic period boundary in bedded cherts from the Inuyama area, central Japan. J. Geosci., Osaka City Univ. 35, 53-65.

Huene, F. von, 1934. Ein neuer Coelurosaurier in der thüringischen Trias. Paläontologische Zeitschrift, 16: 145-170.

Hunt, A.P., 1993. A revision of the Metoposauridae (Amphibia: Temnospondyli) of the Late Triassic with description of a new genus from the western United States. Museum Northern Arizona Bulletin, 59: 67-97.

Johnson, L.A. and Simms, M.J., 1989. The timing and cause of Late Triassic marine invertebrate extinctions: evidence from scallops and crinoids. In: Donovan, S.K. (Ed.), Mass Extinctions: Processes and Evidence. Columbia Univ. Press, New York, pp. 174-194.

Kelber, K.-P., 1998. Phytostratigraphische aspekte der makrofloren des süddeutschen Keupers. Documenta Naturae, 117: 89-115.

Kennedy, W.J., 1977. Ammonite evolution. In: Hallam, A. (Ed.), Patterns of Evolution as Illustrated in the Fossil Record. Elsevier, Amsterdam, pp. 251-304.

Kidder, D.L. and Erwin, D.H., 2001. Secular distribution of biogenic silica through the Phanerozoic: comparison of silica-replaced fossils and bedded cherts at the series level. Journal of Geology, 109: 509-522.

Kiessling, W., 2001. Paleoclimatic significance of Phanerozoic reefs. Geology, 29: 751-754.

Knoll, A.H., 1984. Patterns of extinction in the fossil record of vascular plants. In: Nitecki, M.H. (Ed.), Extinction. University of Chicago Press, Chicago, pp. 21-68.

Lucas, S.G., 1994. Triassic tetrapod extinctions and the compiled correlation effect. Canadian society Petroleum Geologists Memoir, 17: 869-875.

McElwain, J.C., Beerling, D.J.a nd Woodward, F.I., 1999. Fossil plants and global warming at the Triassic-Jurassic boundary. Science, 285: 1386-1390.

McRoberts, C.A., 1994. The Triassic-Jurassic ecostratigraphic transition in the Lombardian Alps, Italy. Palaeogeography, Palaeoclimatology, Palaeoecology, 110: 145-166.

McRoberts, C. A. and Newton, C. R., 1995, Selective extinction among end-Triassic European bivalves. Geology, 23: 102-104.

McRoberts, C.A., Furrer, H. and Jones, D.S., 1997. Palaeoenvironmental interpretation of a Triassic-Jurassic boundary section from western Austria based on palaeoecological and geochemical data. Palaeogeography, Palaeoclimatology, Palaeoecology, 136: 79-95.

McRoberts, C.A., Newton, C.R. and Allasinaz, A., 1995. End-Triassic bivalve extinction: Lombardian Alps, Italy. Historical Biology, 9: 297-317.

Milner, A.R., 1993. Amphibian-grade Tetrapoda. In: Benton, M. J. (Ed.), The Fossil Record 2. Chapman & Hall, London, pp. 665-679.

Milner, A.R., 1994. Late Triassic and Jurassic amphibians: Fossil record and phylogeny. In: Fraser, N.C., Sues, H-D. (Eds.), In the Shadow of the Dinosaurs. Cambridge Univ. Press, Cambridge, UK, pp. 5-22.

Molnar, R.E., 1991. Fossil reptiles in Australia. In: Vickers-Rich, P., Monaghan, J.M., Baird, R.F., Rich, T.H. (Eds.), Vertebrate Palaeontology of Australasia. Pioneer Design Studio, Melbourne, pp. 605-702.

Morbey, J.S., 1975. The palynostratigraphy of the Rhaetian stage, Upper Triassic in the Kendelbachgraben, Austria. Palaeontographica B, 152:1-75.

Mostler, H., Scheuring, R. and Ulrichs, M., 1978. Zur Mega-, Mikrofauna und Mikroflora der Kossenen Schichten (alpine Obertrias) von Weissloferbach in Tirol unter besonderer Berucksichtigung der in der suessi- und marshi- Zone auftreitenden Conodonten. Osterreichische Akademie der Wissenschaften Erdwissenschaftliche Kommission Schriftenreihe 4, 141-174.

Niklas, K.J., Tiffney, B.H. and Knoll, A.H., 1983. Patterns in vascular land plant diversification: A statistical analysis at the species level. Nature, 303: 614-616.

Olsen, P.E. and Sues, H-D., 1986. Correlation of continental Late Triassic and Early Jurassic sediments, and patterns of the Triassic-Jurassic tetrapod transition. In: Padian, K., (Ed.), The Beginning of the Age of Dinosaurs. Cambridge Univ. Press, Cambridge, UK, pp. 321-351.

Olsen, P.E., Fowell, S.J. and Cornet, B., 1990. The Triassic/Jurassic boundary in continental rocks of eastern North America; a progress report. Geological Society of America Special Paper, 247: 585-593.

Olsen, P.E., Shubin, N.H. and Anders, M.H., 1987. New Early Jurassic tetrapod assemblages constrain Triassic-Jurassic tetrapod extinction event. Science, 237: 1025-1029.

Olsen, P.E., Smith, J.B. and McDonald, N.G., 1998. Type material of the type species of the classic theropod footprint genera *Eubrontes*, *Anchisauripus*, and *Grallator* (Early Jurassic, Hartford and Deerfield basins, Connecticut and Massachusetts, U. S. A.): Journal of Vertebrate Paleontology, 18: 586-601.

Olsen, P.E., Kent, D.V., Sues, H.D., Koeberl, C., Huber, H., Montanari, A., Rainforth, E.C., Powell, S.J., Szajna, M.J.and Hartline, B.W., 2002a. Ascent of dinosaurs linked to an iridium anomaly at the Triassic-Jurasic boundary. Science, 296: 1305-1307.

Olsen, P.E., Kent, D.V., Sues, H.D., Koeberl, C., Huber, H., Montanari, A.,

Rainforth, E.C., Powell, S.J., Szajna, M.J.and Hartline, B.W., 2003. Response to comment on “Ascent of dinosaurs linked to an iridium anomaly at the Triassic-Jurassic boundary.” Science, 301: 169c.

Olsen, P.E., Koeberl, C., Huber, H., Montanari, A., Fowell, S.J., Et-Touhani, M., and Kent, D.V., 2002b. The continental Triassic-Jurassic boundary in central Pangea: recent progress and preliminary report of an Ir anomaly. Geological Society of America Special Paper, 356: 505-522.

Orbell, G., 1973. Palynology of the British Rhaeto-Liassic. Bulletin Geological Society Great Britain, 44: 1-44.

Orchard, M. J., 1991. Upper Triassic conodont biochronology and new index species from the Canadian Cordillera. Geological Survey Canada, Bulletin, 417: 299-335.

Orchard, M. J., 2003.Changes in conodont faunas through the Upper Triassic and implications for boundary definitions. Geological Association of Canada, Vancouver 2003 Meeting, Abstracts Volume, 28: CD-ROM.

Pálfy, J., 2003. Volcanism of the central Atlantic magmatic province as a potential driving force in the end-Triassic mass extinction. AGU Geophysical Monograph, 136: 255-267.

Pedersen, K.R.and Lund, J.J., 1980. Palynology of the plant-bearing Rhaetian to Hettangian Kap Stewart Formation, Scoresby Sund, East Greenland. Review of Palaeobotany and Palynology, 31: 1-69.

Racki, G., 2003. Silica-secreting biota and mass extinctions: survival patterns and processes. Palaeogeography, Palaeoclimatology, Palaeoecology, 154: 107-132.

Schuurman, W. M. L., 1979. Aspects of Late Triassic palynology. 3. Palynology of latest Triassic and earliest Jurassic deposits of the northern limestone Alps in Austria and southern Germany, with special reference to a palynological characterization of the Rhaetian stage in Europe. Review of Palaeobotany and Palynology, 27: 53-75.

Sepkoski, J. J., Jr., 1982. Mass extinctions in the Phanerozoic oceans: A review. Geological Society of America Special Paper, 190: 283-289.

Signor, P.W. III and Lipps, J.H., 1982. Sampling bias, gradual extinction patterns and catastrophes in the fossil record. Geological Society of America Special Paper,190: 291-296.

Simms, M.J. and Ruffell, A.H., 1990. Climatic and biotic change in the Late Triassic. Journal Geological Society (London), 147: 321-327.

Skelton, P.W. and Benton, M.J., 1993. Mollusca: Rostroconchia, Scaphopoda and Bivalvia. In: Benton, M.J. (Ed.), The Fossil Record 2. Chapman & Hall, London, pp. 237-263.

Staines, H.R.E. and Woods, J.T., 1964. Recent discovery of Triassic dinosaur footprints in Queensland. Australian Journal of Science, 27: 55.

Stanley, G. D., Jr., 1988. The history of early Mesozoic reef communities: a three-step process. Palaios, 3: 170-183.

Sweet, W.C., 1988. The Conodonta. Clarendon Press, New York, 212 pp.

Szajna, M. J. and Silvestri, S. M., 1996, A new occurrence of the ichnogenus *Brachychirotherium*: Implications for the Triassic-Jurassic mass extinction event. Museum of Northern Arizona Bulletin, 60: 275-283.

Tanner, L. H., Lucas, S. G. and Chapman, M. G., 2004. Assessing the record and causes of late triassic extinctions. Earth-Science Reviews, 65: 103-139.

Taylor, D.G., Boelling, K. and Guex, J., 2000. The Triassic/Jurassic System boundary in the Gabbs Formation, Nevada. In: Hall, R.L., Smith, P.L. (Eds.), Advances in Jurassic Research 2000. Tran Tech Publications LTD, Zurich, pp. 225-236.

Taylor, D.G., Guex, J. and Rakus, M., 2001. Hettangian and Sinemurian ammonoid zonation for the western Cordillera of North America. Bulletin de Géologie de l'Université de Lausanne, 350: 381-421.

Teichert, C., 1988. Crises in cephalopod evolution. In: Marois, M. (Ed.), L'évolution dans sa Réalité et ses Diverses Modalités. Fondation Singer-Polignac, Paris, pp. 7-64.

Thulborn, T. 1998. Australia's earliest theropods: footprint evidence in the Ipswich Coal Measures (Upper Triassic) of Queensland. Gaia, 15: 301-311.

Thulborn, T., 2003. Comment on "Ascent of dinosaurs linked to an iridium anomaly at the Triassic-Jurassic boundary." Science, 301: 169b.

Tipper, H.W., Carter, E.S., Orchard, M.J. and Tozer, E.T., 1994. The Triassic-Jurassic (T-J) boundary in Queen Charlotte Islands, British Columbia defined by ammonites, conodonts, and radiolarians. Geobios Mémoire Special, 17: 485-492.

Traverse, A., 1988. Plant evolution dances to a different beat. Historical Biology, 1: 277-301.

Ulrichs, M., 1972. Ostracoden aus den Kössener Schichten und ihre Abhängigkeit von der Ökologie. Mitteilungen der Gesellschaft der Geologie- und Bergbaustudenten in Österrich, 21: 661-710.

Vishnevskaya, V., 1997. Development of Palaeozoic-Mesozoic Radiolaria in the northwestern Pacific rim. Marine Micropalaeontology, 30: 79-95.

Ward, P.D., Haggart, J.W., Carter, E.S., Wilbur, D., Tipper, H.W. and Evans, T., 2001. Sudden productivity collapse associated with the Triassic-Jurassic boundary mass extinction. Science, 292: 1148-1151.

Welles, S.P., 1984. *Dilophosaurus wetherilli* (Dinosauria, Theropoda) osteology and comparisons. Palaeontographica A, 185: 85-180.

Preliminary paleomagnetic results from the Permian-Triassic boundary interval, Central and NW Iran

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Introduction

The global character of geomagnetic polarity reversals has made magnetostratigraphy an essential tool for precise facies-independent correlation between different depositional environments. Because of the absence of pre-Jurassic seafloor in present oceans and thus marine magnetic anomalies, magnetostratigraphy in Permian and Triassic sections requires good biostratigraphic control. By decision of the IUGS the Global Stratotype Section and Point (GSSP) of the Permian-Triassic boundary (PTB) is now the Meishan section D (China), base of bed 27c, at the first appearance of the conodont *H. parvus* (e.g., Yin et al. 2001), providing a point of reference for both magnetostratigraphic and biostratigraphic investigations. In the last two decades, significant progress has been made in constructing a geomagnetic polarity scale for the PTB interval (e.g., Heller et al. 1988, Steiner et al. 1989, Li & Wang 1989, Ogg & Steiner 1991, Zakharov & Sokarev 1991, Heller et al. 1995, Hounslow et al. 1996, Nawrocki 1997, Scholger et al. 2000, Gallet et al. 2000, Szurlies et al. 2003).

With respect to magneto- and biostratigraphy, two main correlation problems are present at the PTB. First, there are published different geomagnetic polarity patterns for the *C. meishanensis-H. praeparvus* and *H. parvus* zones at Meishan (Li & Wang 1989, Zhu & Liu 1999). Secondly, in several studies the base of the thick normal magnetozone around the PTB is regarded as the PTB (e.g., Steiner et al. 1989, Ogg & Steiner 1991, Scholger et al. 2000, Gallet et al. 2000, Jin et al. 2000), whereas in others it is located within the uppermost Permian (e.g., Li & Wang 1989, Zakharov & Sokarev 1991, Szurlies et al. 2003, Bachmann et al. 2003).

The aim of this and a following more detailed study of the PTB interval from the Jolfa section of NW Iran is to examine the base and size of the thick normal magnetozone around the PTB using both magnetostratigraphy and high-resolution conodont zonation (Kozur, in press).

Remarks to magnetostratigraphies around the Permian-Triassic boundary

Li & Wang (1989) presented a magnetostratigraphy for the Meishan section, in which the relatively thick normal magnetozone (V) begins at least 1.2 m (or 2.7 m, with the first 1.5 m being of unclear polarity) below the Boundary Clay. According to Mei et al. (1998), the base of this normal interval is situated within the *C. yini-C. zhangi* Zone (Upper Permian). However, recently Zhu & Liu (1999) have shown that the normal magnetozone begins much earlier, just about 5.07 m below the PTB within the upper third of the *C. changxingensis-C. deflecta* Zone well below the *C. yini-C. zhangi* Zone. Consistently, in both polarity patterns the normal magnetozone ranges up to the *I. isarcica* Zone, but in the recent study just around the PTB, there is a 0.06 m thick reversed polarity zone within Bed 27, which is straddling the PTB (two samples below the PTB, one sample above it).

Peng et al. (2001) used these new paleomagnetic data from the GSSP at Meishan for a high-resolution correlation with the Shangsi section (China). They compare Bed 26 from Shangsi, being of reversed polarity with the thin reversed magnetozone of Bed 27 from Meishan. As clearly seen by the fauna and also by carbon isotope data, this correlation cannot be confirmed. Whereas Bed 26 from Shangsi is characterized by a rich conodont fauna, before the event boundary, belonging to the *C. changxingensis-C. deflecta* Zone, Bed 27 from Meishan has a poor conodont fauna, after the event boundary, spanning the upper *H. praeparvus* Zone and the entire *H. parvus* Zone. In terms of magnetostratigraphy, Beds 22-26 from Shangsi show reversed polarity, Bed 27 is of unknown polarity and Beds 28-31 belong to a normal magnetozone (e.g., Heller et al. 1988, Steiner et al. 1989). According to Nicoll et al. (2002), the *H. parvus*-calibrated PTB is located within Bed 30. In addition, around the PTB there is a minimum in the carbon isotope curve (Baud et al. 1989). Correspondingly, the base of the Triassic is located within the relatively thick normal interval, which is extending into the uppermost Permian.

According to results from Abadeh, Central Iran (Gallet et al. 2000), the thick normal magnetozone begins latest somewhat above the Boundary Clay (0.77m above the base of the Boundary Clay). Since the FAD of *H. parvus* is 1.38 m above the base of the Boundary Clay (Kozur 2003), the thick normal interval starts in the uppermost Permian. Between 0.45 m below the Boundary Clay (uppermost sample with reversed polarity) and 0.77m above the Boundary Clay (lowermost sample with normal polarity) is an interval which did not yield palaeomagnetic data by Gallet et al. (2000). Thus, the thick normal interval starts probably already in the uppermost Hambast Formation. Close to the FAD of *H. parvus,* there begin negative values in the carbon isotope curve (Korte et al. in press).

In the Dorasham II-3 section of Azerbaijan the thick normal magnetozone starts at 0.5 m below the top of the *Paratirolites* Beds (Zakharov & Sokarev 1991). The *H. parvus*-calibrated PTB is located more than 1 m above the top of the *Paratirolites* Beds, thus the base of the normal interval is situated in the uppermost Permian. In the only a few kilometer distant Jolfa section (Iran), the corresponding level 0.5 m below the top of the *Paratirolites* beds belongs to the upper *C. yini*-*C. zhangi* Zone. Therefore, paleomagnetic results from the GSSP at Meishan (Li & Wang 1989) and the composite Dorasham (Zakharov & Sokarev 1991) and Jolfa sections from the Azerbaijan-NW Iran region, and from the Abadeh section are in good accordance.

In the Bulla (Pufels) section of the Southern Alps (Italy) the thick normal magnetozone (Scholger et al. 2000) begins close to the boundary between the Bellerophon Limestone Formation and the Tesero Horizon (youngest reversed sample 5 cm below the top of the Bellerophon Limestone Fm, oldest normal sample 5 cm above the base of the Tesero Horizon), distinctly below the FAD of *H. parvus*. The carbon isotope values of the lowermost Tesero Horizon correspond to those of the *C. yini*-*C. zhangi* Zone of Meishan and Jolfa (Korte & Kozur in press). In the WSW-ward situated Siusi (Seis) section the base of the normal magnetozone is located in the interval between 42 cm (uppermost reversed magnetised sample) and 72 cm above the base of the Tesero Horizon (lowermost normal magnetised sample) either within the uppermost Tesero Horizon or within the lowermost Mazzin Member (Scholger et al. 2000). Since the PTB in this section is located some 7 m above the base of the Tesero Horizon, being also indicated by negative values in the carbon isotope curve (Newton et al. 2004), the normal magnetozone is extending into the uppermost Permian. The comparison of the beginning of the normal magnetozone which straddles the PTB in the Bulla and Siusi section indicates a clearly diachronous boundary between the Bellerophon Limestone Formation and the Tesero Horizon which was already postulated by Kozur (1994) and can be also confirmed by stable isotope data (Korte & Kozur, in press).

In the Arctic the FAD of *H. parvus* is within the *T. pascoei* Zone, which is located between the *O. boreale* s.s. and the *Ophiceras commune* zones (Kozur 1998b). In terms of magnetostratigraphy, both ammonite zones belong to an interval of normal polarity, to which belongs also the *O. concavum* Zone (Griesbach Creek, Arctic Canada, Ogg & Steiner 1991). Therefore, also in the Boreal realm the base of the relatively thick normal magnetozone is situ-

Figure 1: Position of the studied Iranian sections
1: Kuh-e-Ali Bashi section, 9 km W of Jolfa village.
2: Shahreza section, 14 km NW of Shahreza village, 3.5 km SE of Shahzadeh Ali Akbar village.
3: Abadeh section, Kuh-e-Hambast, 60 km SE of the town of Abadeh

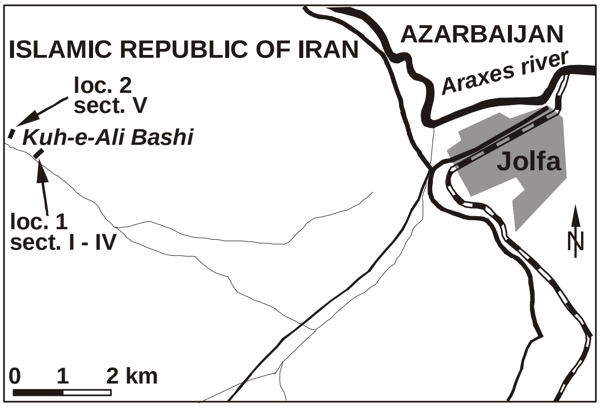

Figure 2: Investigated sections from Kuh-e-Ali Bashi, 9 km SW of Jolfa village (after Korte & Kozur, in press). Palaeomagnetic samples are from section V.

ated within the uppermost Permian.

Summarily, in virtually all well dated marine sections straddling the PTB, there is no reversed horizon around the FAD of *H. parvus*, except the recent study from the GSSP at Meishan (Zhu & Liu 1999).

Preliminary rock and paleomagnetic results from Central and NW Iran

The Iranian sections Abadeh (Conodont Alteration Index, CAI = 3), Shahreza (CAI = 2.5) and Jolfa (CAI = 1) (**Fig. 1**) were sampled for rock and paleomagnetic investigations in order to check the beginning and size of the thick normal interval around the PTB. All these sections were around the PTB on the southern hemisphere between tropic of Capricorn (Abadeh) to about 1000 km north of it (Jolfa), and Shahreza in between. 12 limestone beds were collected, yielding a total of 42 oriented standard (~11 cm^3) paleomagnetic samples. Whereas 26 specimens were subjected to thermal demagnetization, 16 samples were demagnetized by alternating fields. The thermal treatment was performed using an ASC Scientific TD48 oven. Measurements of natural remanent magnetization (NRM) were made using an AGICO JR5A spinner magnetometer. The alternating field demagnetization was performed using the in-line triaxial alternating field demagnetizer of an automatic DC-SQUID 755SRM cryogenic magnetometer (2G Enterprises).

Furthermore, from each horizon one specimen was exposed stepwise, to peak fields of 10 to 2700 mT in order to record complete acquisition curves of isothermal remanent magnetization (IRM). It was applied with a 2G Enterprises 660 pulse magnetizer and measured with a Molyneux MiniSpin fluxgate magnetometer.

The magnetic properties obtained from this preliminary study are similar to results recently presented by Gallet et al. (2000). The NRM intensities of the limestones range between 0.2 and 5.5 mA/m.

In the Abadeh section two horizons were sampled, the first limestone bed above the Boundary Clay (*C. meishanensis-H. praeparvus* Zone) and another one (upper stromatolithe layer) located ~1.8 m above the base of the Boundary Clay (*H. parvus* Zone). All 5 specimens reveal a rather strong present-day overprint. It is removed below 300°C, with the majority of NRM unblocked below 150°C and linked to a high coercivity component not reaching saturation of IRM by 2.7 T, indicating the presence of goethite. Demagnetization to higher temperatures yielded scattered directions. Thus, no identifiable characteristic component of ancient origin is apparently present in these samples. Only one specimen from the *H. parvus* Zone reveals an isolable high temperature component with a maximum unblocking temperature of 570°C. It is linked with a low coercivity component saturated between 100 and 200 mT, which can be ascribed to magnetite. It has a shallow negative inclination and a southeastward declination, similar to recently obtained data (Besse et al. 1998, Gallet et al. 2000). It is regarded as a primary component, aquired during a geomagnetic field of normal polarity.

In the Shahreza section three horizons around the PTB were sampled, yielding a total of 10 specimens. In most cases, the samples are characterized by a strong recent overprint, with the majority of NRM, being unblocked below 200°C, which is attributed to goethite. Above 200°C most samples are indicated by scattered directions, being similar to results obtained from the Abadeh section. Only two samples from a horizon 7-11 cm below the base of the Boundary Clay (around the boundary between the *C. iranica* Zone and *C. hauschkei* Zone of upper Dorashamian) reveal a characteristic component aquired during a normal geomagnetic field. It is carried by a low coercivity component, aquiring majority of IRM below 100 mT and being unblocked at maximum blocking temperatures of 580°C, ascribed to the presence of magnetite.

In the Jolfa section (**Figs. 2, 3**) seven horizons were investigated, yielding a total of 27 specimens. The IRM acquisition curves are all similar in shape acquiring the majority of IRM in fields smaller than 100 mT, but not reaching saturation by 2700 mT. At first, a weak local present-day overprint with maximum unblocking temperatures of 250°C is removed. Usually, above 250°C with maximum unblocking temperatures of 560-580°C a further component is isolated and interpreted as characteristic remanence, carried by magnetite. Only in specimens from site P1 the high-temperature component is characterized by maximum unblocking temperature of 670°C and linked with a high-coercivity component, being saturated between 500 and 1000 mT, indicating the presence of hematite.

Whereas specimens of site P0 from the upper *C. changxingensis-C. deflecta* Zone were magnetized during a reversed geomagnetic field, all other samples (P0A-P5) from the *C. hauschkei, H. parvus* and *I. isarcica* zones aquired their magnetization during a normal geomagnetic field. These preliminary data are consistent with results

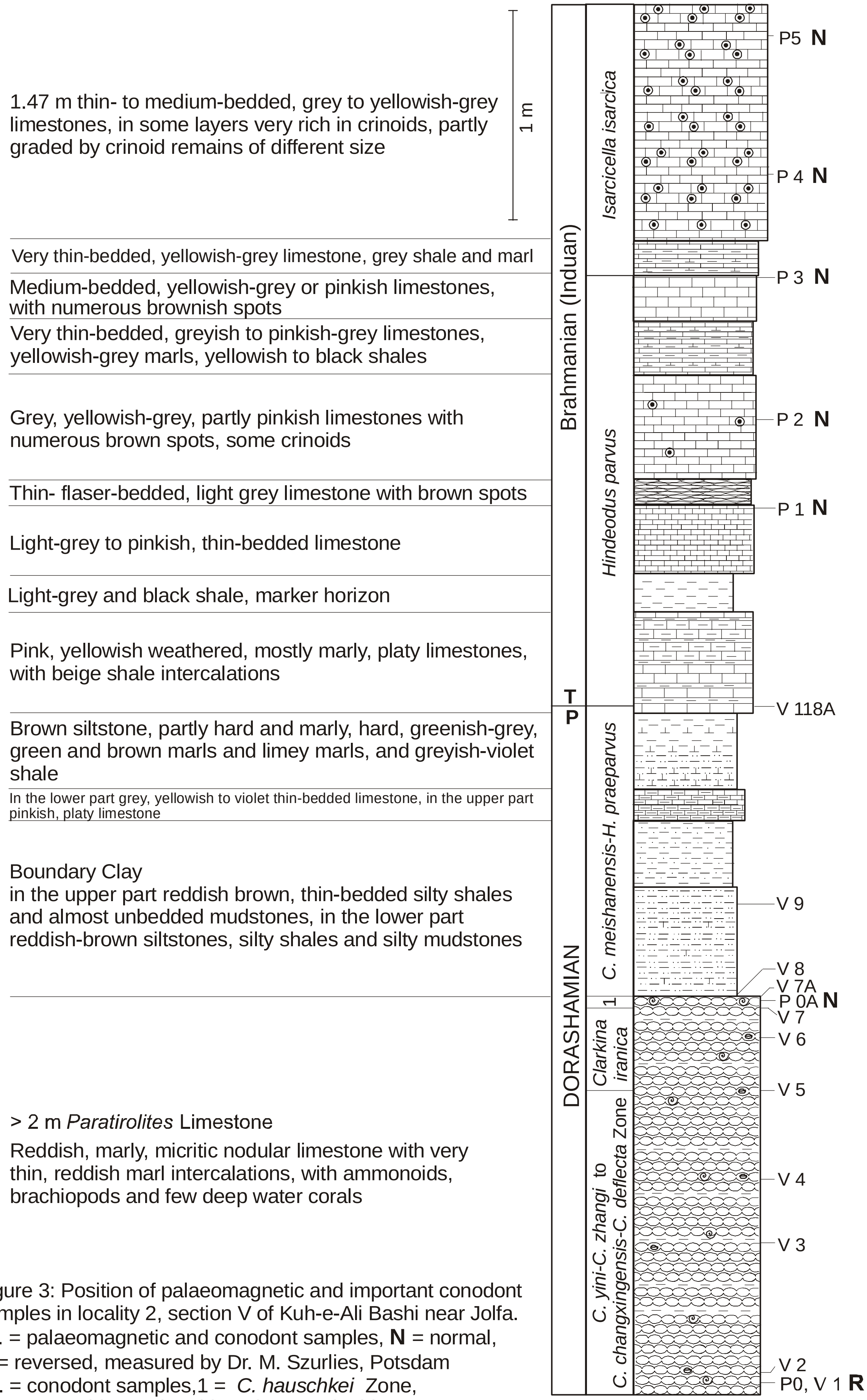

Figure 3: Position of palaeomagnetic and important conodont samples in locality 2, section V of Kuh-e-Ali Bashi near Jolfa. P... = palaeomagnetic and conodont samples, **N** = normal, **R** = reversed, measured by Dr. M. Szurlies, Potsdam V... = conodont samples,1 = *C. hauschkei* Zone, ◎ = ammonoids, ⊖ = brachiopods, ⊙ = crinoids

from Azerbaijan (Zakharov & Sokarev 1991).

Conclusions

As to expect from the Conodont Alteration Index (CAI), the Jolfa section (Kuh-e-Ali Bashi, locality 2, section V) has brought the best paleomagnetic results. In future, this section will be studied in detail. Preliminary results suggest, that the PTB does not coincide with the base of the thick normal magnetozone, but that interval straddles the boundary extending into the uppermost Permian.

Including the beginning of the normal interval 0.5 m below the top of the *Paratirolites* beds in the nearby Dorasham II-3 section in Azerbaijan (Zakharov & Sokarev, 1991) some kilometers toward the north of the Jolfa section, the upper *C. yini-C. zhangi* Zone (proven in Dorasham II-3, Zakharov & Sokarev, 1991), the *C. hauschkei* Zone (proven in Jolfa), the *C. iranica* Zone (proven in Shahreza), the *C. meishanensis-H. praeparvus* Zone (proven in Abadeh, Gallet et al., 2000), the *H. parvus* Zone (proven in Abadeh, Gallet et al., 2000, and confirmed by our rather weak data from this locality and our good data from Jolfa), and the lower and middle *I. isarcica* Zone (proven in Jolfa) belong to the normal interval which straddles the PTB. Beneath, the upper third of the *C. changxingensis-C. deflecta* Zone (proven in Jolfa), and perhaps the lower part of the *C. yini-C. zhangi* Zone (no data) belongs to a short reversed Zone.

Presented preliminary results and previous studies around the *H. parvus*-calibrated PTB (e.g., Heller et al. 1988, Zakharov & Sokarev 1991, Scholger et al. 2000) confirm the paleomagnetic data published by Li & Wang (1989) from the GSSP at Meishan. Furthermore, the results confirm the position of the PTB within the lower Calvörde Formation of the Lower Buntsandstein (e.g., Kozur, 1989, 1998a, 1999, Szurlies, 2001), situated within the lower part of the thick normal interval (sn1) (Szurlies, 2001, Bachmann et al., 2003, Kozur, 2003, Szurlies et al. 2003). The underlying thin reversed Zone (zrz) (Szurlies at al., 2003) corresponds to the upper third of the *C. changxingensis-C. deflecta* Zone, and to the lower part of the *C. yini-C. zhangi* Zone. In the Germanic Basin it comprises the lower Fulda Formation and the basal part of the overlying upper Fulda Fm (Szurlies et al. 2003).

References

Bachmann, G.H., Kozur, H.W. & Szurlies, M. (2003):Cyclostratigraphy, magnetostratigraphy and microspherules of the continental Permian-Triassic Boundary interval, Germany.- XVth Intern. Congr. on Carboniferous and Permian Stratigraphy, Abstracts Volume, 36-38, August 2003, Utrecht.

Baud, A., Magaritz, M. & Holser, W.T. (1989): Permian-Triassic of the Tethys: Carbon isotope studies.- Geol. Rdsch., **78**(2): 649-677.

Besse et al. (1998): Late Permian to Late Triassic palaeomagnetic data from Iran: constraints on the migration of the Iranian block through the Tethyan Ocean and initial destruction of Pangaea.- Geophys. J. Int., **135**: 77-92.

Gallet, Y., Krystyn, L., Besse, J. & Saidi, A. (2000): New constraints on the Upper Permian and Lower Triassic geomagnetic polarity timescale from the Abadeh section (central Iran).- J. Geophys. Res., **105** (B2): 2805-2815.

Heller, F., Lowrie, W., Li, H.M. & Wang, J.D. (1988): Magnetostratigraphy of the Permian-Triassic boundary section at Shangsi.- Earth. Planet. Sci. Lett., **88**: 348-356.

Heller, F., Chen H., Dobson, J. & Haag, M. (1995): Permian-Triassic magnetostratigraphy - new results from South China.- Physics Earth Planet. Inter., **89**: 281-295.

Hounslow, M.W., Mørk, A. Peters, C. & Weitschat, W. (1996): Boreal Lower Triassic magnetostratigraphy from Deltadalen, Central Svalbard.- Albertiana, **17**: 3-10.

Jin, Y., Shang, Q. & Cao C. (2000): Late Permian magnetostratigraphy and its global correlation.- Chinese Sci. Bull., **45**(8): 698-704.

Korte, C. & Kozur, H.W. (in press): Carbon isotope stratigraphy across the Permian/Triassic boundary at Jolfa (NW-Iran), Sass de Putia, Pufels/Bulla, Tesero (Southern Alps).- GeoAustria.

Korte, C., Kozur, H.W., Joachimski, M.M., Strauss, H. Veizer, J. & Schwark, L. (in press): Carbon, sulfur, oxygen and strontium isotope records, organic geochemistry and biostratigraphy across the Permian/Triassic boundary in Abadeh, Iran.- Int. Earth Sci.

Kozur, H. (1989): The Permian-Triassic boundary in marine and continental sediments.- Zbl. Geol. Paläont., **1988** (11/12): 1245-1277.

Kozur, H. (1994): The correlation of the Zechstein with the marine Standard.- Jb. Geol. B.-A., **137**(1): 85-103.

Kozur, H.W. (1998a): Some aspects of the Permian-Triassic boundary (PTB) and of the possible causes for the biotic crisis around this boundary.- Palaeogeogr., Palaeoclimatol., Palaeoecol., **143**: 227-272.

Kozur, H.W. (1998b): Problems for evaluation of the scenario of the Permian-Triassic boundary biotic crisis and its causes.- Geol. Croat., **51**(2): 135-162.

Kozur, H.W. (1999): The correlation of the Germanic Buntsandstein and Muschelkalk with the Tethyan scale.- Zbl. Geol. Paläont. Teil I, **1998** (7-8): 701-725, Stuttgart.

Kozur, H.W. (2003): Integrated ammonoid, conodont and radiolarian zonation of the Triassic and some remarks to Stage/Substage subdivision and the numeric age of the Triassic stages.- Albertiana, **28**: 57-74.

Kozur, H.W. (in press): Pelagic uppermost Permian and the Permian-Triassic boundary conodonts of Iran. Part I: Taxonomy.- Halle. Jb. Geowiss.

Li H. & Wang J. (1989): Magnetostratigraphy of Permo-Triassic boundary section of Meishan of Changxing, Zhejang.- Science in China, **8**(6): 652-658.

Mei S., Zhang K. & Wardlaw, B.R. (1998): A refined succession of Changhsingian and Griesbachian neogondolellid conodonts from the Meishan section, candidate of the global stratotype section and point of the Permian-Triassic boundary.- Palaeogeogr., Palaeoclimatol., Palaeoecol., **143**: 213-226.

Nawrocki, J. (1997): Permian to Early Triassic magnetostratigraphy from the Central European Basin in Poland: Implications on regional and worldwide correlations, Earth Planet. Sci. Lett., **152**: 37-58.

Newton, R.J., Pevitt, E.L., Wignall, P.B. & Bottrell, S.H. (2004): Large shifts in the isotopic composition of seawater sulphate across the Permo-Triassic boundary in northern Italy.- Earth Planet. Sci. Lett., **218**: 331-345.

Nicoll, R.S., Metcalfe, I. & Wang C. (2002): New species of the conodont genus *Hindeodus* and the conodont biostratigraphy of the Permian-Triassic boundary interval.- J. Asian Earth Sci., **20**: 609-631.

Ogg, J.G. & & Steiner, M.B. (1991): Early Triassic magnetic polarity time scale - integration of magnetostratigraphy, ammonite zonation and sequence stratigraphy from stratotype sections (Canadian Arctic Archipelago).- Earth Planet. Sci. Lett., **107**: 69-89.

Peng Y., Tong J., Shi G.R & Hansen, H.J. (2001): The Permian-Triassic boundary stratigraphic set: Characteristics and correlation.- Newsl. Stratigr., **39**:55-71.

Scholger, R., Mauritsch, H.J. & Brandner, R. (2000): Permian-Triassic boundary magnetostratigraphy from the Southern Alps (Italy).- Earth Planet. Sci. Lett., **176**: 495-508.

Steiner, M., Ogg, J., Zhang, Z. & Sun, S. (1989): The Late Permian-Early Triassic magnetic polarity time scale and plate motions of South China.- J. Geophys. Res., **94**(86): 7343-7363.

Szurlies, M. (2001): Zyklische Stratigraphie und Magnetostratigraphy des Unteren Buntsandsteins in Mitteldeutschland.- Diss. Uni. Halle, 116 pp.

Szurlies, M., Bachmann, G.H., Menning, M., Novaczyk, N.R. & Käding, K.-C. (2003): Magnetostratigraphy and high-resolution lithostratigraphy of the Permian-Triassic boundary interval in Central Germany.- Earth Planet. Sci. Lett., **212**: 263-278.

Yin H., Zhang K., Tong J., Yang Z. & Wu S. (2001): The Global Stratotype Section and Point (GSSP) of the Permian-Triassic boundary.- Episodes, **24**(2): 102-114.

Zakharov, Y. D. & Sokarev, A. N. (1991): Biostratigrafija i paleomagnetism permi i triasa Evrazii.- AN SSSR, Dalnevostochnoe otdelenie, Dalnevostochnyj Geologicheskij Institut, 135 pp., Nauka (Moskva).

Zhu Y. & Liu Y. (1999): Magnetostratigraphy of the Permian-Triassic boundary section at Meishan, Changxing, Zhejiang Province.- In: Yin H. & Tong J. (eds.) - Proceedings of the International Conference on Pangaea and the Paleozoic-Mesozoic transition. 79-84, Wuhan.

Triassic sediment fills the Mjølnir Impact Crater (J-K boundary), Barents Sea – Arctic Norway

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Abstract - The Mjølnir Crater in the Barents Sea is 40 kilometres in diameter. Chaotic brecciated sediment named the Ragnarok Formation fills the crater, and according to macrofossils and palynomorphs from above-lying strata, it was formed by a large bolide at the time of the Jurassic – Cretaceous boundary. The central peak of the crater was drilled in 1998, and palynological analyses of the drilled sediment show that the main volume of the infill is derived from Triassic sedimentary rocks. The fossil occurrences as well as organic content and gamma radiation pattern indicate that the poorly- to non-consolidated Jurassic sediment forming the sea bottom at impact time was ejected from the area, while the slightly better consolidated Triassic sediments were redeposited in the crater. The present note informs the community of Triassic researchers about this peculiar occurrence of mixed late-Early, Middle and Late Triassic and minor Jurassic sediments in the crater infill.

The Mjølnir Crater

An approximately 1.5 km diameter bolide impacted the Barents Sea (Fig. 1) at the Jurassic – Cretaceous boundary and created a 40 kilometre-wide crater. Triassic and Jurassic sediments were excavated by the impact, and Triassic sedimentary debris dominates the crater infill. The underlying Permian sediments seem undisturbed (Fig. 2). The Mjølnir crater was first recognised by Gudlaugsson (1993) based on geophysical data. The impact nature of the crater was clearly supported by the records of shocked quartz grains and increased iridium values in a drillhole 30 km from the crater periphery (Dypvik et al. 1996). From these findings it was evident that the impact took place in the upper part of the Hekkingen Formation. In 1998, the drilling of a core penetrating the central peak of the crater (Fig. 3) gave information about the lithologies, structures and fossil content of the crater-infill material as well as the first biostratigraphic dating of the overlying beds (Smelror et al. 2001).

The Mjølnir Crater is named after the hammer 'Mjølnir' used by the Norse God Tor to create thunder and lightning. The sediment filling the crater is called the Ragnarok Formation (Dypvik et al. 2004b). Ragnarok means Armageddon or a catastrophe of devastating consequences. Tor threw the hammer as a projectile at items he would destroy.

Outside the crater itself the ejecta material form a wedge thinning away from the crater and this wedge is named the Sindre Bed. Sindre is the name of the dwarf and blacksmith who made Tor's hammer Mjølnir. Forging the hammer involved lots of sparks, fire and glowing melts, which also is the meaning of the name Sindre (cinder, hammerscale), a proper name characterizing the air-borne ejecta from the Mjølnir crater.

A large group of scientists from both Norway and other countries have worked with the material. Geophysical, sedimentological and palaeontological results have been integrated to model the formation of the crater and its subsequent infilling.

The Ragnarok Formation

The disturbed rocks cored between 171 m and 74.05 m below seabed in the corehole 7329/03-U-01 represent crater infill. They consist of chaotic and slump-dominated sediments overlain by avalanche and mass- and gravity-flow deposits (Fig. 4). The succession contains rock fragments of lithologies resembling rocks found in surrounding areas of the Barents Shelf and on Svalbard (Mørk et al. 1992, 1999). The sedimentology of the core and a review of our knowledge of the Mjølnir structure are presented by Dypvik et al. (2004a,b).

The present core only penetrates the uppermost part (97 m) of the Ragnarok Formation. The base of the unit is defined according to seismic data. The Ragnarok Formation is succeeded by the Hekkingen and Klippfisk formations and above them a 50 m thick Quaternary cover (Smelror et al. 1998, 2001, Mørk et al. 1999).

The Ragnarok Formation was formed during Late Volgian - Ryazanian times based on dating of the underlying and overlying sediments (Smelror et al. 2001; Bremer et al. 2003; Smelror & Dypvik in press.). The formation, however, is dominated by re-sedimented fragments of late Early to Late Triassic age. Material of Jurassic age is subordinate.

Palynology of the Crater infill

The palynomorphs of the Ragnarok Formation represent a stratigraphic mixture representing upper Lower Triassic (Spathian) to Upper Jurassic deposits. At irregular in-

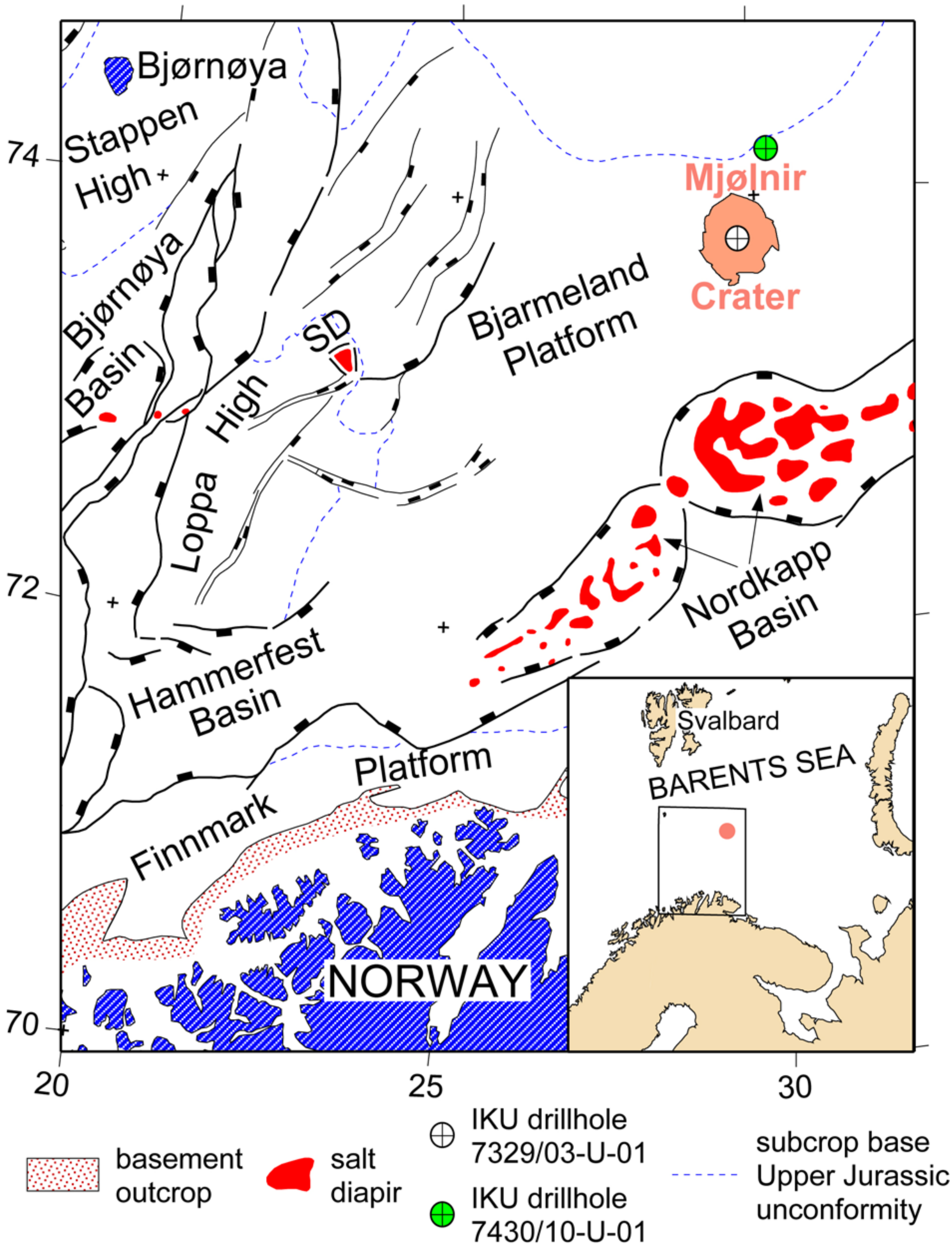
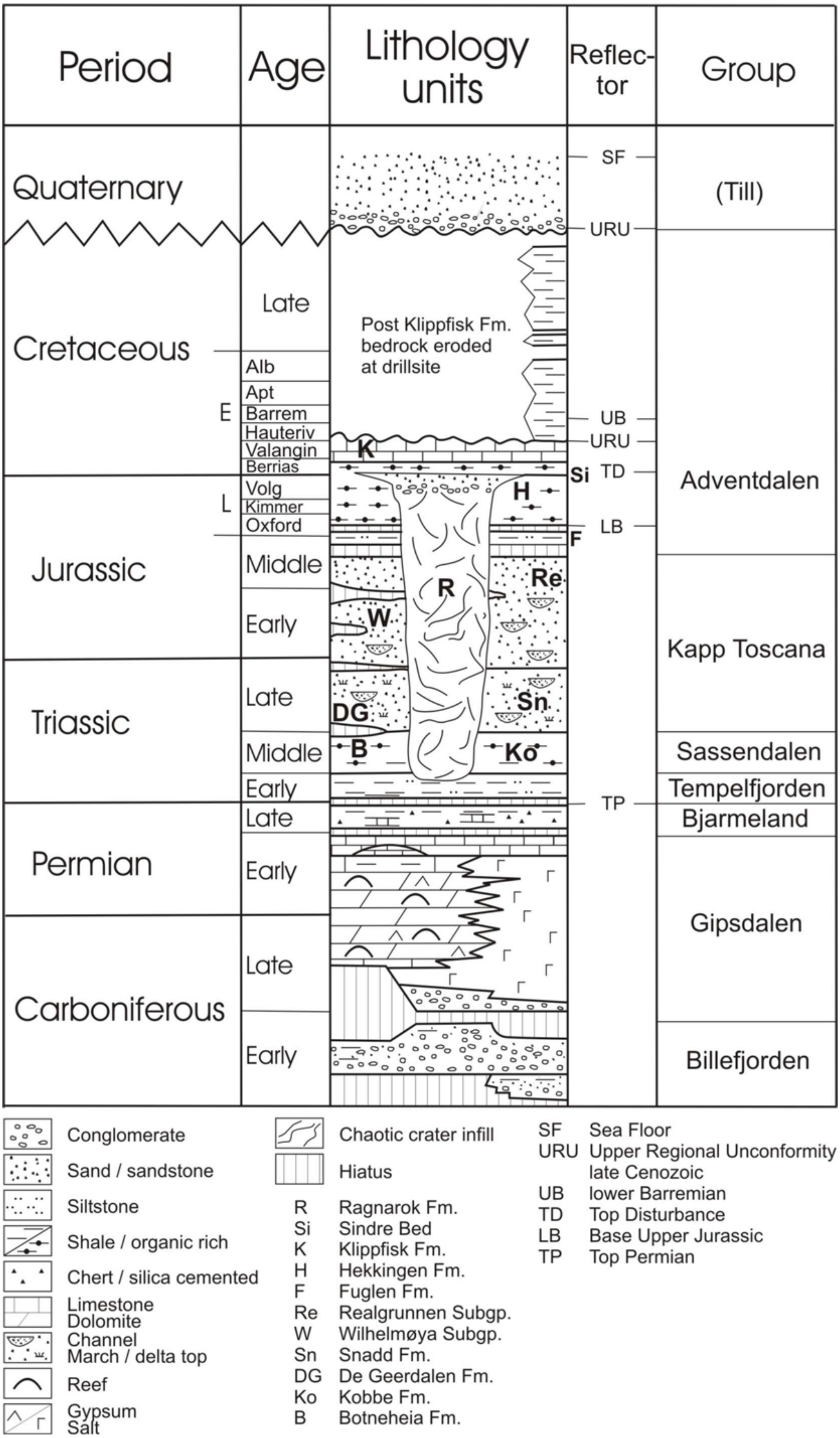


Figure 1. Location of the 40 km diameter Mjølnir Crater relative to the structural elements in the Barents Sea (from Tsikalas et al. 1998b).

Figure 2 (opposite page). General stratigraphy of the Bjarmeland Platform and the Mjølnir Crater filled with the Ragnarok Formation. Lithostratigraphical units of the Bjarmeland Platform are indicated to the right of the crater, units occurring on land Svalbard to the left. Note that the crater disturbs beds down into the late Early Triassic but not the top Permian. The crater is overlain by earliest Cretaceous sediments of the Hekkingen Formation.


Period
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Kapp Toscana
Sassendalen
Tempelfjorden
Bjarmeland
Gipsdalen
Billefjorden
Conglomerate
Sand / sandstone
Siltstone
Shale / organic rich
Chert / silica cemented
Limestone
Dolomite
Channel
March / delta top
Reef
Gypsum
Salt
Chaotic crater infill
Hiatus
R Ragnarok Fm.
Si Sindre Bed
K Klippfisk Fm.
H Hekkingen Fm.
F Fuglen Fm.
Re Realgrunnen Subgp.
W Wilhelmøya Subgp.
Sn Snadd Fm.
DG De Geerdalen Fm.
Ko Kobbe Fm.
B Botneheia Fm.
SF Sea Floor
URU Upper Regional Unconformity late Cenozoic
UB lower Barremian
TD Top Disturbance
LB Base Upper Jurassic
TP Top Permian

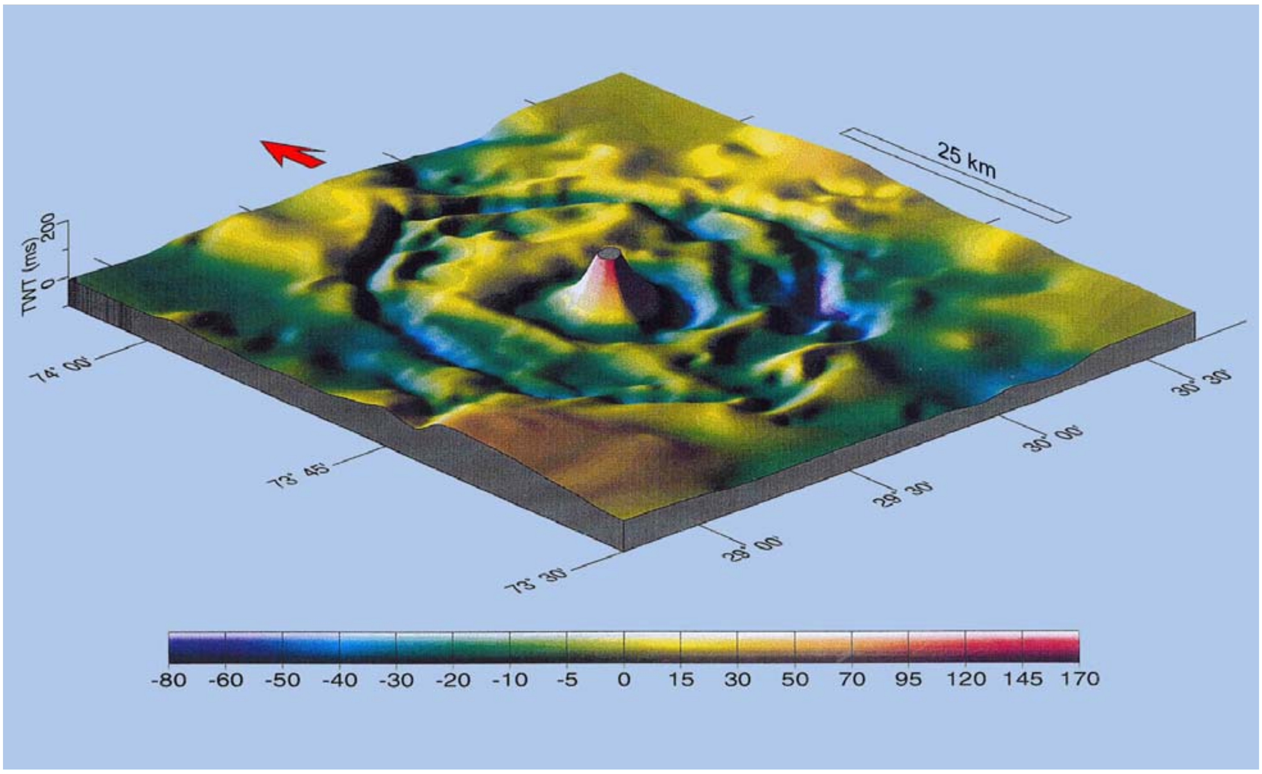

Figure 3. Illuminated perspective image of residual two-way traveltime to a reflector close to top of the crater fill to illustrate the present structural morphology of the Mjølnir Crater (from Dypvik et al. 1996).

tervals *Leiospheridia*, an algal species, appears. In the uppermost 2.5 m of the Ragnarok Formation abundant *Tasmanites* algae, about ½ mm in diameter appear as black spheres, which in thin-sections have a well-defined green to orange appearance. *Tasmanites* algae of similar size and preservation are abundant in Middle Triassic deposits on Svalbard. The dominance of *Botryococcus* and marine plankton of presumed Jurassic age distinguishes samples from the uppermost part of the formation, and also have records in the overlying Hekkingen Formation (Bremer et al. 2003). An algal bloom is also recorded in the overlying Hekkingen Formation and indicates flourishing condition with abundant nutrient immediately following the impact (Smelror et al. 2002).

Recorded age-significant Triassic taxa include *Jerseyiaspora punctispinosa* (Fig. 5f) which occurs regularly. It ranges from the late Spathian and is restricted upwards to middle Anisian deposits. *Triadispora obscura* (Fig. 5e) ranges from the late Anisian to the early Carnian, and *Echinitosporites iliacoides* (Fig. 5b) is restricted to Ladinian deposits of Svalbard and the Barents Sea Shelf (Vigran et al. 1998). *Protodiploxypinus macroverrucosus* (Fig. 5c) ranges from the Ladinian to the early Norian. A late Ladinian - early Carnian association is recognised on the basis of *Doubingerispora filamentosa* (Fig. 5d) with a range from the late Ladinian to the late Carnian, and *Paracirculina tenebrosa* with a range from the late Ladinian to the early Carnian. Poorly preserved specimens recorded as Early Jurassic dinocysts occur sporadically throughout and confirm the presence of Lower Jurassic deposits throughout the Ragnarok Formation.

Dominantly Middle Triassic palynomorphs seem related to the Middle Triassic associations recovered from deposits of the Sassendalen Group of Early and Middle Triassic age (Mørk et al. 1992, 1999). Some of the palynomorphs probably represent lower Carnian associations, i.e. the oldest deposits of the Wilhelmøya Subgroup. It should be noted therefore, that the diverse evidence described by Bjærke (1977) and Bjærke & Manum (1977) from the youngest Upper Triassic deposits of Hopen and Kong Karls Land has no records in the Ragnarok Formation. There is thus no evidence of Carnian-Norian and Rhaetian deposits from palynology. Early Jurassic evidence is recorded only sporadically, and in minor proportions.

References

Bjærke, T.A., 1977. Mesozoic palynology of Svalbard II. Palynomorphs from the Mesozoic sequence of Kong Karls Land. Norsk Polarinstitutt Årbok 1976: 83-120.

Bjærke, T.A. & Manum, S.B., 1977. Mesozoic palynology of Svalbard – I. The Rhaetian of Hopen, with preliminary report on the Rhaetian and Jurassic of Kong Karls Land. Norsk Polarinstitutt Skrifter 165: 1- 48.

Bremer, G.A.M, Smelror, M., Nagy, J. & Vigran, J.O., 2003. Biotic responses to the Mjølnir meteorite impact, Barents Sea: Evidence from a core drilled within the crater. In: Dypvik, H., Burchell, M & Claeys, P.(eds.) Cratering in marine environments and on ice. Springer Verlag, Heidelberg, 21-38.

Dypvik, H. & Ferrell, R.E. Jr., 1998. Clay mineral alter-

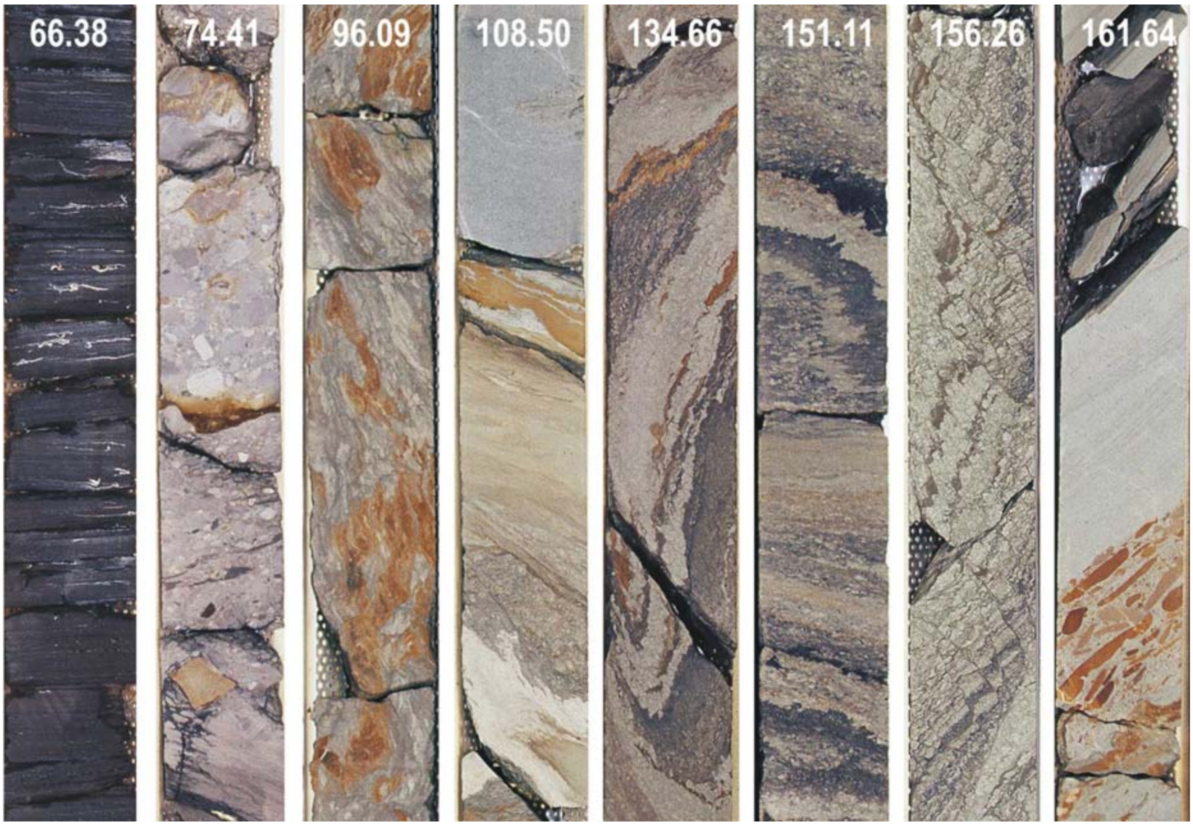

Figure 4. Photographs of the Mjølnir core. The core sections are 5.4 cm wide and 34 cm long. Numbers refer to the depth below seabed. 66.38: Finely laminated, dark organic rich shale of the Hekkingen Formation with crushed shells of *Buchia* and ammonites (white). 74.41: Diamicton and conglomerates with interbedded shales from the upper part of the Ragnarok Formation. 96.09: Folded and mixed sandstone and siltstone with spotted brownish oxidation surfaces. 108.50: Obliquely and disturbed siltstone and sandstone overlain at top by a calcite cemented sandstone. 134.66: Extremely folded, partly faulted and fluidised sandstone and mudstone beds. 151.11: Fluidised mixture of sandstone and mudstone. 156.26: Zig-zag folded and micro-faulted sandstone. 161.64: Obliquely folded siderite conglomerate overlain by well sorted calcite cemented sandstone.

ation associated with a meteorite impact in the marine environment (Barents Sea). Clay Minerals 33: 51-64.

Dypvik, H. & Attrep, M. Jr., 1999. Geochemical signals of the late Jurassic, marine Mjølnir impact. Meteoritics and Planetary Science 34: 393-406.

Dypvik, H. & Jansa, L., 2003. Sedimentary signatures and processes during marine bolide impacts: a review. Sedimentary Geology 161: 308-341.

Dypvik, H., Burchell, M.J. & Claeys, P., 2004. Impacts into marine and icy environments. In: Dypvik, H., Burchell, M. & Claeys, P. (eds.) Cratering in marine environments and on ice. Springer Verlag, Heidelberg, 1-20.

Dypvik, H., Ferrell, R.E. Jr. & Sandbakken, P.T., 2003. The clay mineralogy of sediments related to the marine Mjølnir impact Crater. Meteoritics and Planetary Science, 38: 1-14.

Dypvik, H., Sandbakken, P.T., Postma, G. & Mørk, A., 2004a. Early-post impact sedimentation around the central high of the Mjølnir impact crater (Barents Sea, Late Jurassic). Sedimentary Geology 168: 227-247.

Dypvik, H., Mørk, A., Smelror, M., Sandbakken, P.T., Tsikalas, F., Vigran, J.O., Bremer, G.M.A., Nagy, J., Gabrielsen, R.H., Faleide, J.I., Bahiru, G.M. & Weiss, H.M., 2004b. Impact breccia and ejecta from the Mjølnir crater in the Barents Sea – The Ragnarok Formation and Sindre Bed. Norwegian Journal of Geology, 84: in press. Oslo 2004. ISSN 029-196X.

Dypvik, H., Gudlaugsson, S.T., Tsikalas, F., Attrep, M. Jr., Ferrell, R.E. Jr., Krinsley, D.H., Mørk, A., Faleide, J.-I. & Nagy, J., 1996. Mjølnir structure: An impact crater in the Barents Sea. Geology 24: 779-782.

Gudlaugsson, S.T., 1993. Large impact crater in the Barents Sea, Geology 21, 291-294. Melosh, H.J., 1989. Impact Cratering. A Geologic Process. Oxford University Press, 245 pp.

Mørk, A., Dallmann, W.K, Dypvik, H., Johannessen, E.P., Larssen, G.B., Nagy, J., Nøttvedt, A., Olaussen, S., Pchelina, T.M. & Worsley, D., 1999. Mesozoic lithostratigraphy. In: Dallmann, W.K. (ed.) Lithostratigraphic lexicon of Svalbard. Review and recommendations for nomenclature use. Upper Palaeozoic to Quaternary bedrock. Norsk Polarinstitutt, Tromsø, 127-214.

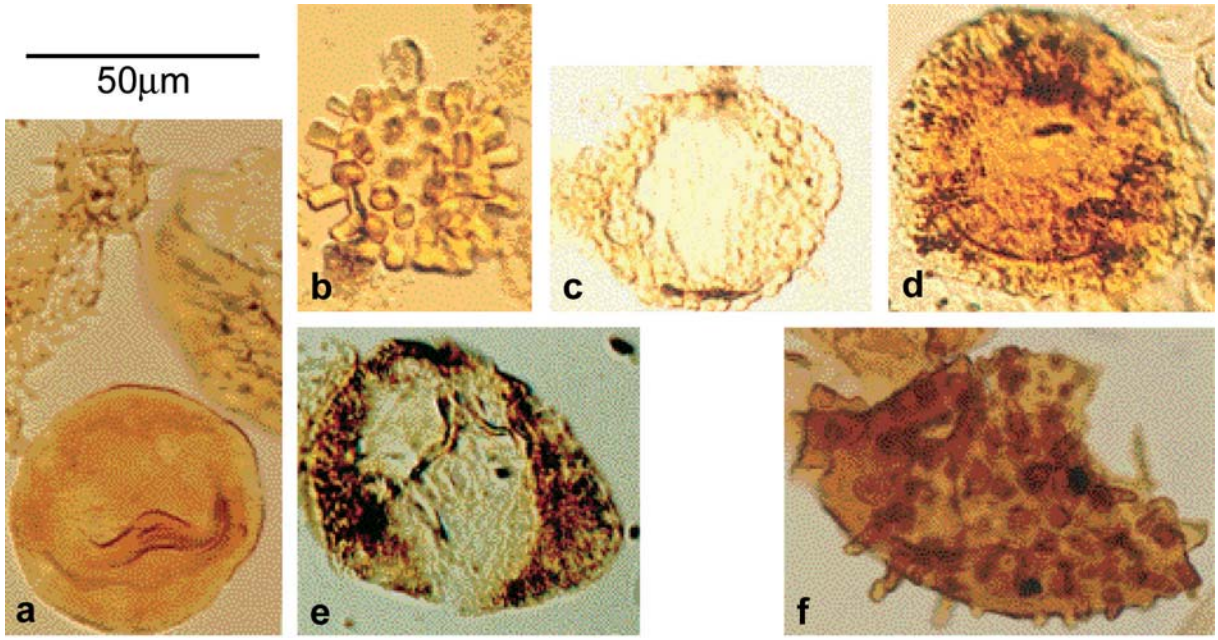

Figure 5. Palynomorphs from the Ragnarok Formation.
a) *Tasmanites* sp. Small morphoform and *Micrhystridium* sp. (the upper left corner), 164.34 m.
b) *Echinitosporites iliacoides* Schulz & Krutzsch 1961, 77.80 m.
c) *Protodiploxypinus macroverrucosus* Bjærke & Manum 1977, 77.80 m.
d) *Doubingerispora filamentosa* Scheuring 1978, 77.80 m.
e) *Triadispora obscura* Scheuring 1970, 93.7 m.
f) *Jerseyiaspora punctispinosa* Kar, Kieser & Jain 1972, 164.34 m.

Mørk, A., Vigran, J.O., Korchinskaya, M.V., Pchelina, T.M., Fefilova, L.A., Vavilov, M.N. & Weitschat, W., 1992. Triassic rocks in Svalbard, the Arctic Soviet islands and the Barents Shelf: bearing on their correlations. In Vorren, T.O. et al. (eds.) Arctic Geology and Petroleum Potential. NPF Special Publication no. 2, Elsevier Sci.Publ., 457-479.

Ormö, J. and Lindström, M., 2000. When a cosmic impact strikes the sea bed. Geological Magazine 137 (1): 67-80.

Shuvalov, V.V. & Dypvik, H., 2004. Ejecta formation and crater development of the Mjølnir impact. Meteoritics and Planetary Science, in press.

Shuvalov, V., Dypvik, H. & Tsikalas, F. 2002. Numerical simulations of the Mjølnir marine impact crater. J. Geophys. Res.107, E7, 10.1029, 1-1 to 1-13.

Smelror, M. & Dypvik, H., in press. Dinoflagellate cyst and prasinophyte biostratigraphy of the Volgian-Ryazanian boundary strata, western Barents Shelf. Norges geologiske undersøkelse Bulletin

Smelror, M., Dypvik, H. & Mørk, A. 2002. Phytoplankton blooms in the Jurassic-Cretaceous boundary beds of the Barents Sea possibly induced by the Mjølnir impact. In Buffetaut, E. & Koeberl, C. (eds.) Geological and Biological Effects of Impact Events. Lecture notes in Earth Sciences, Impact Studies, Springer Verlag, 69-81.

Smelror, M., Mørk, A., Monteil, E., Rutledge, D. & Leereveld, H., 1998. The Klippfisk Formation – a new lithostratigraphic unit of Lower Cretaceous platform carbonates on the Western Barents Shelf. Polar Research, 7(2): 81-202.

Smelror, M., Kelly, R.A., Dypvik, H., Mørk, A., Nagy, J. & Tsikalas, F. 2001. Mjølnir (Barents Sea) meteorite impact ejecta offers a Volgian – Ryazanian boundary marker. Newsl. Stratigr. 38: 129-140.

Tsikalas, F., Gudlaugsson, S.T. & Faleide, J.I., 1998a. The anatomy of a buried complex impact structure: the Mjølnir Structure, Barents Sea. J. Geophys. Res., 103: 30469-30484.

Tsikalas, F., Gudlaugsson, S.T. & Faleide, J.I., 1998b. Integrated geophysical, analysis supporting the impact origin of the Mjølnir Structure, Barents Sea. Tectonophysics, 289: 257-280.

Tsikalas, F., Gudlaugsson, S.T. & Faleide, J.I.1998c. Collapse, infilling, and postimpact deformation at the Mjølnir impact structure, Barents Sea. Geol. Soc. Amer. Bull., 110: 537-552.

Tsikalas, F., Gudlaugsson, S.T., Faleide, J.I. & Eldholm, O., 1999. Mjølnir Structure, Barents Sea: a marine impact crater laboratory. Geol. Soc. Amer. Spec. Paper 339: 193-204.

Tsikalas, F., Faleide, J.-I., Eldholm, O. & Dypvik, H. 2002a. Seismic correlation of the Mjølnir marine impact crater to shallow boreholes. In Plado, J. & Pesonen L.J. (eds.) Impact studies (Impacts in Precambrian

Shields), Springer Verlag, Berlin – Heidelberg, 307–321.

Tsikalas, F., Gudlaugsson, S.T., Faleide, J.I. & Eldholm, O. 2002b. The Mjølnir marine impact crater porosity anomaly, Deep-Sea Research Part II 49: 1103-1120.

Tsikalas, F. & Faleide, J.I. 2003. Near-field erosional features at the Mjølnir impact crater: the role of marine sedimentary target. In Dypvik. H., Burchell, M.J. & Clayes, P. (eds.) Impact Studies (Cratering in Marine environments and on Ice), Springer Verlag, Berlin-Heidelberg, 39-55.

Tsikalas, F. 2004. Mjølnir crater as a result of an oblique impact: asymmetry evidence constrains impact direction and angle. In: Henkel, H. & Koeberl, C. (eds) Impact Studies (Impact Tectonism), Springer Verlag, Berlin-Heidelberg, in press.

Vigran, J.O., Mangerud, G., Mørk, A., Bugge, T. & Weitschat, W., 1998. Biostratigraphy and sequence stratigraphy of the Lower and Middle Triassic deposits from the Svalis Dome, Central Barents Sea, Norway. Palynology 22: 89-141.

Zacharov, V.A., Lapukhov, A.S. & Shenfil, O.V., 1993. Iridium anomaly of Jurassic-Cretaceous boundary Northern Siberia. Russian Journal Geol.Geophys., 34: 83-90.

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Triassic Ammonoid Succession in South Primorye: 3. Late Olenekian – Early Anisian Zones (*Neocolumbites insignis*, *Subcolumbites multiformis*, *Ussuriphyllites amurensis* and *Leiophyllites pradyumna*)

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Abstract - A review of a new data on the Upper Olenekian (*Neocolumbites insignis* and *Subcolumbites multiphormis* Zones) and Lower Anisian (*Ussuriphyllites amurensis* Zone) biostratigraphy of South Primorye is given on the basis of the three main sections: Zhitkov Peninsula, Tchernyschew Bay and Golyi Cape. South Primorye area seems to be one of most perspective regions of Far East for detailed investigation of the Olenekian-Anisian boundary.

Introduction

Late Olenekian and Anisian marine deposits in South Primorye were firstly studied by D.L. Ivanov, the chief of a geological team making reconnaissance work for the construction of the Trans-Siberian railroad. He collected Early and Middle Triassic ammonoids on Russian Island. Representative collection of D.L. Ivanov was forwarded to Austrian palaeontologist C. Diener (1895), who described some Triassic ammonoids, including Middle Olenekian *Kazakhstanites nicolai* (Diener) and Anisian *Ptychites* sp., *Acrohordiceras* sp. indet. and *Ussurites sikhoticus* (Diener). The role of Late Olenekian and Anisian rocks in the South Primorye increased after publication of monographs by L.D. Kiparisova (1961, 1972)

Figure 1. Zhitkov Peninsula section, Russian Island, South Primorye.

and some later works (Zakharov, 1968, 1978, 1997; Burij et al., 1976; Buryi, 1979; Zharnikova, 1981).

Late Olenekian and Early Anisian ammonoid, brachiopod and conodont distribution

Zhitkov Peninsula

The Zhitkov Peninsula section is described at the north-eastern part of Russian Island (Fig. 1). It is the stratotype of the Zhitkov Suite (Formation), represented by *Neocolumbites insignis* and *Subcolumbites* Zones. The full thickness of the Suite is about 113 m. In descending order, its sequence and overlying Anisian sediments in the stratotype section are (Zakharov et al., 2003, Fig.2):

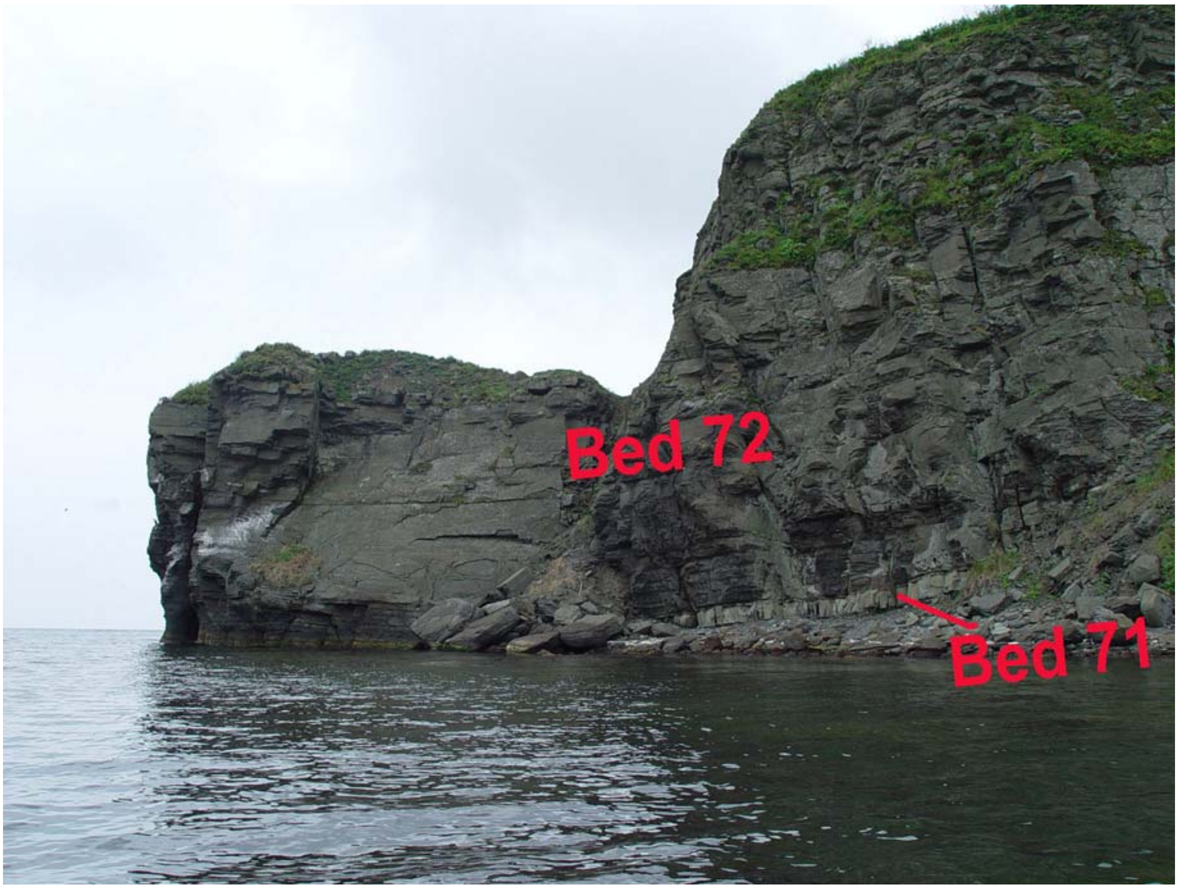

Figure 2. Lower Anisian *Leiophyllites pradiumna* Zone, Karazin Cape, Zhitkov Peninsula (Russian Island).

Anisian (Karazin Suite)
***Leiophyllites pradyumna* Zone**
72. Sandy siltstone and striped sandstone with calcareous-marly nodules and lenses (Fig.2)..............................12.0 m
Bivalves – *Pteria hoffmani* Bittn., *Gervilia panonica* Bittn., ammonoids – *Pseudosageceras simplex* Kipar. and *Leiophyllites pradyumna* Diener.
Apparently here were discovered *Hollandites* cf. *japonicus* Mojs. and *Ptychites austroussuriensis* Kipar., described by L.D. Kiparisova (1961).
71. Middle grained arkose and quartz sandstone (Fig. 3).......………………………...0.9 m
70 Sandy siltstone, middle grained sandstone and striped sandstone with calcareous-marly nodules andlenses..14.0 m
Ammonoids – *Hollandites tozeri* Zakharov, “*Japonites” russkiensis* Zakh. and *Sturia japonica* Mojs.
69. Striped mudstone and siltstone with sandstone interbeds and calcareous-marly nodules...……………………..………...........................……1.2 m
Ammonoids – *Leiophyllites pradyumna* Diener.

***Ussuriphyllites amurensis* Zone**

68. Mudstone and siltstone with interbeds of calcareous sandstone and calcareous-marly nodules (Fig. 4 and 5).……………………………………………………………..…………...................................…..2.5 m
Brachiopods, bivalves – *Leda skorochodi* Kipar., *Entolium microtis* Witt. and *Neoschizodus laevigatus* (Zieten).

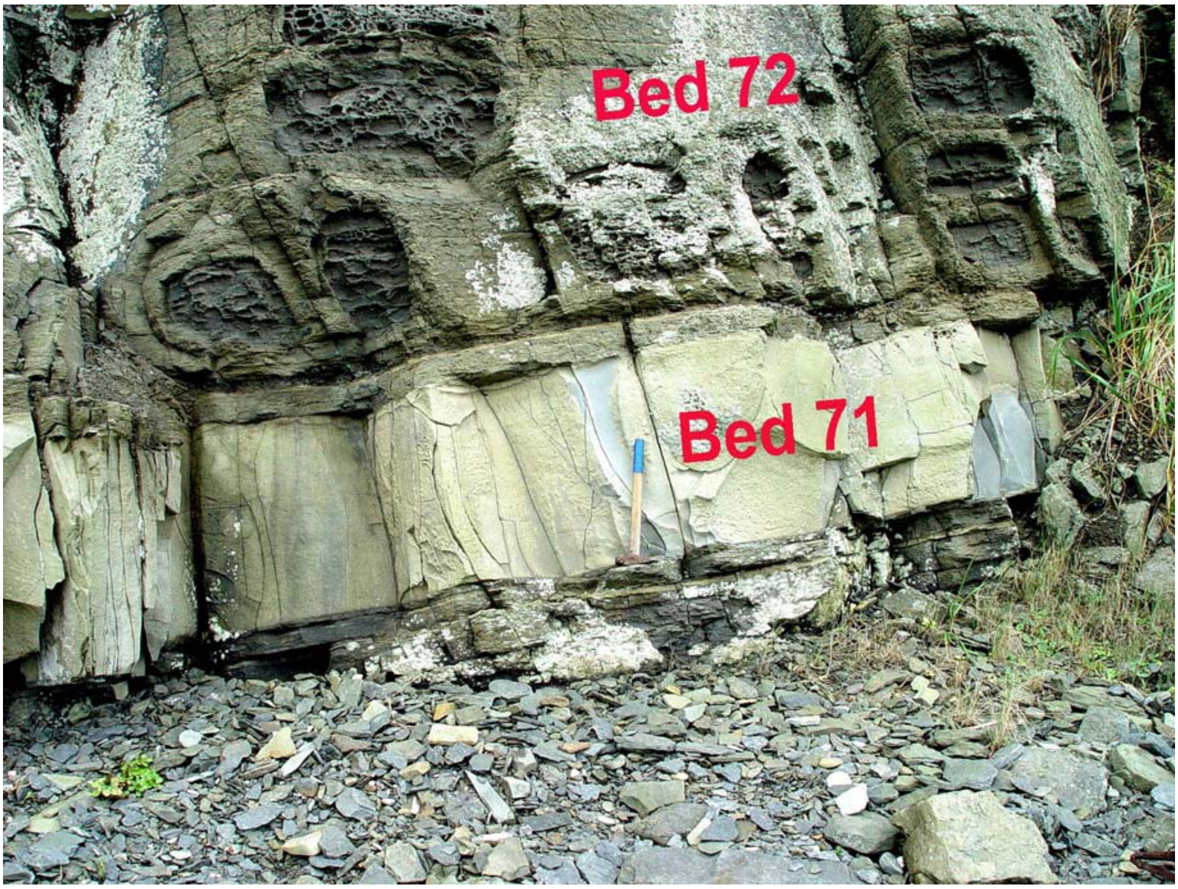

Figure 3. Lower Anisian arrose and quarts sandstone bed, Zhitkov Peninsula, Russian Island.

Figure 4. *Ussuriphyllites amurensis* Zone, Zhitkov Peninsula, Russian Island.

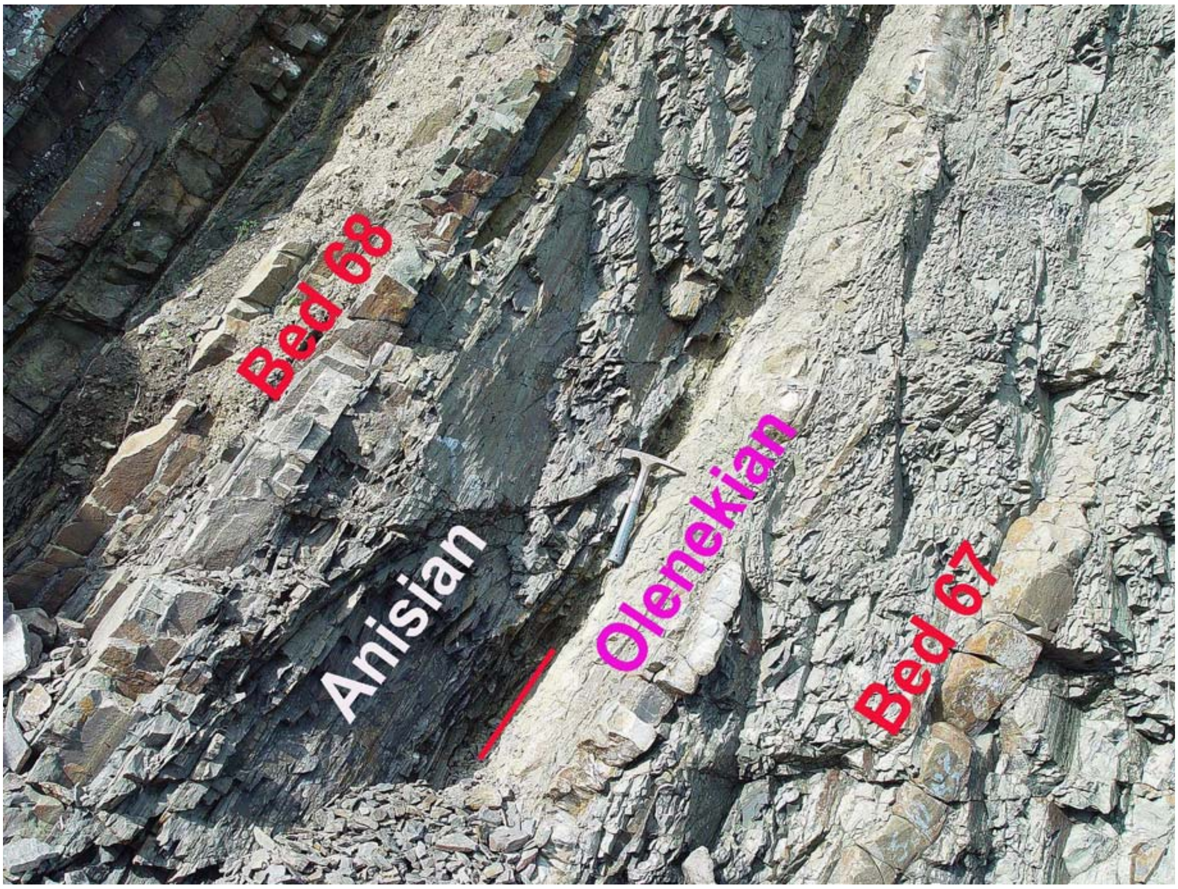

Figure 5. Olenekian-Anisian boundary, Zhitkov Peninsula, Russian Island.

Ammonoid shell remains (*Prohungarites?* sp., *Paracrochordiceras?* sp. and *Cuccoceras?* sp.) in this level were found in neighbour locality (Paris Bay) (Zakharov and Rybalka, 1987).

Upper Olenekian (Zhitkov Suite)
***Subcolumbites multiformis* Zone**

67. Mudstone and siltstone with sandstone interbeds, calcareous-marly nodules and lenses………......................5.3 m
Brachiopods – *Paranorellina parisi* Dagys (1974), ammonoids – *Arnautoceltites* sp., *Columbites* sp. and *Subcolumbites multiformis* Kipar.
66. Calcareous-marly lensis ....………………………………...…..0.2 m
Ammonoids - *Subcolumbites multiformis* Kipar.
65 Mudstone and siltstone with sandstone interbeds, calcareous-marly nodules and lenses (Fig. 6)...…………………………………………...……...12 m
Ammonoids – *Subcolumbites multiformis* Kipar.
64. Calcareous-marly lensis..............................……………………………..…………..0.3 m
Rhynchonellid brachiopods, *Costispirifena* sp., bivalves –*Palaeoneilo prynadai* Kipar., *P. elliptica* Gold., *Leda skorochodi* Kipar., *Neoschizodus laevigatus* (Ziet.), *Pteria ussurica* Kipar., cephalopods – *Trematoceras subcampanile* (Kipar.), *Grypoceras ussuriense* Kipar., *Pseudosageceras longilobatum* Kipar., *P. simplex* Kipar., *Zhitkovites insularis* (Kipar.), *Pseudoprosphingites globosus* (Kipar.), *Isculitoides? suboviformis* (Kipar.), *Arnautoceltites gracilis* (Kipar.), *Prenkites* aff. *timorensis* Spath, *Preflorianites maritimus* Kipar., *Dieneroceras karasini* Kummel et Teichert and *Subcolumbites multiformis* Kipar.

***Neocolumbites insignis* Zone**

63. Fine grained sandstone with mudstone and siltstone interbeds ....………………...................................5-8 m
62. Sandy siltstone and mudstone with rare sandstone interbeds and calcareous-marly nodules and lenses..………………………………………………...15-20 m

Figure 6. *Subcolumbites multiformis* Zone (underwater slump), Zhitkov Peninsula, Russian Island.

Ammonoids - *Columbites* sp.
61. Mudstone and siltstone with calcareous sandstone interbeds..5-7 m
60. Sandy siltstone and mudstone with calcareous sandstone interbeds and calcareous-marly nodules and lenses ....………………………………...……………8-10 m
59. Fine grained calcareous sandstone........................…………………………...………0.12 m
Labirintodonts – *Aphaneramma* sp. (=*Lonchorhynchus)* (Shishkin, 1964), ammonoids – *Hellenites inopinatus* Kipar., *Olenekoceras miroshnikovi* Burij et Zharnikova and *Procarnites* sp.
58. Sandy mudstone and siltstone with rare sandstone interbeds and calcareous nodules................................20-45 m
Ammonoids – *Columbites* sp. indet. (in the upper part).
57 Sandy mudstone and siltstone with rare calcareous-marly nodules. ....………10-15 m
Plant remains – *Pleuromeia stenbergi* Münst. (Korzh, 1959), bivalves, gastropods, ammonoids – *Svalbardiceras zhitkoviense* Zakh., *Tirolites* cf. *subcassianus* Zakh., *Khvalinites* cf. *unicus* (Kipar.), *Hellenites inopinatus* Kipar., *Neocolumbites grammi* Zakh. and *Columbites* sp. indet.
56. Siltstone with rare fine grained interbeds and calcareous-marly nodules..10.5 m
Nautiloids - *Phaedrysmocheilus* sp. and ammonoids – *Olenekoceras* sp.
55. Mudstone and siltstone with sandstone interbeds (Fig. 7)..3.3 m
Bivalves, nautiloids - *Phaedrysmocheilus* sp., and ammonoids – *Pseudosageceras* sp. indet., *Nordophiceras* sp. and *Columbites* sp. indet.

Tchenyschew Bay

In descending order, the sequence of the Zhitkov Suite (82 m) and overlying Anisian sediments at the south-eastern part of Russian Island are (Fig. 8):

Lower Anisian (Karazin Suite)
***Leiophyllites pradyumna* Zone**
42. Sandy, striped siltstone with rare calcareous-marly nodules (Zakharov et a., 2003, Fig.4)…............……13-20 m
Bivalves, ammonoids – *Balatonites* sp. indet.
41. Fine grained, striped sandstone with sandy siltstone and mudstone interbeds……………….........................6.0 m

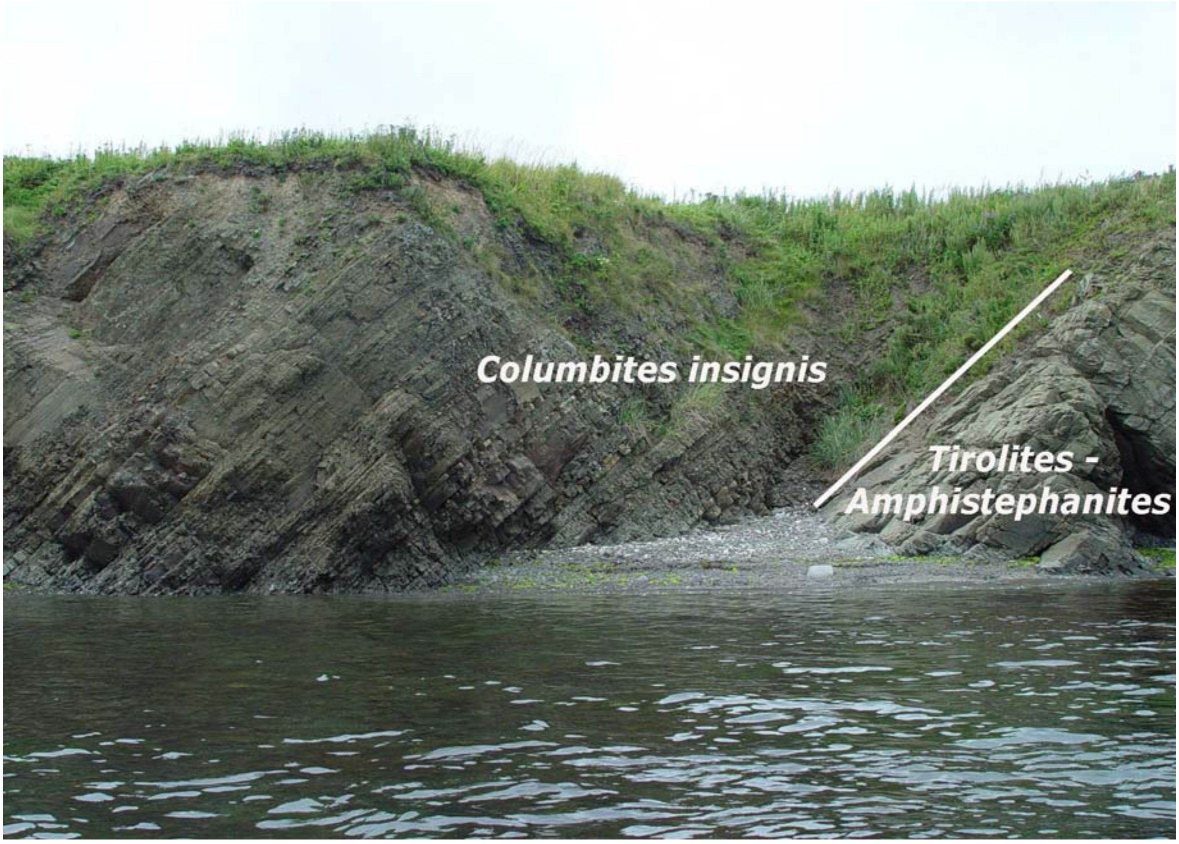

Figure 7. Busal beds of the *Neocolumbites insignis* Zone, Zhitkov Peninsula, Russian Island.

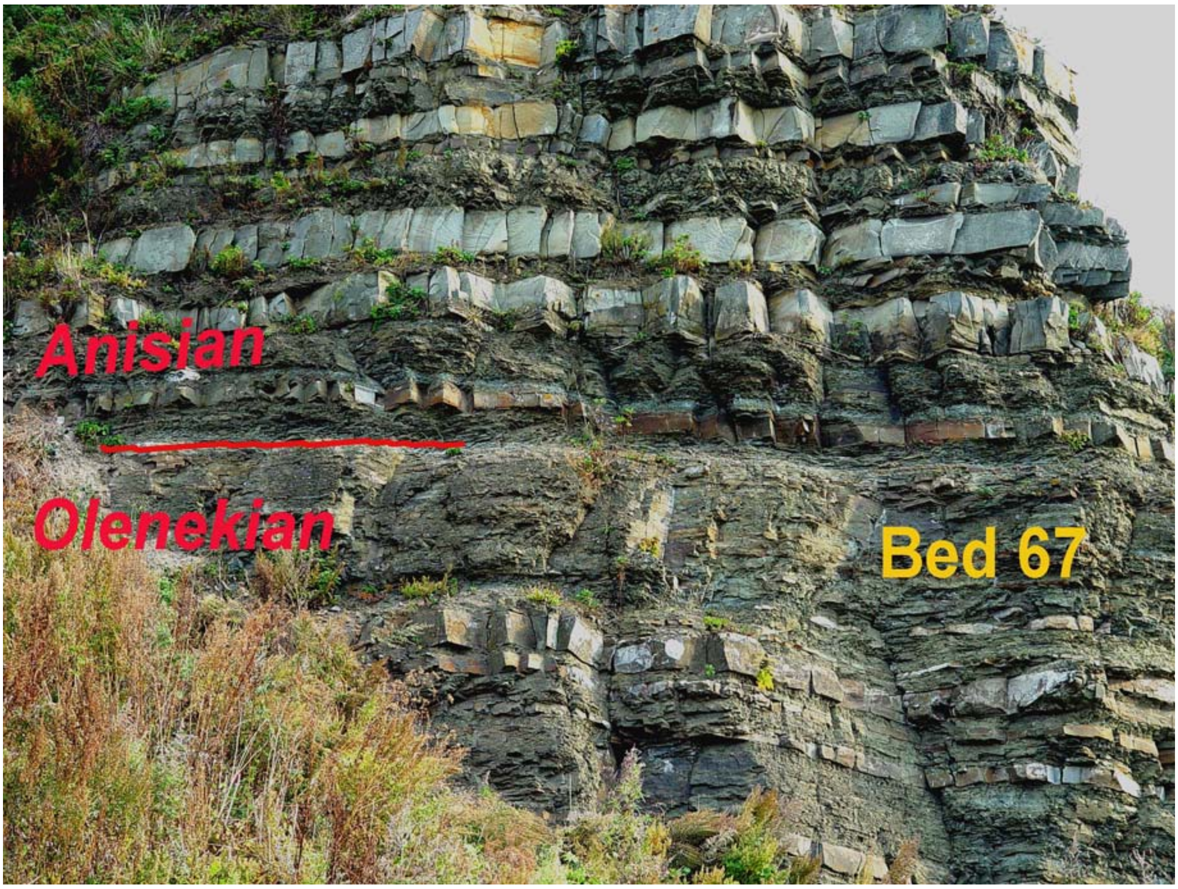

Figure 8. Tchernyschew Bay section (upper portion), Russian Island, South Primorye.

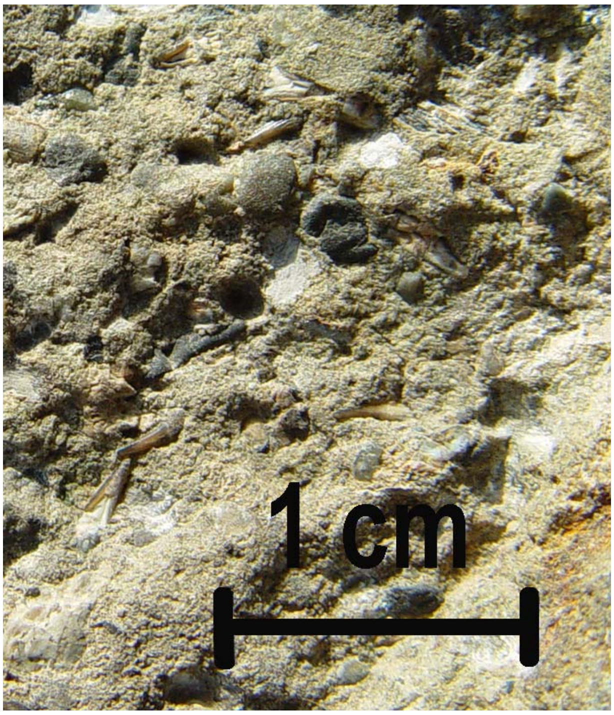

Figure 9. Earliest Anisian shark teeth, Tchernyschew Bay, Russian Island.

Ammonoids – *Leiophyllites* aff. *pradyumna* (Dien.).
40. Middle grained, arkose, light-grey sandstone........………………………..0.6 m
39. Fine grained , grey sandstone with sandy siltstone and mudstone interbeds .... 3.0 m
38. Fine grained, arkose with pieces of mudstone and fragments of brachiopod and mollusk shells.
.....…………………………………………………………………………………... 0.35 m
Conodonts – *Hindeodella* sp., *Enantiognathus ziegleri* (Dieb.), *Neospathodus triangularis* (Bend.), *N. homeri* (Bend.).

***Ussuriphyllites amurensis* Zone**

37. Sandy mudstone and siltstone with lenses of calcareous sandstone and calcareous boulders containing some terebratullid and rhynchonellid brachiopod and nautiloid shells......................................…………………………...1.1 m
Shark teeth in association with terebratullid and rhynchonellid brachiopods (from talus) (Fig. 9).
36. Sandy mudstone and siltstone. ....…………………………...0.35 m
35. Mudstone and siltstone with lenses of calcareous-marl (15 cm), calcareous sandstone-coquina (20 cm) and arkose sandstone (10 cm) (Fig. 10)…………………………………………………………....…....................1.5 m
Terebratullid and rhynchonellid brachiopod, bivalves, gastropods, ammonoids – *Ussuriphyllites amurensis* (Kipar.).

Upper Olenekian (Zhitkov Suite)
***Subcolumbites multiformis* Zone**

34. Mudstone and siltstone with fine sandstone interbeds………………………….......................…… …....0.8 m
33. Fine grained sandstone...………………………………...0.17 m
32. Sandy mudstone and siltstone with calcareous sandstone interbeds, containing small bivalve shells
…………………………………………….……………….………………………....................…………3.2 m
31. Sandy mudstone and siltstone with calcareous-marly nodules and lenses of calcareous sandstone and calcareous sandstone-coquina interbeds..........……………………………………...……..1.4 m
Brachiopods - *Costispiriferina* sp., bivalves –*Bakevellia exporrecta* Leps, gastropods, nautiloids – *Trematoceras* sp., ammonoids – *Zhitkovites globosus* (Kipar.), *Subcolumbites multiformis* Kipar. (dominant), *Palaeophyllites superior* Zakh., labirintodont remains.
30. Sandy mudstone and siltstone with rare fine grained, calcareous sandstone. ....…………1.3 m
29. Intercalation of fine grained, calcareous sandstone and sandy siltstone and mudstone. ……..........................0.7 m
28. Siltstone with calcareous-marly nodules. ....1.5 m
Bivalves, cephalopods - *Phaedrysmocheilus* sp., *Pseudosageceras* sp., *Arnautoceltites gracilis* (Kipar.)., *Subcolumbites multiformis* Kipar., plants – *Cladophlebis gracilis* Sze (V.I. Burago’s determination).

Figure 10. Olenekian-Anisian boundary, Tchernyschew Bay, Russian Island.

27. Sandy siltstone with calcareous-marly nodules ………………………..………………….........................1.0 m
Bivalves, ammonoids - *Subcolumbites multiformis* Kipar.
26. Striped siltstone with calcareous-marly lenses and calcareous sandstone interbeds……..................……….0.8 m
25. Mudstone and siltstone with calcareous-marly nodules and lenses and fine grained sandstone interbeds.
.................………………………...………………………………………………….................……….4.2 m
Bivalves, cephalopods - *Pseudosageceras* sp., *Arnautoceltites* sp., *Subcolumbites multiformis* Kipar. One *Prenkites* aff. *timorensis* Spath shell was found by H. Maeda in talus.
24. Fine grained, calcareous sandstone……...........………………………………..…...….......................0.2-0.5 m
Cephalopods – *Phaedrysmocheilus* sp., *Pseudosageceras* sp., *Arnautoceltites* sp., *Subcolumbites multiformis* Kipar. Closed interval (1-3 m in thickness).

***Neocolumbites insignis* Zone**

23. Mudstone and siltstone with calcareous sandstone interbeds calcareous-marly nodules……..................…..3.0 m
Cephalopods - *Phaedrysmocheilus* sp.), *Khvalinites unicus* (Kipar.), *Olenekoceras meridianus* (Zakh).
22. Mudstone and siltstone with calcareous-marly nodules and rare calcareous sandstone and calcareous sandstone-coquina interbeds and lenses. ....……………………………………………………….................…..2.5 m
Plants - *Pleuromeia obrutschewii* Elias, bivalves – *Palaeoneilo prynadai* Kipar., *Pteria ussurica* (Bittn.), *Bakevellia exporrecta* (Leps.), *Entolium* sp., *Anadontofora fassaensis* (Wissm.), *Nucula goldfussi* (Alb.), *Leda skorochodi* Kipar., scaphopods, cephalopods - *Phaedrysmocheilus russkiensis* (Zakh.), *Khvalinites unicus* (Kipar.), *Hellenites inopinatus* Kipar., *Hemilecanites discoideus* Burij et Zharn., *Hemilecanites* sp., *Columbites ussuriensis* Burij et Zharn., *Procolumbites subquadratus* Burij et Zharn., *Olenekoceras miroshnikovi* (Burij et Zharn.), *Burijites skorochodi* (Burij et Zharn.), conodonts – *Neospathodus homeri* (Bend.) (Buryi, 1979).
21. Mudstone and siltstone with calcareous sandstone and calcareous sandstone-coquina interbeds...................1.5 m
Bivalves – *Leda* sp., *Pteria* sp., *Bakevellia* sp., gastropods, cephalopods – *Phaedrysmocheilus* sp., *Khvalinites unicus* (Kipar.), *Hellenites* sp., *Neocolumbites grammi* Zakh., *Procolumbites subquadratus* Burij et Zharn., *Olenekoceras* sp.
20. Fine grained, calcareous sandstone with lenses of calcareous sandstone-coquina……………..............……1.5 m
Bivalves - *Bakevellia exporrecta* (Leps.), *Neoschizodus laevigatus* (Ziet.), cephalopods - *Phaedrysmocheilus*

Figure 11. Golyi (Kom-Pikho-Sakho) Cape section, east Ussuri Gulf, South Primorye.

russkiensis (Zakh.), *Khvalinites unicus* (Kipar.), *Neocolumbites grammi* Zakh., *Olenekoceras miroshnikovi* Burij et Zharn.
19. Mudstone and siltstone with lenses of calcareous sandstone-coquina interbeds and fine grained , calcareous sandstone interbeds. .....……………………………………………………………..1.5 m
Plants - *Pleuromeia obrutschewii* Elias (V.A. Krassilov's determination), bivalves – *Bakevellia exporrecta* (Leps.), *Neoschizodus laevigatus* (Ziet.), cephalopods - *Phaedrysmocheilus russkiensis* (Zakh.), *Columbites ussuriensis* Burij et Zharn. (dominant), *Neocolumbites grammi* Zakh., *Olenekoceras miroshnikovi* Burij et Zharn.
18. Mudstone and siltstone with fine grained, calcareous sandstone and lenses of calcareous sandstone-coquina and rare calcareous-marly nodules...2.5 m
Ammonoids - *Columbites ussuriensis* Burij et Zharn.
17. Mudstone and siltstone with calcareous-marly nodules and plant detritus, intercalating with fine grained sandstone………………………………………………………………….............................……….4.0 m
Plants – *Pleuromeia obrutschewii* Elias (V.A. Krassilov's determination), bivalves, cephalopods – *Phaedrysmocheilus ussuriense* (Kipar.), *Khvalinites unicus* (Kipar.), *Columbites ussuriensis* Burij et Zharn. (Zakharov, 1997), labirintodonts – *Aphanerama* or *Gonioglyptus* (Shishkin, 1964).
16. Fine grained, calcareous sandstone. ....……………….…………………….......................................0.2 m
Ammonoids –*Neocolumbites grammi* Zakh.
15. Mudstone and siltstone with numerous calcareous-marly nodules and plant detritus......................................1.0 m
Ammonoids – *Proptychitoides* sp., *Khvalinites unicus* (Kipar.), *Neocolumbites insignis* Zakh. (dominant), *Leiophyllites praematurus* (Kipar.).
14. Mudstone and siltstone with calcareous-marly nodules.……………………..……..9.0 m
Bivalves – *Bakevellia* sp.
13. Mudstone and siltstone with calcareous-marly nodules. .....…………………….....................................…....1.0 m
Ammonoids – *Neocolumbites insignis* Zakh., *Columbites ussuriensis* Burij et Zharn.
12. Mudstone and siltstone with numerous calcareous-marly nodules. ....………8.0 m
Ammonoids – *Pseudosageceras* sp., *Khvalinites unicus* (Kipar.) (dominant), *Columbites ussuriensis* Burij et Zharn., *Columbites* cf. *parisianus* Hyatt et Smith, *Burijites skorochodi* (Burij et Zharn.), *Leiophyllites praematurus* Kipar.
11. Intercalation of mudstone, siltstone and fine grained sandstone ....12.0 m

Brachiopods – Spirifeacea, small bivalve and gastropod shells, ammonoids – *Pseudosageceras* sp., *Khvalinites unicus* (Kipar.), *Hellenites tchernyschewiensis* Zakh,

10. Mudstone and siltstone with fine grained, calcareous sandstone and rare calcareous-marly nodules ....16-18 m

Ammonoids - *Hemilecanites discoideus* Burij et Zharn., *Columbites* cf. *parisianus* Hyatt et Smith, *Burijites skorochodi* (Burij et Zharn.).

Golyi (Com-Pikho-Sakho) Cape

In descending order, the sequence of the Russian Substage (80 m) and overlying Anisian sediments of the eastern Ussuri Gulf are (Fig. 11):

Lower Anisian (Karazin Suite)
***Ussuriphyllites amurensis* and *Leiophyllites pradyumna* Zones**

29. Sandy siltstone with striped mudstone interbeds rare calcareous-marly nodules (Zakharov et al., 2002, Fig. 16).. 15 m

Ammonoids – *Tropigastrites sublahontanus* Zakh., *Tropigastrites?* sp., *Leiophyllites* cf. *pradyumna* (Dien.), *Hollandites tozeri* Zakh.

Closed interval (10-15 m in thickness).

28. Striped, sandy siltstone with rare calcareous-marly nodules, containing bad preserved ammonoids...30-40 m

27. Mudstone and siltstone with fine grained sandstone interbeds and rare calcareous boulders.........................18 m

26. Fine grained, light grey, arkose sandstone...2.5 m

Bivalves, aptychi.

25. Striped mudstone and siltstone with fine grained sandstone interbeds. ....6 m

Closed interval (25 m in thickness).

24. Intercalation of sandy siltstone (7-20 cm) and fine grained sandstone (5-60 cm) ....6 m

23. Fine grained, light grey, arkose sandstone with pieces of mudstone at the base calcareous sandstone boulders..1.5 m

22. Intercalation of fine grained sandstone (12-20 cm) and siltstone (10-30 cm) ....3.0 m

Ammonoids - *Leiophyllites?* sp.

21. Fine grained sandstone with siltstone interbeds (5-7 cm)..7.3 m

20. Mudstone and siltstone..1.5 m

19. Intercalation of mudstone, siltstone and calcareous siltstone...11 m

Ammonoids - *Hollandites?* sp.

18. Intercalation of mudstone, siltstone and sandy siltstone (with signs of underwater slump)..0.5 m

Ammonoids – *Hollandites?* sp. (at 0.5 m below the base of the porphyrite dyke).

17. Striped, fine grained sandstone...0.35 m

16. Striped sandy siltstone with lenses (2-3 cm) of light-grey arkose sandstone ....1.2 m

Upper Olenekian (Zhitkov Suite)
***Subcolumbites multiformis* (?) Zone**

15. Thin intercalation (5-20 cm) of sandy siltstone and fine grained sandstone..12 m

***Neocolumbites insignis* Zone**

14. Sandy siltstone with thin (5-10 cm) interbeds of fine grained sandstone and rare calcareous-marly nodules ....60 m

Ammonoids - *Olenekoceras?* sp., *Khvalinites unicus* (Kipar.), *Hellenites* sp.

13. Mudstone and siltstone with numerous calcareous-marly nodules and interbeds (2-10 cm) of fine grained sandstone...8 m

Rhynchonellid brachiopods, small bivalve shells, cephalopods – *Phaedrysmocheilus russkiensis (Zakh.), Columbites ussuriensis* Burij et Zharn., *Neocolumbites* sp., *Columbites* sp., conodonts – *Neospathodus triangularis* (Bender) (Buryi, 1979), fish remains.

Conclusions

South Primorye area seems to be one of most perspective Far East regions for detailed investigation of the Olenekian-Anisian boundary, taking account the good exposition of its Lower and Middle Triassic sediments characterized by abundant fossils.

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References

Burij, I.V., Zharnikova, N.K. and Buryi, G.I. 1976. On the stage division of the Lower Triassic in South Primorye. Geologiya I Geophizica, 1976(7): 150-156 (in Russian).

Buryi, G.I. 1979. Lower Triassic conodonts in South Primorye. Nauka, Moskva, 144 pp., 14 pls. (in Russian).

Dagys, A.S. 1974. Triassic brachiopods (morphology, classification, phylogeny, stratigraphic significance and biogeography). Novosibirsk, Nauka, 387 pp., 49 pls. (in Russian).

Diener, C. 1895. Triadische Cephalopodenfaunen der Ostsibirischen Küstenprovinz. Mém. Com. Géol., 14(3): 1-59, 5 pls.

Kiparisova, L.D. 1961. Paleontological basis of Triassic stratigraphy of Primorye region. I. Cephalopods. Trudy VSEGEI, 48: 1-278, 38 pls. (in Russian).

Kiparisova, L.D. 1972. Paleontological basis of Triassic stratigraphy of Primorye region. I. Cephalopods. Trudy VSEGEI, 181: 1-246, 17 pls. (in Russian).

Korzh, M.V. 1959. Petrography of Triassic sediments of South Primorye and Triassic paleogeography. Izdat. AN SSSR, Moskva, 83 pp. (in Russian).

Shishkin, M.A. 1964. Suborder Stereospondyli. *In* Y.A. Orlov (ed.), Osnovy Paleont. Zemnovodnye Presm. i Ptitsy. Nauka, Moskva, p. 83-124 (in Russian).

Zharnikova, N.K. 1981. New Anisian ceratites of Acrochordiceratidae family of South Primorye. Paleont. Zhurn., 1981(1): 29-37, 1 pls. (in Russian).

Zakharov. Y.D. 1968. Biostratigraphy and ammonoids of the Lower Triassic of South Primorye. Nauka, Moscow. 175 pp., 31 pls. (in Russian).

Zakharov. Y.D. 1978.Early Triassic ammonoids of the East USSR. Nauka, Moscow, 224 pp., pls. (in Russian).

Zakharov. Y.D. 1997. Ammonoid evolution and the problem of the stage and substage division of the Lower Triassic. Mem. Geologie (Lausanne), 1997(30): 121-132, 3 pls.

Zakharov, Y.D. and Rybalka, S.V. 1987. Standards for the Permian-Triassic in the Tethys. In: Y.D. Zakharov and Y.I. Onoprienko (eds.), Problems of the Permian and Triassic biostratigraphy of the East USSR. DVNC AN SSSR, Vladivostok , p.6-48, 6 pls. (in Russian).

Zakharov, Y.D., Shigeta Y., Popov, A.M., Buryi G.I., Oleinikov, A.V., Dorukhovskaya E.A. and Mikhailik, T. M. 2002. Triassic ammonoid succession in South Primorye: 1. Lower Olenekian *Hedenstroemia bosphorensis* and *Anasibirites nevolini* Zones. Albertiana, 2002(27): 42-64.

Zakharov, Y.D., Popov, A.M., Buryi G.I. 2004. Triassic ammonoid succession in South Primorye: 2. Middle Olenekian *Tirolites-Amphistephanites* Zone. Albertiana, 2004(29): 42-64.

Lower Triassic Ammonoid Zonation in Chaohu, Anhui Province, China

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Abstract - The ammonoid fossils are rich throughout the Lower Triassic of Chaohu, Anhui Province, Southeast China. Six Lower Triassic ammonoid zones have been well recognized and described here in ascending order: *Ophiceras-Lytophiceras* Zone, *Gyronites-Prionolobus* Zone, *Flemingites-Euflemingites* Zone, *Anasibirites* Zone, *Tirolites-Columbites* Zone and *Subcolumbites* Zone.

Chaohu is a mid-sized city in the central part of the Anhui Province, southeastern China. It was on a deep part of carbonate ramp in the Lower Yangtze Block, which was situated in the low-latitude East Tethyan archipelago (Yin et al., 1999). The best-studied Lower Triassic sections are outcropped in the northwestern suburb within five kilometers from the center of the downtown. The Lower Triassic has been extensively studied in the area. A complete Lower Triassic sequence is integrated by three exposed sections, among which the North and West Pingdingshan sections cover the strata from the Upper Permian to the middle Olenekian while the South Majiashan Section consists of the rocks from the lower Olenekian to lower Anisian. The West Pingdingshan Section has been proposed as a candidate GSSP of the Induan-Olenekian boundary (Tong et al., 2003).

Ammonoid fossils are rich throughout the Lower Triassic in Chaohu though they are commonly preserved as mould fossils in the modrocks so that a definite identification is usually difficult at a specific level. But most Lower Triassic ammonoids are fortunately valuable in stratigraphy at a generic level. Gu and Xu (1980) first reported some Lower Triassic ammonoid fossils from the South Majiashan Section in Chaohu. Then Gu (1982a, b) and Wang and Guo (1982) described the rich collections from the Lower Triassic at the same section and established many new species, especially from the upper part of the Lower Triassic, where the fossils are preserved better. In the recent studies we also collected many ammonoid specimens in the area, especially from the strata around the Induan-Olenekian boundary at the Pingdingshan sections. The collection was made as well from the middle part of the Lower Triassic (upper Yinkeng Formation and Helongshan Formation) at the Majiashan sections. These fossils are mostly from mudrocks and the preservation is usually poor. Some ammonoids are described in a paper which has been in publication (Tong et al., 1994). Based on the collection from the South Majiashan Section, Guo and Xu (1980) proposed a Lower Triassic ammonoid zonation in ascending order: *Lytophiceras-Ophiceras* Zone, *Prionolobus* Zone, *Flemingites* Zone, *Anasibirites* Zone, *Tirolites-Columbites* Zone and *Subcolumbites* Zone. Late studies in the adjacent areas had basically confirmed this zonation except for only few revisions, e.g. the *Prionolobus* Zone was expanded as *Gyronites-Prionolobus* Zone (Gu, 1982b; Xu, 1987; Tong et al., 2003, 2004) and the *Flemingites* Zone

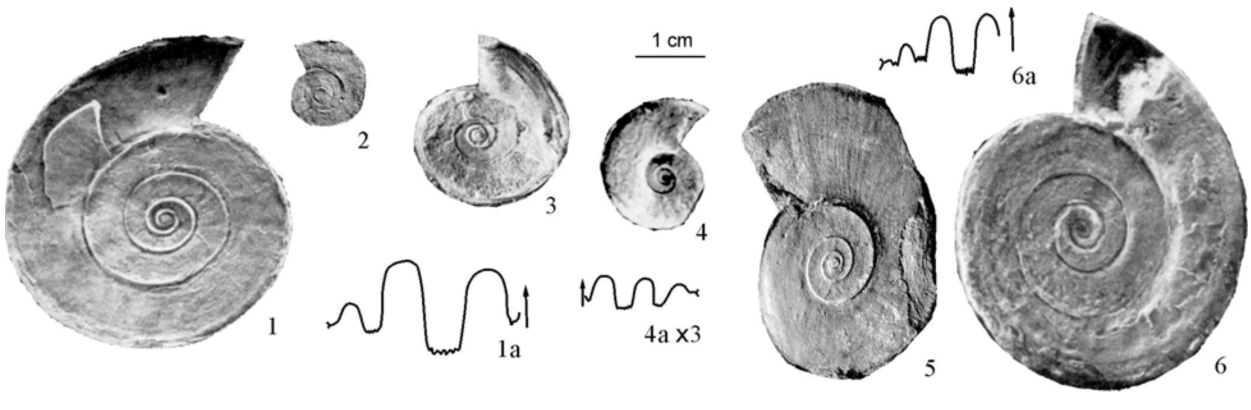

Figure 1 Some ammonoids from the *Ophiceras–Lytophiceras* Zone of Chaohu
1. *Ophiceras demissum* (Oppel), 2. *O.* sp., 3. *O.* cf. *compressum* Spath, 4. *Lytophiceras sakuntala* (Diener), 5. *L.* sp., 6. *L.* cf. *chamunda* (Diener); 1, 3, 4, 6 copied from Wang and Guo (1982), 2, 5 copied from Tong et al. (2004).

as *Flemingites-Euflemingites* Zone (Tong et al., 2003). It can be seen that the ammonoid zonation covers the whole Lower Triassic sequence, indicating the completeness of the Lower Triassic in the area. The biostratigraphic sequence is also confirmed by the conodont sequence co-existing with the ammonoid zonal fossils (Tong et al., 1993).

1. *Ophiceras–Lytophiceras* Zone (Fig. 1)

This zone is characteristic of genera *Ophiceras* and *Lytophiceras*. Most specimens are preserved as mould fossils and hardly identified at a specific level but only few species, e.g. *Ophiceras demissum* (Oppel) (Wang and Guo, 1982; Tong et al., 2004), *O.* cf. *compressus* Spath (Wang and Guo, 1982), *Lytophiceras sakutala* Diener (Wang and Guo, 1982), *L. commune* Spath (Guo, 1982b) and *L.* cf. *chamunda* (Diener) (Wang and Guo, 1982), are recognized. This zone is situated in the lower part of the Yinkeng Formation in Chaohu and the first appearance of the index fossils of this zone is in Bed 11, 1.8 m above the Permian-Triassic boundary, at the North Pingdingshan Section. This zone contains conodonts *Neogondolella carinata*, *N. planata*, *N. krystyni*, *N. orchardi* and *Hindeodus typicalis*. Its age is the Early Induan.

2. *Gyronites–Prionolobus* Zone (Fig. 2)

The very common ammonoids in this zone are genus *Prionolobus*. Most specimens are moulds and only few of them can be recognized as species, e.g. *Prionolobus hsuyuchiei* Chao (Tong et al., 2004), *P. impressus* (Waagen) (Wang and Guo, 1982). No definite *Gyronites* is found in Chaohu yet except for some questioned forms (Tong et al., 2004) though it is common in the adjacent areas (Guo, 1982). *Koninckites* is also a common form in this zone of Chaohu. Other ammonoid genera occurring in the zone include *Ambites*, ?*Kymatites* and ?*Metophiceras* (Tong et al., 2004). This zone is located in the middle part of the Yinkeng Formation in Chaohu. It covers the conodont zones from the top part of the *Neogondolella krystyni* Zone to the lowermost of the *Neospathodus waageni* Zone (Tong et al., 2003; Zhao et al., 2003). The coexisting conodonts include *Neospathodus kummeli*, *N. dieneri*, *N.* n. sp. C, *N.* n. sp. D, *N. waageni eowaageni* and others. Its age is the Late Induan, probably overlapping slightly the base of the Olenekian.

3. *Flemingites–Euflemingites* Zone (Fig. 3)

This zone is defined by the appearance of *Flemingites* and/or *Euflemingites*. *Flemingites* is the age-distinct form of this zone. But the *Flemingites* with traverse ribs is sometime hardly identified in mould specimens, whereas the *Euflemingites* with distinctive spiral ridges is quite recognizable though it may not be so common as *Flemingites* at some sections and occasionally extend into the base of the overlying *Anasibirites* Zone. The coexisting genera include *Owenites*, *Pseudoceltites*, *Preflorianites*, *Arctoceras* and *Koninckites*, *Dieneroceras*, *Clypeoceras*. The common species are *Flemingites ellipticus* Chao, *Flemingites kaoyunlingensis* Chao, *Euflemingites* cf. *tsotengensis* Chao, *Koninckites lolowensis* Chao, *Owenites pakungensis* Chao, *Dieneroceras dieneri* (Hyatt et Smith), etc. This zone correlates with the upper part of the Yinkeng Formation and the lower part of the Helongshan Formation in Chaohu, and with the lower part of conodont *Neospathodus waageni* Zone (Tong et al., 2003; Zhao et al., 2003), containing rich *Neospathodus cristagalli*, *N. waageni eowaageni*, *N. waageni elongata*, *N. waageni waageni*, *Platyvillosus costatus*, and some *N. dieneri*, *N. discretus*, *N. peculiaris*, *N. alberti*, *N. spitiensis*, *N. novaehollandiae*, *N. conservatives*, *Platyvillosus hamadai*. This age is the early Olenekian. It base is 26

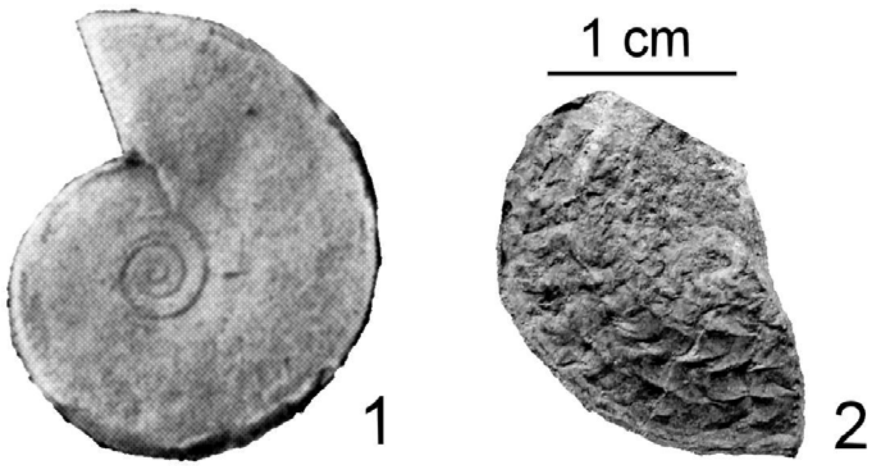

Figure 2 Some ammonoids from the *Gyronites–Prionolobus* Zone of Chaohu
1. *Prionolobus impressus* (Waagen) copied from Wang and Guo (1982), 2. *P. hsuyuchieni* Chao copied from Tong et al. (2004)

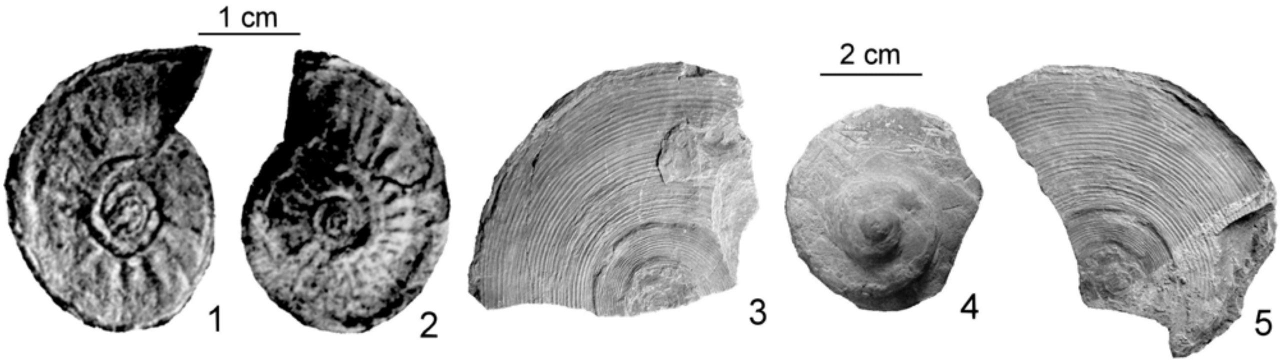

Figure 3 Some ammonoids from the *Flemingites–Euflemingites* Zone of Chaohu
1-2. *Flemingites kaoyunlingensis* Chao copied from Wang and Guo (1982), 3-5. *Euflemingites* cf. *tsotengensis* Chao copied from Tong et al. (2004)

cm above the proposed Induan-Olenekian boundary defined by the FAD of conodont *Neospathodus waageni* at the West Pingdingshan Section (Tong et al., 2003).

4. *Anasibirites* Zone (Fig. 4)

This zone is rich in genus *Anasibirites* and the very common species is *Anasibirites kingianus* (Waagen). The common coexisting genera include *Dieneroceras*, *Koninckites* and *Juvenites*. This zone also yields *Arctoceras*, *Prosphingitoides*, *Aspenites*, *Preflorianites*, *Xenodiscoides*, *Clypeoceras*, *Eophyllites*, *Hemiprionites*, *Isculitoides*, and occasionally questioned *Euflemingites*. This zone corresponds with the upper part of conodont *Neospathodus waageni* Zone, occurring the upper part of the Helongshan Formation in Chaohu. The conodonts recorded in this zone of Chaohu are not so common as in the underlying and overlying zones and most of them are ramiform elements and *Neospathodus* spp., which might include some new species, except for some *Neospathodus waageni*, *Aduncodina unicosta* and *Cornudina breviramulis*. The age of this zone is the middle Olenekian (late Smithian).

5. *Columbites–Tirolites* Zone (Fig. 5)

This zone is characterized by the existence of *Tirolites* and *Columbites* and the ammonoid fossils from the carbonate rocks are preserved relatively better. The common species are *Columbites parisianus* Hyatt and Smith, *C.*

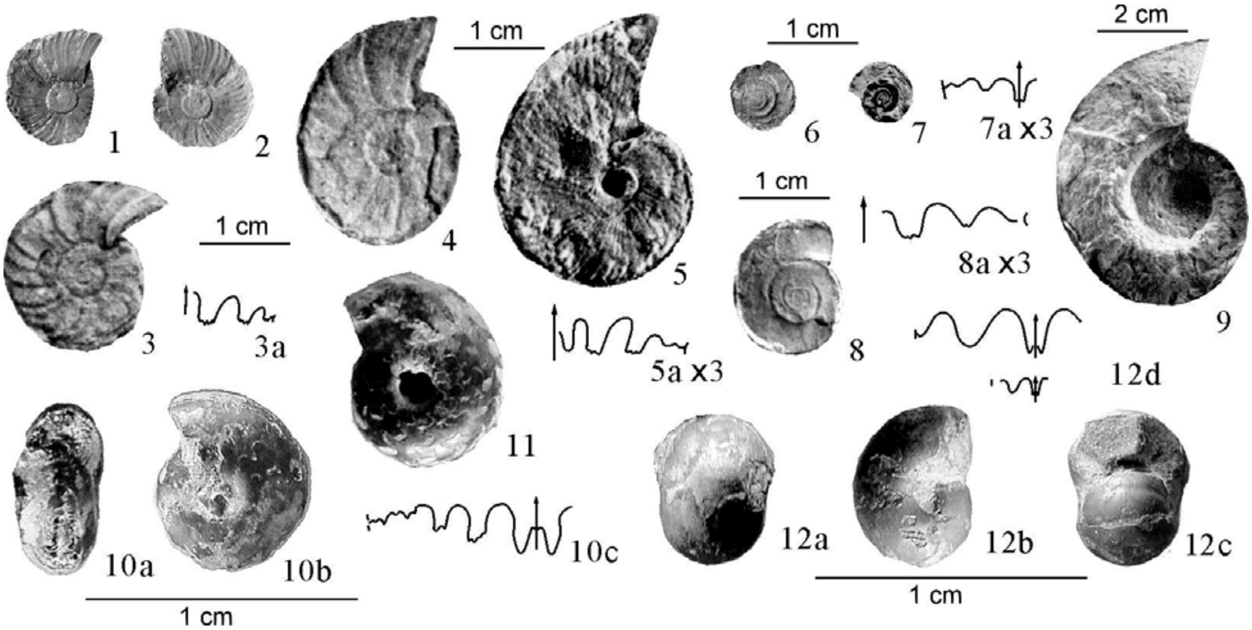

Figure 4 Some ammonoids from the *Anasibirites* Zone of Chaohu
1-3. *Anasibirites kingianus* (Waagen), 4. *A.* cf. *nevolini* Burij and Zharnikova, 5. *A. onoi* (Yehara), 6-7. *Dieneroceras* cf. *ovale* Chao, 8. *D.* cf. *tientungense* Chao, 9. *Meekoceras pulchriforme* Chao, 10-11. *Owenites pakungensis* Chao, 12. *Juvenites orientalis* Chao; 1, 2, 6, 7, 10-12 copied from Tong et al. (2004), 3-5 copied from Guo (1982a), 8, 9 copied from Wang and Guo (1982).

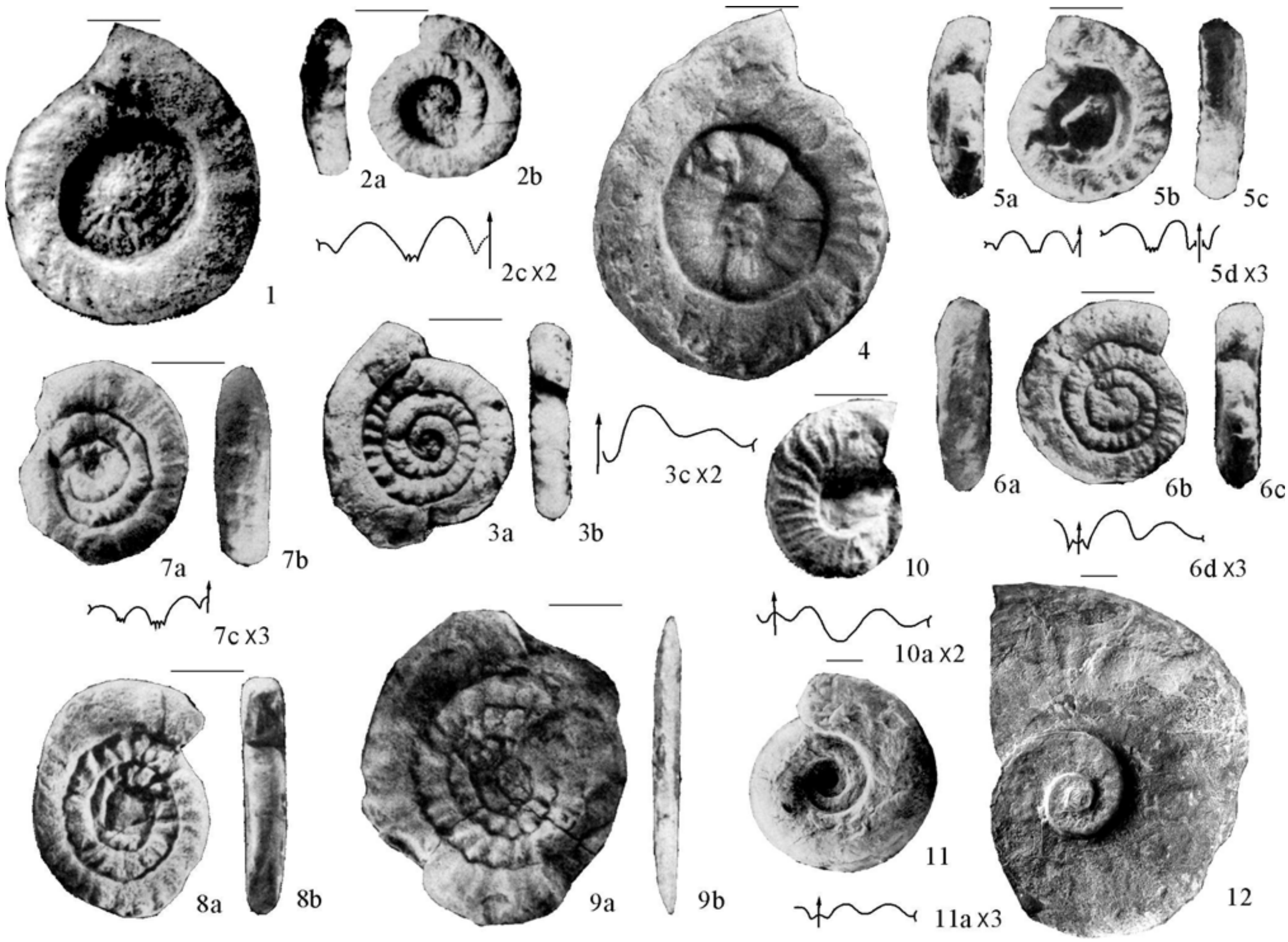

Figure 5 Some ammonoids from the *Columbites–Tirolites* Zone of Chaohu
1-2. *Columbites contractus* Guo, 3. *Tirolites latiunbilicatus* Guo, 4-5. *T. jiangsuensis* Guo, 6. *Xenoceltites praematurus* Guo, 7. *X. opimus* Guo, 8. *Proflorianite ellipticus* Guo, 9. *Columbites*(?) *discoides* Guo, 10. *Sibirites eichwaldi* (Keys), 11. *Arnautoceltites subglobosus* Guo, 12. *Eophyllites* sp.; 1, 9 copied from Guo and Xu (1980), 2-4, 10, 11 copied from Guo (1980a), 5-8 copied from Wang and Guo (1982), 12 copied from Tong et al. (2004). The short lines in the figure are all 1 cm long.

contractus Guo, *Tirolites latiumbilicatus* Guo, *T. jiangsuensis* Guo, *Columbites*(?) *discoides* Guo, and *Hellenites compressus* Guo. Other species include *Beneckeia majiashanensis* Guo, *Pseudosageceras multilobatum* Noetling, *Sibirites eichwaldi* (Keyserling), *Nordophiceras* sp., *Eophyllites* sp., *Tirolites* aff. *cassianus* (Questedt), etc. This zone is located mostly in the Lower Member of the Nanlinghu Formation at the Chaohu sections. It correlates with the conodont *Neospathodus* n. sp. M Zone, *N. eotriangularis* Zone and *N. homeri-N. abruptus* Zone in Chaohu (Tong et al., 2003; Zhao et al., 2003), containing conodont *Neospathodus* n. sp. M, *N. eotriangularis*, *N. triangularis*, *N. abruptus*, *N. homeri*, *N. brevissimus*, *N. spathi*, *Icrispathodus collinsoni*, and *Aduncodina unicosta*. The age of this zone is the middle Olenekian (early Spathian).

6. *Subcolumbites* Zone (Fig. 6)

The fossils of this zone are yielded in the Middle and Upper Members of the Nanlinghu Formation in Chaohu and the characteristic forms are the species of *Subcolumbites*, e.g. *S. perrinismithi* (Arthober), *S.* cf. *perrinismithi* (Arthober), *S. chaoxianensis* Guo, *S. chaohuensis* Guo. This zone also yields *Pseudoceltites evolutus* Guo, *Arnautoceltites subglobosus* Guo, *Hellenites* cf. *praematurus* (Arthober), *Proptychitoides* sp., etc. This zone corresponds with the conodont *Neospathodus anhuinensis* Zone, containing conodont *Neospathodus anhuinensis*, *N. homeri*, *N. abruptus*, *N. brevissimus*, *N. spathi*, *Aduncodina unicosta*, *Cornudina breviramulis*. The age of the zone is the late Olenekian (late Spathian).

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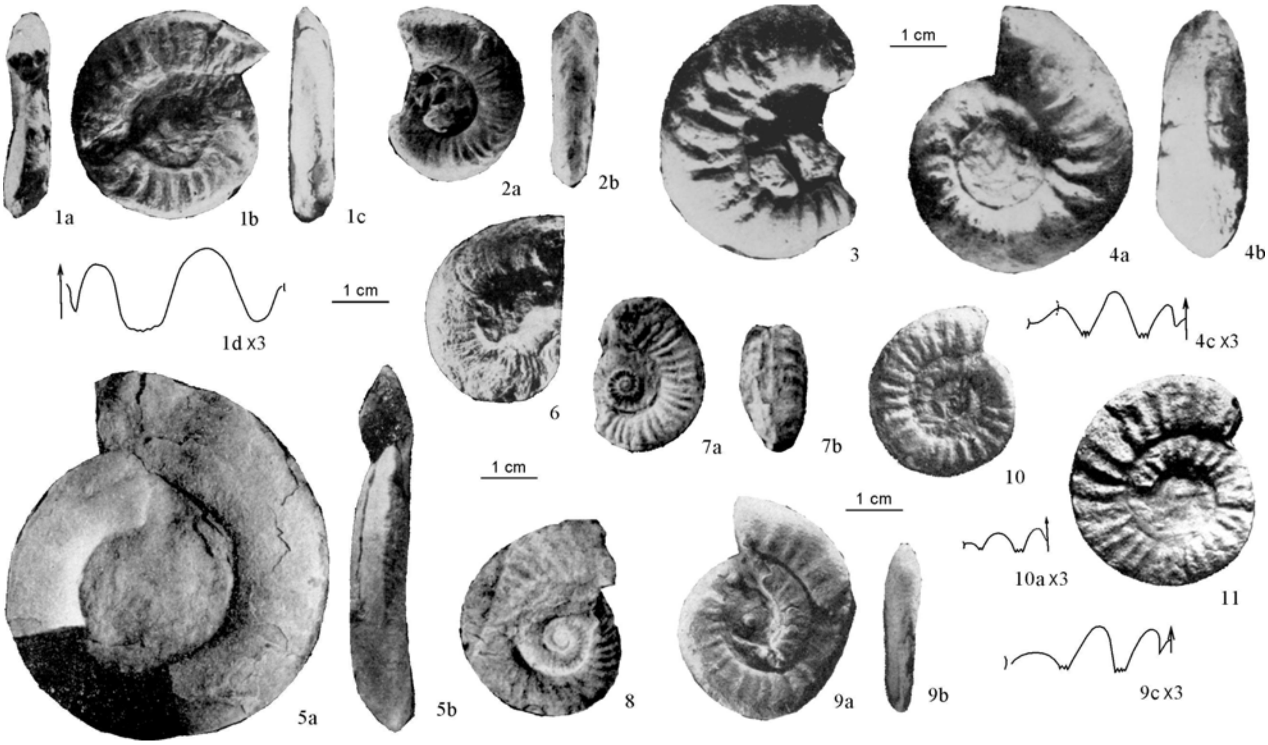

Figure 6 Some ammonoids from the *Subcolumbites* Zone of Chaohu
1-2. *Subcolumbites chaohuensis* Guo, 3-4. *S. chaoxianensis* Guo, 5. *S.* cf. *perrinismithi* (Arthober), 6. *S. perrinismithi* (Arthober), 7. *Hellenites compressus* Guo, 8. *H.* cf. *praematurus* (Arthober), 9. *Pseudoceltites anhuiensis* Guo, 10-11. *P. evolutus* Guo; 1, 5, 9-11 copied from Wang and Guo (1982), 2-4, 6 copied from Guo (1982a), 7, 8 copied from Guo and Xu (1980)

References

Guo Peixia, 1982a, On the occurrence of late Lower Triassic ammonoids from Anhui and Jiangsu. Acta Palaeontologica Sinica, 21(5): 560-568. (in Chinese with English abstract).

Guo Peixia, 1982b, The stratigraphy and ammonites of Qinglong Group, Anhui. Bull. Nanjing Inst. Gel. M. R., Acad. Geol. Sci., 3(3): 92-110. (in Chinese with English abstract).

Guo Peixia, Xu Jiacong, 1980, Knowledge on the age of the Qinglong Group in Chaoxian, Anhui Province. Journal of Stratigraphy, 4(4): 310-315. (in Chinese).

Tong Jinnan, Zakharov, Y. D., Orchard, M. J., Yin Hongfu, Hansen, H. J. 2003. A candidate of the Induan-Olenekian boundary stratotype in the Tethyan region. Science in China (Series D), 46(1): 1182-1200.

Tong Jinnan, Zakharov, Y. D., Wu Shunbao, 2004, Early Triassic ammonoid succession in Chaohu, Anhui Province. Acta Palaeontologica Sinica (*in press*).

Wang Guixiang, Guo Peixia, 1982, Cephalopoda. Paleontological Atlas of East China, Part 3: Volume of Mesozoic and Cenozoic. Geological Publishing House, Beijing, 116-135 (in Chinese).

Yin Hongfu, Wu Shunbao, Du Yuanshen, Peng Yuanqiao, 1999, South China defined as part of Tethyan archipelagic ocean system. Earth Science —— Journal of China University of Geosciences, 24(1): 1-12 (in Chinese with English abstract).

Zhao Laishi, Tong Jinnan, Zuo Jingxun, 2003, Lower Triassic conodont biostratigraphical sequence at West Pingdingshan Section, Chaohu, Anhui Province, China. Earth Science ¾ Journal of China University of Geosciences, 28(4): 414-418 (in Chinese with English abstract).

New Triassic Literature

Triassic Bibliography

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Abdala, F., Ribeiro, A.M., 2003. A new traversodontid cynodont from the Santa Maria formation (Ladinian-Carnian) of southern Brazil, with a phylogenetic analysis of Gondwanan traversodontids. Zoological Journal of the Linnean Society, 139: 529-545. Al-Husseini, M. I. (ed.). 2004. Carboniferous, Permian and Early Triassic Arabian Stratigraphy. GeoArabia Special Publication 3: 221pp.

Agadjanian, A.K., 2003. Adaptive radiation of mammals: major stages. Paleontological Journal, 37: 179-186.

Ahlberg, A., Olsson, I., Simkevicius, P., 2003. Triassic-Jurassic weathering and clay mineral dispersal in basement areas and sedimentary basins of southern Sweden. Sedimentary Geology, 161: 15-29.

Altmeyer, H.2003. Muschelkalkgebiete mit eigenen Bruchschill- oder Oolithtypen. Mainzer naturwissenschaftliches Archiv, 41: 5-13.

Amati, L., Feldmann, R. M. & Zonnefeld, J.-P. 2004. A new family of Triassic lobsters (Decapoda: Astacidea) from British Columbia and its phylogenetic context. Journal of Paleontology, 78 (1): 150-168.

Ambrose, K. & Williams, F. 2004. Bibliography of the geology of Leicestershire and Rutland. Part 2: 1971-2003. Mercian Geologist, 16 (1): 5-26.

Anon. 2004. Errata. Carboniferous, Permian and Early Triassic Arabian Stratigraphy. GeoArabia Special Publication 3, Edited by Moujahed I. Al-Husseini. GeoArabia, 9 (4): 164.

Anon. 2004. New time. Geology Today, 20 (5): 177-178.

Arcucci, A.B., Coria, R.A., 2003. A new Triassic carnivorous dinosaur from Argentina. Ameghiniana, 40: 217-228.

Aristov, D.S., 2003. Revision of the family Tomiidae (Insecta: Grylloblattida). Paleontological Journal, 37: 31-38.

Artabe, A.E., Morel, E.M., Spalletti, L.A., 2003. Characterization of the phytogeographic Triassic provinces from extratropical Gondwana. Ameghiniana, 40: 387-405.

Axsmith, B. J., Andrews, F. M. & Fraser, N. C. 2004. The structure and phylogenetic significance of the conifer *Pseudohimerella delawarensis* n.comb. from the Upper Triassic of North America. Review of Palaeobotany and Palynology, 129 (4): 251-263.

Backhaus, E. & Schwarz, S. 2003. Ein Sammelprofil des Buntsandsteins und Zechstein im mittleren Odenwald anhand von Bohrungen und Gamma-Logs. Geologisches Jahrbuch Hessen, 130: 91-107.

Bamford, M.K., 2004. Diversity of the woody vegetation of Gondwanan southern Africa. Gondwana Research, 7: 153-164.

Becker, L., Poreda, R. J., Basu, A. R., Pope, K. O., Harrison, T. M., Nicholson, C. & Iasky, R. 2004. Bedout: a possible end-Permian impact crater offshore of northwestern Australia. Science, 304: 1469-1476.

Belivanova, V. K. & Sapunov, I. G. 2003. The pre-Callovian stratigraphic gap in the Central Balkanids: a key for the interpretation of the other Early-Middle Jurassic gaps in Bulgaria. Geologica Balcanica, 33 (1-2): 17-33.

Belivanova, V. K. & Sapunov, I. G. 2003. Features of some Early-Middle Jurassic diastems in Bulgaria. Geologica Balcanica, 33 (1-2): 35-45.

Benton, M.J., Twitchett, R.J., 2003. How to kill (almost) all life: the end-Permian extinction event. Trends in Ecology & Evolution, 18: 358-365.

Berner, R.A., Beerling, D.J., Dudley, R., Robinson, J.M., Wildman, R.A., 2003. Phanerozoic atmospheric oxygen. Annual Review of Earth and Planetary Sciences, 31: 105-134.

Blake, D.B., Hotchkiss, F.H.C., 2004. Recognition of the asteroid (Echinodermata) crown group: Implications of the ventral skeleton. Journal of Paleontology, 78: 359-370.

Blake, D. B. & Zonneveld, J.-P. 2004. *Carniaster orchardi* new genus and species (Echinodermata: Asteroidea), the first Triassic asteroid from the western hemisphere. Journal of Paleontology, 78 (4): 723-730.

Blechschmidt, I., Dumitica, P., Matter, A., Krystyn, L. & Peters, T. 2004. Stratigraphic architecture of the northern Oman continental margin – Mesozoic Hamrat Duru Group, Hawasina complex, Oman. GeoArabia, 9 (2): 81-132.

Blendinger, W. 2004. Sea level changes versus hydrothermal diagenesis: origin of Triassic carbonate platform cycles in the Dolomites, Italy. Sedimentary Geology, 169 (1-2): 21-28.

Blendinger, W., Brack, P., Norborg, A. K. & Wulff-Pedersen, E. 2004. Three dimensional modelling of an isolated carbonate buildup (Triassic, Dolomites, Italy). Sedimentology, 51 (2): 297-314.

Bloos, G. 2004. The protection of fossils in Baden-

Württemberg (Federal Republic of Germany). Rivista Italiana di Paleontologia e Stratigrafia, 110 (1): 399-406.

Bordy, E. M., Hancox, P. J. & Rubidge, B. S. 2004. Fluvial style variations in the Late Triassic-Early Jurassic Elliot Formation, main Karoo Basin, South Africa. Journal of African Earth Sciences, 38 (4): 383-400.

Bortolotti, V., Carras, N., Chiari, M., Fazzuoli, M., Marcucci, M., Photiades, A., Principi, G. 2003. The Argolis Peninsula in the palaeogeographic and geodynamic frame of the Hellenides. Ofioliti, 28: 79-94.

Boyer, D. L., Bottjer, D. J. & Droser, M. L. 2004. Ecological signature of Lower Triassic shell beds of the western United States. Palaios, 19 (4): 372-380.

Brew, G., Best, J., Barazangi, M., Sawaf, T., 2003. Tectonic evolution of the NE Palmyride mountain belt, Syria: the Bishri crustal block. Journal of the Geological Society, 160: 677-685.

Bromley, R. G. 2004. A stratigraphy of marine bioerosion. Geological Society, London, Special Publications, 228: 455-479.

Brookfield, M. E. 2004. The enigma of fine-grained alluvial basin fills: the Permo-Triassic (Cumbrian Coastal and Sherwood Sandstone Groups) of the Solway Basin, NW England and SW Scotland. International Journal of Earth Sciences, 93 (2): 282-296.

Bouatmani, R., Medina, F., Salem, A.A., Hoepffner, C., 2003. Thin-skin tectonics in the Essaouira basin (western High Atlas, Morocco): evidence from seismic interpretation and modelling. Journal of African Earth Sciences, 37: 25-34.

Carter, J. G. & Stanley, G. D., Jr. 2004. Late Triassic gastrochaenid and lithophaginid borings (Mollusca: Bivalvia) from Nevada (USA) and Austria. Journal of Paleontology, 78 (1): 230-234.

Callot, J.P., Gurevitch, E., Westphal, M., Pozzi, J.P., 2004. Flow patterns in the Siberian traps deduced from magnetic fabric studies. Geophysical Journal International, 156: 426-430.

Chandra, S. 2002. Gondwana revisited. Indian Journal of Earth Sciences, 29 (1-4): 53-67.

Chen, Z. Q., Shi, G. R. & Kaiho, K. 2004. New ophiuroids from the Permian/Triassic boundary beds of South China. Palaeontology, 47 (5): 1301-1312.

Chen, X.H., Yin, A., Gehrels, G.E., Cowgill, E.S., Grove, M., Harrison, T.M., Wang, X.F., 2003. Two phases of Mesozoic north-south extension in the eastern Altyn Tagh range, northern Tibetan Plateau. Tectonics, 22(5), Art. no. 1053.

Chun, L., 2003. First record of protorosaurid reptile (Order Protorosauria) from the Middle Triassic of China. Acta Geologica Sinica - English Edition, 77: 419-423.

Chun Lli, Rieppel, O. & LaBarbera, M. C. 2004. A Triassic aquatic protorsaur with an extremely long neck. Science, 305: 1931.

Cohen, A. S. 2004. The rhenium-osmium isotope system: applications to geochronological and palaeoenvironmental problems. Journal of the Geological Society, London, 161 (4): 729-734.

Courel, L., Salem, H.A., Benaouiss, N., Et-Touhami, M., Fekirine, B., Oujidi, M., Soussi, M., Tourani, A., 2003. Mid-Triassic to Early Liassic clastic/evaporitic deposits over the Maghreb Platform. Palaeogeography Palaeoclimatology Palaeoecology, 196: 157-176.

Coward, M. P. & Ries, A. C. 2003. Tectonic development of North African basins. Geological Society, London, Special Publications, 207: 61-83.

Crasquin-Soleau, S., Marcoux, J., Angiolini, L. & Nicora, A. 2004. Palaeocopida (Ostracoda) across the Permian-Triassic events: new data from southwestern Taurus (Turkey). Journal of Micropalaeontology, 23 (1): 67-76.

Crouzet, C., Gautam, P., Schill, E., Appel, E. 2003. Multicomponent magnetization in western Dolpo (Tethyan Himalaya, Nepal): tectonic implications. Tectonophysics, 377: 179-196.

Crowhurst, P.V., Maas, R., Hill, K.C., Foster, D.A., Fanning, C.M., 2004. Isotopic constraints on crustal architecture and Permo-Triassic tectonics in New Guinea: possible links with eastern Australia. Australian Journal of Earth Sciences. 51: 107-122.

Csontos, L. & Vörös, A. 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. Palaeogeography, Palaeoclimatology, Palaeoecology, 210 (1): 1-56.

Dadlez, R., 2003. Mesozoic thickness pattern in the Mid-Polish Trough. Geological Quarterly, 47: 223-240.

Dalla Vecchia, F. M. 2004. First record of the rare marine reptile *Tholodus schmidi* from the Middle Triassic of the southern Alps. Rivista Italiana di Paleontologia e Stratigrafia, 110 (2): 479-492.

Davis, A. D., Beaver, F. W. & Stetler, L. D. 2003. Engineering problems of gypsum karst along the Interstate 90 Development Corridor in the Black Hills of South Dakota. Oklahoma Geological Survey Circular, 109: 255-261.

Damiani, R., Modesto, S., Yates, A., Neveling, J., 2003. Earliest evidence of cynodont burrowing. Proceedings of the Royal Society of London Series B, Biological Sciences 270: 1747-1751.

Decrouez, D. & Juriens-Cottet, I. 2003. Les collections du department de géologie et de paléontologie du Muséum d'histoire naturelle de Genève. 79. La collection générale (Bryozoa). Revue de Paléobiologie, 22 (2): 925-929.

De Wit, M.J., Anderson, J.M., 2003. Gondwana alive corridors: Extending Gondwana research to incorporate stemming the sixth extinction. Gondwana Research, 6: 369-408.

Dickens, G.R., 2003. Rethinking the global carbon cycle with a large, dynamic and microbially mediated gas hydrate capacitor. Earth and Planetary Science Letters, 213: 169-183.

Dickson, J. A. D. 2004. Echinoderm skeletal preservation: calcite-aragonite seas and the Mg/Ca ratio of Phanerozoic oceans. Journal of Sedimentary Research, 74 (3): 355-365.

Dolenec, M., Ogorelec, B., Lojen, S., 2003. Upper Carboniferous to Lower Triassic carbon isotopic signature in carbonate rocks of the Western Tethys (Slovenia). Geologica Carpathica, 54: 217-228.

Dorka, M., 2003. Teeth of *Polyacrodus* Jaeckel, 1889 from the Triassic of the Germanic Basin. Mitteilungen aus dem Museum für Naturkunde, Geowissenschaftliche Reihe, 6: 147-155.

Dragièeviæ, I. & Veliæ,I. 2002. The northeastern margin of the Adriatic Carbonate Platform. Geologia Croatica, 55 (2): 185-232.

Dzik, J., 2003. A beaked herbivorous archosaur with dinosaur affinities from the early Late Triassic of Poland. Journal of Vertebrate Paleontology, 23: 556-574.

El Arabi, E., Ferrandini, J., Essamoud, R., 2003. Triassic stratigraphy and structural evolution of a rift basin: the Ec Cour basin, High atlas of Marrakech, Morocco. Journal of African Earth Sciences, 36: 29-39.

Emmel, B., Jacobs, J. & Razakamanana, T. 2004. Titanite and apatite fission track analysis on basement rocks of central-southern Madagascar: constraints on exhumation and denudation rates along the eastern rift shoulder of the Morondava basin. Journal of African Earth Sciences, 38 (4): 343-361.

Engoren, M. 2004. Vertebrate extinction across Permian-Triassic boundary in Karoo Basin, South Africa: discussion. Geological Society of America Bulletin, 116 (9-10): 1294.

Epstein, J. B. 2003. Gypsum karst in the Black Hills, South Dakota – Wyoming: geomorphic development, hazards and hydrology. Oklahoma Geological Survey Circular, 109: 241-254.

Evans, S.E., 2003. At the feet of the dinosaurs: the early history and radiation of lizards. Biological Reviews, 78: 513-551.

Ezaki, Y., Jianbo Liu & Adachi, N. 2004. Reply (to Kershaw, S., 2004; q.v.). Palaios, 19 (4): 416-417.

Falletti, P. & Ivanova, D. 2003. Monte Guglielmo Limestone: a Middle-Late Anisian carbonate platform in central Southern Alps (Italy). Atti Ticinensi di Scienze della Terra, 44: 75-83.

Fang Zong-lie. 2004 Discussion on the study of the genera *Claraia* and *Claraioides* (Bivalvia) of Late Permian age. Acta Palaeontologica Sinica, 42 (4): 613-619.

Fantoni, R., Decarlis, A. & Fantoni, E. 2003. Mesozoic extension at the western margin of the Southern Alps (Piemonte Settentionale, Italia). Atti Ticinensi di Scienze della Terra, 44: 97-110.

Fastnach, M. 2004.An intriguing temnospondyl skeleton from the Lower Triassic of Germany. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, (2-3): 195-213.

Felber, M., Furrer, H. & Tintori, A. 2004. The Triassic of Monte San Giorgio in the World Heritage List of UNESCO: an opportunity for science, the local people and tourism. Eclogae Geologicae Helvetiae, 97 (1): 1-2.

Fels, A., Brunner, H., Engesser, W. & Simon, T. 2003. Steinsalz im Oberen Rötton des Baulands. Jahreshefte des Landesamts für Geologie, Rohstoffe und Bergbau Baden-Württemberg, 39: 7-23.

Filippov, A.N., Kemkin, I.V., 2003. Clastic rocks from Permian and Triassic cherty sequences in Sikhote Alin and Japan. Lithology And Mineral Resources, 38: 36-47.

Franzese, J., Spalletti, L., Perez, I.G., MacDonald, D., 2003. Tectonic and paleoenvironmental evolution of Mesozoic sedimentary basins along the Andean foothills of Argentina (32°-54° S). Journal of South American Earth Sciences, 16: 81-90.

Fraiser, M. L. & Bottjer, D. J. 2004. The non-actualistic Early Triassic gastropod fauna: a case study of the Lower Triassic Sinbad Limestone Member. Palaios, 19 (3): 259-275.

Freytet, P., Broutin, J. & Durand, M. 2000. Distribution and palaeoecology of freshwater algae and stromatolites: III, some new froms from the Carboniferous, Permian and Triassic of France and Spain. Annales de Paléontologie, 86 (4): 195-241.

Gardein, V. & Paquette, J. L. 2004. Ion microprobe and ID-TIMS U-Pb dating on zircon grains from leg 173 amphibolites: evidence for Permian magmatism on the West Iberian margin. Terra Nova, 16 (4): 226-231.

Gaetani, M., Dercourt, J., Vrielynck, B., 2003. The Peri-Tethys Programme: achievements and results. Episodes, 26: 79-93.

Gallet, Y., Krystyn, L., Besse, J., Marcoux, J., 2003. Improving the Upper Triassic numerical time scale from cross-correlation between Tethyan marine sections and the continental Newark basin sequence. Earth and Planetary Science Letters, 212: 255-261.

Garassino, A., Pasini, G., Teruzzi, G., 2003. Macrurans (Crustacea, Decapoda) from the Lower Triassic (Olenekian) of the Ambilobe area (NW Madagascar). Contributions to Zoology, 72: 137-139.

Geiger, M., Clark, D. N. & Mette, W. 2004. Reappraisal of the timing of the breakup of Gondwana based on sedimentological and seismic evidence from the Morondava Basin. Journal of African Earth Sciences, 38 (4): 363-381.

Genise, J. F. 2004. Ichnotaxonomy and ichnostratigraphy of chambered trace fossils in palaeosols attributed to coleopterans, ants and termites. Geological Society, London, Special Publications, 228: 419-453.

Genise, J. F., Bellosi, E. S. & Gonzalez, M. G. 2004. An approach to the description and interpretation of ichnofacies in palaeosols. Geological Society, London, Special Publications, 228: 355-382.

Gianolla, P., De Zanche, V., Roghi, G. 2003. An Upper Tuvalian (Triassic) platform-basin system in the Julian

Alps: The start-up of the Dolomia Principale (Southern Alps, Italy). Facies, 49: 135-150.

Gore, D.B., Taylor, M.P., 2003. Grooves and striations on the Stanthorpe Adamellite: evidence for a possible late Middle-Late Triassic age glaciation - Discussion. Australian Journal of Earth Sciences, 50: 467-469.

Goodenough, K. & Bradwell, T. 2004. Rum and the small isles – a landscape fashioned by geology. Perth: Scottish Natural Heritage, 39pp.

Gradstein, F. M. & Ogg, J. G. 2004. Geologic Time Scale 2004 – why, how, and where next! Lethaia, 37 (2): 175-181.

Grakhanov, S.A., Koptil', V.I., 2003. Triassic diamond placers on the northeastern Siberian platform. Geologiya i Geofizika, 44: 1191-1201.

Graversen, O. 2004. Upper Triassic–Lower Cretaceous seismic sequence stratigraphy and basin tectonics at Bornholm, Denmark, Tornquist Zone, NW Europe. Marine and Petroleum Geology, 21 (5): 579-612.

Grimaldi, D., Shmakov, A. & Fraser, N. 2004. Mesozoic thrips and early evolution of the Order Thysanoptera (Insecta). Journal of Paleontology, 78 (5): 941-952.

Groves, J.R., Rettori, R., Altiner, D., 2004. Wall structures in selected Paleozoic lagenide foraminifera. Journal of Paleontology, 78: 245-256.

Guex, J., Bartolini, A., Atudorei, V., Taylor, D., 2003. Two negative $\delta^{13}C_{org}$ excursions near the Triassic-Jurassic boundary in the New York Canyon area (Gabbs Valley Range, Nevada). Bulletin de Géologie, Lausanne, 360: 4 pp.

Guex, J., Bartolini, A., Atudorei, V. & Taylor, D. 2004. High-resolution ammonite and carbon isotope stratigraphy across the Triassic-Jurassic boundary in New York Canyon (Nevada). Earth and Planetary Science Letters, 225 (1): 29-41.

Gurevitch, E.L., Heunemann, C., Rad'ko, V., Westphal, M., Bachtadse, V., Pozzi, J.P., Feinberg, H., 2004. Palaeomagnetism and magnetostratigraphy of the Permian-Triassic northwest central Siberian Trap Basalts. Tectonophysics. 379: 211-226.

Haas, J. & Péró. 2004. Mesozoic evolution of the Tisza Mega-unit. International Journal of Earth Sciences, 93 (2): 297-313.

Haas, J. & Tardy-Filácz, E. 2004. Facies changes in the Triassic-Jurassic boundary interval in an intraplatform basin succession at Csövár (Transdanubian Range, Hungary). Sedimentary Geology, 168 (1-2): 19-48.

Hall, R. & Pitaru, S. 2004. New Hettangian ammonite faunas and a Triassic-Jurassic boundary succession, Fernie Formation, Williston Lake, British Columbia. Rivista Italiana di Paleontologia e Stratigrafia, 110 (1): 53-60.

Harker, S.D., Richardson, G., Sides, L.E., Cooper, R., 2003. Alwyn North Triassic Main gas-condensate: drilling deeper promotes production. Petroleum Geoscience, 9: 133-143.

Hartz, E.H., Eide, E.A., Andresen, A., Midboe, P., Hodges, K.V., Kristiansen, S.N., 2002. Ar-40/Ar-39 geochronology and structural analysis: Basin evolution and detrital feedback mechanisms, Hold with Hope region, East Greenland. Norwegian Journal of Geology, 82: 341-358.

Hautmann, M. 2004. Early Mesozoic evolution of alivincular bivalve ligaments and its implications for the timing of the 'Mesozoic marine revolution'. Lethaia, 37 (2): 165-172.

Hautmann, M. 2004. Effect of end-Triassic CO_2 maximum on carbonate sedimentation and marine mass extinction. Facies, 50: 257-261.

He, B., Xu, Y.G., Chung, S.L., Xiao, L., Wang, Y., 2003. Sedimentary evidence for a rapid, kilometer-scale crustal doming prior to the eruption of the Emeishan flood basalts. Earth and Planetary Science Letters, 213: 391-405.

Hejl, E., Sekyra, G., Friedl, G., 2003. Fission-track dating of the south-eastern Bohemian massif (Waldviertel, Austria): thermochronology and long-term erosion. International Journal of Earth Sciences 92: 677-690.

Heller, P.L., Dueker, K., McMillan, M.E., 2003. Post-Paleozoic alluvial gravel transport as evidence of continental tilting in the US Cordillera.Geological Society of America Bulletin, 115: 1122-1132.

Hervé, F., Fanning, C.M., Pankhurst, R.J., 2003. Detrital zircon age patterns and provenance of the metamorphic complexes of southern Chile. Journal of South American Earth Sciences, 16: 107-123.

Hesselbo, S. P., Robinson, S. A. & Surlyk, F. 2004. Sea-level change and facies development across potential Triassic-Jurassic boundary horizons, SW Britain. Journal of the Geological Society, London, 161 (3): 365-379.

Heydari, E., Hassanzadeh, J. 2003. Deev Jahi Model of the Permian-Triassic boundary mass extinction: a case for gas hydrates as the main cause of biological crisis on Earth. Sedimentary Geology, 163: 147-163.

Holliday, D. W., Holloway, S., McMillan, A. A., Jones, N. S., Warrington, G. & Akhurst, M. C. 2004. The evolution of the Carlisle Basin, NW England and SW Scotland. Proceedings of the Yorkshire Geological Society, 55 (1): 1-19.

Hou Zengqian, Yang Zhusen, Li Yinqing, Zeng Pusheng & Meng Yifeng. 2004. Large-scale migration of fluids towards foreland basins during collisional orgeny: evidence from Triassic Anhydrock sequences and regional alteration in the Middle-Lower Yangtze area. Acta Geologica Sinica, 78 (1): 203-220.

Huggett, J. 2004. Comments on Kirkham's "Glauconitic spherules from the Triassic of the Bristol area, SW England: probable microtektite pseudomorphs" with reply by A. Kirkham. Proceedings of the Geologists' Association, 115 (2): 189-192.

Ismagilov, DF; Kozlov, VN; Martirosyan, VN; Terekhov, AA. 2003. The Sediments of the Middle Caspian Region: Structure and sedimentation history based on seismic data. Geotectonics, 37: 304-315.

Isosaki, Y., Jianxin Yao, Matsuda, T., Sakai, H., Zhansheng Ji, Shimizu, N., Kobayashi, N., Kawahata, H., Nishi, H., Takano, M. & Kubo, T. 2004. Stratigraphy of the Middle-Upper Permian and lowermost Triassic at Chaotian, Sichuan, China. Record of a Late Permian double mass extinction event. Proceedings of the Japan Academy, Series B, Physical and Biological Sciences, 80 (1): 10-16.

Jacques, J.M.,. 2003. A tectonostratigraphic synthesis of the Sub-Andean basins: implications for the geotectonic segmentation of the Andean Belt. Journal of the Geological Society, 160: 687-701.

Jarvis, T. 2003. The Money Pit: karst failure of Anchor Dam, Wyoming. Oklahoma Geological Survey Circular, 109: 271-278.

Jarvis, T. & Huntoon, P. 2003. A stinking lake and perpetual potholes: living with gypsite karst in Laramie, Wyoming. Oklahoma Geological Survey Circular, 109: 263-269.

Jingeng Sha, Johnson A. L. A. & Fürsich, F. T. 2004. From deep-sea to high mountain ranges: palaeogeographic and biotic changes in Hohxil, the source area of the Yangtze River (Tibet Plateau) since the Late Palaeozoic. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 233 (2): 169-195.

Johnson, K. S. & Neal, J. T. (eds). 2003. Evaporite Karst and Engineering/Environmental Problems in the United States. Oklahoma Geological Survey Circular, 109: iii+353pp.

Jones, C. 2004. Abberley and Malvern Hills Geopark. Mercian Geologist, 16 (1): 46-47.

Joyce, W.G., Gauthier, J.A. 2004., Palaeoecology of Triassic stem turtles sheds new light on turtle origins. Proceedings of the Royal Society of London, Series B - Biological Sciences 271: 1-5.

Jun Li, Changqun Cao, Servais, T. & Youhua Zhu. 2004. Late Permian acritarchs from Meishan (SE China) in the context of Permian palaeobiogeography and palaeoecology. Neues Jahrbuch für Geologie und Paläontologie Monatshefte, 2004 (7): 427-448.

Kamali, M.R., Rezaee, M.R., 2003. Burial history reconstruction and thermal modelling at Kuh-e Mond, SW Iran. Journal of Petroleum Geology, 26: 451-464.

Karasawa, H., Takahashi, F., Doi, E., Ishida, H., 2003. First record of *Coleia broderip* (Crustacea, Decapoda, Coleiidae) from the Upper Triassic of Japan. Contributions to Zoology, 72: 153-155.

Kashiwagi, K. & Kurimoto, C. 2003. Reexamination of radiolarian biochronology of the Shimizu Formation (Northern Chichibu Belt) in the Shimizu - Misato area, western Kii Peninsula, Southwest Japan. Bulletin of the Geological Survey of Japan, 54 (7-8): 279-293.

Kerr, R. A. 2004. Evidence of huge, deadly impact found off Australian coast? Science, 304: 942.

Kershaw, S. 2004. Comment – earliest Triassic microbialite micro- to megastructures in the Huaying area of Sichuan Province, south China: implications for the nature of oceanic conditions after the end-Permian extinction (Ezaki et al., 2003). Palaios, 19 (4): 414-416.

Kiessling, W., Flügel, E. & Golonka, J. 2003. Patterns of Phanerozoic carbonate platform sedimentation. Lethaia, 36 (3): 195-226.

Klavins, S. D., Taylor, T. N. & Taylor, E. L. 2004. Matoniaceous ferns (Gleicheniales) from the Middle Triassic of Antarctica. Journal of Paleontology, 78 (1): 211-217.

Klavins, S.D., Taylor, E.L., Krings, M., Taylor, T.N., 2003. Gymnosperms from the Middle Triassic of Antarctica: The first structurally preserved cycad pollen cone. International Journal of Plant Sciences, 164: 1007-1020.

Klug, C. & Lehmkuhl, A. 2004. Soft-tissue attachment structures and taphonomy of the Middle Triassic nautiloid *Germanonautilus*. Acta Palaeontologica Polonica, 49 (2): 243-258.

Kobayashi, F., 2003. Palaeogeographic constraints on the tectonic evolution of the Maizuru Terrane of Southwest Japan to the eastern continental margin of South China during the Permian and Triassic. Palaeogeography Palaeoclimatology Palaeoecology, 195: 299-317.

Koike, T. 2004. Early Triassic *Neospathodus* (Conodonta) apparatuses from the Taho Formation, southwest Japan. Palaeontological Research, 8 (2): 129-140.

Kolar-Jurkovsek, T., Jurkovsek, B., 2003. *Clypenia besici* Pantic (Chlorophyta, Dasycladales) from the “Raibl Beds” of the Western Karavanke Mountains (Slovenia). Geologica Carpathica, 54: 237-242.

Konstantinov, A.G., Sobolev, E.S., Klets, T.V., 2003. New data on fauna and biostratigraphy of Norian deposits in the Kotel’nyi Island (New Siberian Islands). Stratigraphy and Geological Correlation, 11: 231-243.

Komatsu, T., Akasaki, M., Jin-hua Chen, Mei-zen Cao & Stiller, F. 2004. Benthic fossil assemblages and depositional facies of the Middle Triassic (Anisian) Yuqing Member of the Qingyan Formation, southern China. Palaeontological Research, 8 (1): 43-52.

Komatsu, T., Chen, J-h., Cao, M-z., Stiller, F. & Naruse, H. 2004. Middle Triassic (Anisian) diversified bivalves: depositional environments and bivalve assemblages in the Leidapo Member of the Qingyan Formation, southern China. Palaeogeography, Palaeoclimatology, Palaeoecology, 208 (3-4): 207-223.

Korchagin, O.A., Kuznetsova, K.I., Bragin, N.Y., 2003. Find of early planktonic foraminifers in the Triassic of the Crimea. Doklady Earth Sciences, 390: 482-486.

Kotañski, Z., Gierliñski, G. & Ptaszyñski, T. 2004. Reptile tracks (*Rotodactylus*) from the Middle Triassic of the Djurdjura Mountains of Algeria. Geological Quarterly, 48 (1): 89-96.

Kotlyar, G. V., Zakharov, Y. D. & Polubotko, I. V. 2004. Late Changhsingian fauna of the northwestern Caucasus mountains, Russia. Journal of Paleontology, 78 (3): 513-527.

Krause, T., Katzung, G., 2002. Dolomitisierte Werkstein-

Horizonte im Unteren Muschelkalk der Remdaer Störungszonen (Thüringer Mulde) - Anzeichen für Zechsteinsalz-Instrusionen. Geowissenschaftliche Mitteilungen Thüringen, 10: 21-37.

Krzywiec, P. 2004. Triassic evolution of the K³odawa salt structure: basement controlled salt tectonics within the Mid-Polish Trough (Central Poland). Geological Quarterly, 48 (2): 123-134.

Kumar, P. 2002. Depositional environment of Bagra Formation (Upper Triassic), Satpura Basin, India: a palynological approach. Palaeobotanist, 51: 99-106.

Lai, S.C., Zhang, G.W., Li, S.Z. 2004. Ophiolites from the Mianlue Suture in the southern Qinling and their relationship with the eastern Paleotethys evolution. Acta Geologica Sinica, 78: 107-117.

Langer, M., Boniface, M., Cuny, G. & Barbieri, L. 2000. The phylogenetic position of *Isalorhynchus genovefae*, a Late Triassic rhynchosaur from Madagascar. Annales de Paléontologie, 86 (2): 101-127.

Laville, E., Pique, A., Amrhar, M., Charroud, M., 2004. A restatement of the Mesozoic Atlasic Rifting (Morocco). Journal of African Earth Sciences, 38: 145-153.

Le Tourneau, P. M. & Olsen, P. E. (eds). 2003. The Great Rift Valleys of Pangea in Eastern North America. Volume 1: Tectonics, Structure, and Volcanism, xi+214pp. New York, Columbia University Press.

Le Tourneau, P. M. & Olsen, P. E. (eds). 2003. The Great Rift Valleys of Pangea in Eastern North America. Volume 2: Sedimentology, Stratigraphy, and Paleontology, xxv+384pp. New York, Columbia University Press.

Leppe, M., Moisan, P., 2003. New records of Upper Triassic Cycadales and Cycadeoidales of Bio-Bio River, Chile. Revista Chilena de Historia Natural, 76: 475-484.

Li Yuejun, Sun Longde, Wu Haoruo, Wang Guolin, Su Yushan & Huang Zhibin. 2004. Radiolarian fossils from chert gravels of Triassic conglomerate in NW margin of the Tarim Basin and their geological significance. Chinese Journal of Geology, 39 (2): 159-167.

Liang Handong & Ding Tiping. 2004. Evidence of extremely light gypsum from the Permian-Triassic (P/T) event boundary at the Meishan section of South China. Acta Geoscientica Sinica, 25 (1): 33-37.

Lisker, F., Brown, R., Fabel, D., 2003. Denudational and thermal history along a transect across the Lambert Graben, northern Prince Charles Mountains, Antarctica, derived from apatite fission track thermochronology. Tectonics, 22(5), Art. no. 1055.

Liu, S.F., Heller, P.L., Zhang, G.W., 2003. Mesozoic basin development and tectonic evolution of the Dabieshan orogenic belt, central China. Tectonics, 22(4), art. no. 1038.

Liu, Z.S., Hao, Z.K., Chen, B., Li-Xiao, Y., 2003. New evidences of Late Triassic fish swimming traces in Hengshan County, Shaanxi Province, China. Acta Palaeontologica Sinica, 42: 266-276.

Loope, D. B., Steiner, M. B., Rowe, C. M. & Lancaster, N. 2004. Tropical westerlies over Pangaean sand seas. Sedimentology, 51 (2): 315-322.

Lu, Z.S., Hou, J.X., Chen, B., Hao, C.K., Li, X.Y., 2004. Genetic interpretation of fish swimming trails and calculation of fish-body length in Late Triassic Hengshan, Shaanxi Province, China. Science in China Series D, Earth Sciences, 47: 272-279.

Luptak, B., Janak, M., Plasienka, D., Schmidt, S.T., 2003. Alpine low-grade metamorphism of the Permian-Triassic sedimentary rocks from the Veporic Superunit, Western Carpathians: Phyllosilicate composition and “crystallinity” data. Geologica Carpathica, 54: 367-375.

Lutz, M. & Etzold, M. 2003. Der Keuper im Untergrund des Oberrhengrabens in Baden. Jahreshefte des Landesamts für Geologie, Rohstoffe und Bergbau Baden-Württemberg, 39: 55-110.

Macdonald, D., Gomez-Perez, I., Franzese, J., Spalletti, L., Lawver, L., Gahagan, L., Dalziel, I., Thomas, C., Trewin, N., Hole, M., Paton, D., 2003. Mesozoic break-up of SW Gondwana: implications for regional hydrocarbon potential of the southern South Atlantic. Marine and Petroleum Geology, 20: 287-308.

Maisch, M. W. & Matzke, A. T. 2004. Observations on Triassic ichthyosaurs. Part XIII: new data on the cranial osteology of *Cymbospondylus petrinus* (LEIDY, 1868) from the Middle Triassic Prida Formation of Nevada. Neues Jahrbuch für Geologie und Paläontologie Monatshefte, 2004 (6): 370-384.

Mancuso, A.C., 2003. Continental fish taphonomy: a case study in the Triassic of Argentina. Journal of South American Earth Sciences, 16: 275-286.

Mao, D.B., Chen, Z.H., Zhong, C.T., Zuo, Y.C., Shi, S., Hu, X.D., 2003. Studies on the geochronology and geochemical characteristics of Mesozoic intrusions in Beichagoumen area, northern Hebei province. Acta Petrologica Sinica, 19: 661-674.

Markevich, P.V., Zakharov, Y.D., Khanchuk, A.I., 2003. New data on Lower-Middle Triassic formations of the southwestern Sikhote Alin. Doklady Earth Sciences, 393A (9): 1235-1238.

Martini, R., Zaninetti, L., Lathuillière, B., Cirilli, S., Cornée, J.-J. & Villeneuve, M. 2004. Upper Triassic carbonate deposits of Seram (Indonesia): palaeogeographic and geodynamic implications. Palaeogeography, Palaeoclimatology, Palaeoecology, 206: 75-102.

May, V. J. 2003. Ladram Bay, Devon. Pp.138-141 in May, V. J. & Hansom, J. D., q.v.).

May, V. J. 2003. Blue Anchor-Watchet-Lilstock, Somerset. Pp.145-148 in May, V. J. & Hansom, J. D., q.v.).

May, V. J. 2003. Budleigh Salterton Beach, Devon. Pp.251-254 in May, V. J. & Hansom, J. D., q.v.).

May, V. J. & Hansom, J. D. 2003. Coastal Geomorphology of Great Britain. Geological Conservation Review Series, No.28. Joint Nature Conservation Committee, Peterborough, xvii+737pp.

McCarthy, D. 2003. The trans-Pacific zipper effect: disjunct sister taxa and matching geological outlines that link the Pacific margins. Journal of Biogeography, 30: 1545-1561.

McGhee, G. R., Sheehan, P. M., Bottjer, D. J. & Droser, M. L. 2004. Ecological ranking of Phanerozoic biodiversity crises: ecological and taxonomic severitiesare decoupled. Palaeogeography, Palaeoclimatology, Palaeoecology, 211 (3-4): 289-297.

McGowan, A. J. 2004. Ammonoid taxonomic and morphologic recovery patterns after the Permian-Triassic. Geology, 32 (8): 665-668.

McGowan, A. J. 2004. The effect of Permo-Triassic bottleneck on Triassic ammonoid morphological evolution. Paleobiology, 30 (3): 369-395.

McIlroy, D. (ed.). 2004. The Application of Ichnology to Palaeoenvironmental and Stratigraphic Analysis. Geological Society, London, Special Publications, 228: 490pp.

McKinley, J. M., Worden, R. H. & Ruffell, A. H. 2001. Contact diagenesis: the effect of an intrusion on reservoir quality in the Triassic Sherwood Sandstones, N. Ireland. Journal of Sedimentary Research, 71: 484-495.

Melchor, R. N. 2004. Trace fossil distribution in lacustrine deltas: examples from the Triassic rift lakes of the Ischigualasto – Villa Unión basin, Argentina. Geological Society, London, Special Publications, 228: 335-354.

Miall, A.D., Jones, B.G., 2003. Fluvial architecture of the Hawkesbury Sandstone (Triassic), near Sydney, Australia. Journal of Sedimentary Research, 73: 531-545.

Milner, A. R. & Schoch, R. R. 2004. The latest metaposaurid amphibians from Europe. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, (2-3): 231-252.

Modesto, S.P., Damiani, R.J., 2003. Taxonomic status of *Thelegnathus browni* Broom, a procolophonid reptile from the South African Triassic. Annals of the Carnegie Museum, 72: 53-64.

Modesto, S.R., Damiani, R.J., Neveling, J., Yates, A.M., 2003. A new Triassic Owenettid parareptile and the mother of mass extinctions. Journal of Vertebrate Paleontology, 23: 715-719.

Mørk, M.B.E., Vigran, J.O. Smelror, M., Fjerdingstad, V., Boe, R. 2003. Mesozoic mudstone compositions and the role of kaolinite weathering - a view from shallow cores in the Norwegian Sea (More to Troms). Norwegian Journal of Geology, 83: 61-78.

Mundil, R., Ludwig, K.R., Metcalfe, I. & Renne, P. R. 2004. Age and timing of the Permian mass extinctions: U/Pb dating of closed-system zircons. Science, 305: 1760-1763.

Muttoni, G., Kent, D. V., Olsen, P. E., Di Stefano, P., Lowrie, W., Bernasconi, S. M. & Hernández, F. M. 2004. Tethyan magnetostratigraphy from Pizzo Mondello (Sicily) and correlation to the Late Triassic Newark astrochronological polarity time scale. Geological Society of America Bulletin, 116 (9-10): 1043-1058.

Naish, D. 2004. Fossils explained 48. Placodonts. Geology Today, 20 (4): 153-158.

Narkiewicz, K. & Szulc, J. 2004. Controls on migration of conodont fauna in peripheral oceanic areas. An example from the Middle Triassic of the Northern Peri-Tethys. Geobios, 37 (4): 425-436.

Nawrocki, J., Kuleta, M., Zbroja, S., 2003. Buntsandstein magnetostratigraphy from the northern part of the Holy Cross Mountains. Geological Quarterly, 47: 253-260.

Nawrocki, J. 2004. The Permian-Triassic boundary in the Central European Basin: magnetostratigraphic constraints. Terra Nova, 16 (3): 139-145.

Nel, A., Marie, V. & Schmeissner, S. 2002. Revision of the Lower Mesozoic dragonfly family Triassolestidae [Tillyard, 1918] (Odonata: Epiproctophora). Annales de Paléontologie, 88 (4): 189-214.

Nesbitt, S.J., 2003. *Arizonasaurus* and its implications for archosaur divergence. Proceedings of the Royal Society of London, Series B - Biological Sciences, 270: S234-S237, Suppl. 2.

Novikov, I. V. & Sues, H.-D. 2004. Cranial osteology of *Kapes* (Parareptilia: Procolophonide) from the Lower Triassic of Orenburg Province, Russia. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, (2-3): 267-281.

Ochev, V.G., Shishkin, M. A., Kukhtinov, D.A., Tverdokhlebov, V.P., Makarova, I. S. 2004. Some unsolved problems of the Triassic stratigraphy in Eastern Europe. Stratigraphy and Geological Correlation, 12: 262-274.

Ogg, J. G. 2004. Status of divisions of the International Geologic Time Scale. Lethaia, 37 (2): 183-199.

O'Leary, N., White, N., Tull, S., Bashilov, V., Kuprin, V., Natapov, L. & MacDonald, D. 2004. Evolution of the Timan – Pechora and South Barents Sea Basins. Geological Magazine, 141 (2): 141-160.

Olempska, E. 2004. Late Triassic spinicaudatan crustaceans from southwestern Poland. Acta Palaeontologica Polonica, 49 (3): 429-442.

Osmundsen, PT., Sommaruga, A., Skilbrei, JR., Olesen, O., 2002. Deep structure of the Mid Norway rifted margin. Norwegian Journal of Geology, 82: 205-224.

Osterloff, P., Al-Harthy, A., Penney, R., Spaak, P., Williams, G., Al-Zadjali, F., Jones, N., Knox, R., Stephenson, M. H., Oliver, G. & Al-Husseini, M. I. 2004. Depositional sequences of the Gharif and Khuff formations, subsurface Interior Oman. GeoArabia Special Publication 3: 83-147.

Pashkov, B.R., Budanov, V.I., 2003. The tectonics of the early cimmerides in the Southern Pamirs. Geotectonics, 37: 15-30.

Payne, J. L., Lehrmann, D. J., Jiayong Wei, Orchard, M. J., Schrag, D. P. & Knoll, A. H. 2004. Large perturbations of the carbon cycle during recovery from the end-Permian extinction. Science, 305: 506-509.

Payton, C. C. & Hansen, M. N. 2003. Gypsum karst in southwestern Utah: failure and reconstruction of Quail Creek Dike. Oklahoma Geological Survey Circular, 109: 293-303.

Perri, E., Mastandrea, A., Neri, C., Russo, F. 2003. A micrite-dominated Norian carbonate platform from Northern Calabria (Southern Italy). Facies, 49: 101-118.

Perri, M. C., Molloy, P. D. & Talent, J. A. 2004. Earliest Triassic conodonts from Chitral, northernmost Pakistan. Rivista Italiana di Paleontologia e Stratigrafia, 110 (2): 467-478.

Pöppelreiter, M. C., Simone, A. & Hoetz, G. 2004. Reservoir characteristics of intracontinental carbonate ramp deposits – Upper Muschelkalk, Middle Triassic, NE Netherlands. Netherlands Journal of Geosciences (Geologie en Mijnbouw), 83 (1): 1-16.

Prokoph, A., Rampino, M.R., El Bilali, H. 2004. Periodic components in the diversity of calcareous plankton and geological events over the past 230 Myr. Palaeogeography Palaeoclimatology Palaeoecology, 207: 105-125.

Pruss, S. B. & Bottjer, D. J. 2004. Late Early Triassic microbial reefs of the western United States: a description and model for their deposition in the aftermath of the end-Permian mass extinction. Palaeogeography, Palaeoclimatology, Palaeoecology, 211 (1-2): 127-137.

Pruss, S., Fraiser, M. & Bottjer, D. J. 2004. Proliferation of Early Triassic wrinkle structures: implications for environmental stress following the end-Permian mass extinction. Geology, 32 (5): 461-464.

Ptaszyñski, T. & NiedŸwiedzki, G. 2004. Late Permian vertebrate tracks from the Tumlin Sandstone, Holy Cross Mountains, Poland. Acta Palaeontologica Polonica, 49 (2): 289-320.

Qarbous, A., Medina, F., Hoepffner, C., 2003. The Tizi n'Test basin (High Atlas, Morocco): Example of the evolution of an oblique segment in the central Atlantic rift during the Triassic. Canadian Journal of Earth Sciences, 40: 949-964.

Qian, Q., Chu, M.F., Chung, S.L., Lee, T.Y., Xiong, X.M., 2003. Was Triassic continental subduction solely responsible for the generation of mesozoic mafic magmas and mantle source enrichment in the Dabie-Sulu orogen? International Geology Review, 45: 659-670.

Radley, J. D. 2003. Section of the Langport Member (Lilstock Formation, Triassic) near Loxley, Warwickshire. Proceedings of the Cotteswold Naturalists' Field Club, 42 (3): 185-186.

Rauhut, O.WM.,. 2003. The interrelationships and evolution of basal theropod dinosaurs. Special Papers in Palaeontology, 3-213.

Ram-Awatar. 2003. A Triassic palynoflora from Pali Formation, South Rewa Gondwana Basin, Madhya Pradesh, India. Palaeobtanist, 52 (1-3): 49-54.

Renesto, S., Fraser, N.C., 2003. Drepanosaurid (Reptilia: Diapsida) remains from a Late Triassic fissure infilling at Cromhall Quarry (Avon, Great Britain). Journal of Vertebrate Paleontology, 23: 703-705.

Renesto, S., Lombardo, C., Tintori, A., Danini, G., 2003. Nothosaurid embryos from the Middle Triassic of northern Italy: An insight into the viviparity of nothosaurs? Journal of Vertebrate Paleontology 23: 957-960.

Renesto, S., Pareo, M. & Lombardo, C. 2004. A new specimen of the sauropterygian reptile *Lariosaurus* from the Kalkschieferzon (Uppermost Ladinian) of Valceresio (Varese, N. Italy). Neues Jahrbuch für Geologie und Paläontologie Monatshefte, 2004 (6): 351-369.

Retallack, G. J. 2004. Comment – contrasting deep-water records from the Upper Permian and Lower Triassic of South Tibet and British Columbia: evidence for a diachronous mass extinction (Wignall and Newton, 2003). Palaios, 19 (1): 101-102.

Retallack, G. J. 2004. Reply (to Engoren, M., 2004. Geological Society of America Bulletin, 116 (9-10): 1294). Geological Society of America Bulletin, 116 (9-10): 1295-1296.

Riccardi, A. C., Damborenea, S. E., Manceñido, M. O. & Iglesia Llanos, M. P. 2004. The Triassic/Jurassic boundary in the Andes of Argentina. Rivista Italiana di Paleontologia e Stratigrafia, 110 (1): 69-76.

Richards, D. R., Butler, R. F. & Sempere, T. 2004. Vertical-axis rotation determined from paleomagnetism of Mesozoic and Cenozoic strata of the Bolivian Andes. Journal of Geophysical Research, 109 (B7): B07104, 21pp.

Rieppel, O. 2001. The cranial anatomy of *Placochelys placodonta* Jaekel, 1902, and a review of the Cyamodontoidea (Reptilia, Placodonta). Fieldiana (Geology, new series, 45: 1-104.

Rieppel, O. 2002. Feeding mechanisms in Triassic stem-group sauropterygians: the anatomy of a successful invasion of Mesozoic seas. Zoological Journal of the Linnean Society, 135: 33-63.

Ritts, B. D., Hanson, A. D., Darby, B. J., Nanson, L. & Berry, A. 2004. Sedimentary record of Triassic intraplate extension in North China: evidence from the nonmarine NW Ordos Basin, Helan Shan and Zhuozi Shan. Tectonophysics, 386 (3-4): 177-202.

Robertson, A. H. F., Ustaömer, T., Pickett, E. A., Collins, A. S., Andrew, T. & Dixon, J. E. 2004. Testing models of Late Palaeozoic – Early Mesozoic orogeny in Western Turkey: support for an evolving open-Tethys model. Journal of the Geological Society, London, 161 (3): 501-511.

Robinson, E. 2004. Blue-collar geologists. Mercian Geologist, 16 (1): 51-52.

Rodland, D.L., Kowalewski, M., Dettman, D.L., Flessa, K.W., Atudorei, V., Sharp, Z.D., 2003.High-resolution analysis of $\delta^{18}O$ in the biogenic phosphate of modern and fossil lingulid brachiopods. Journal of Geology, 111: 441-453.

Roger, F., Arnaud, N., Gilder, S., Tapponnier, P., Jolivet, M., Brunel, M., Malavieille, J., Xu, Z.Q., Yang, J.S.,

2003. Geochronological and geochemical constraints on Mesozoic suturing in east central Tibet. Tectonics, 22, art. no. 1037.

Rossi, P., Cocherie, A., Fanning, C.M., Ternet, Y., 2003. U-Pb zircon SHRIMP dating of Pyrenean tholeiitic dolerites (ophites): evidence for an age encompassing the Trias-Jurassic limit and relationships with earliest North Pyrenean 'Infraliassic' tuffs. Comptes Rendus Geoscience, 335: 1071-1080.

Rossi, C., Kälin, O., Arribas, J. & Tortosa, A. 2002. Diagenesis, provenance and reservoir quality of Triassic TAG1 sandstones from Ourhoud field, Berkine (Ghadames) Basin, Algeria. Marine and Petroleum Geology, 19: 117-142.

Ruf, M. & Aigner, T. 2004. Facies and poroperm characterstics of a carbonate shoal (Muschelkalk, South German Basin): a reservoir analogue investigation. Journal of Petroleum Geology, 27 (3): 215-239.

Ruffell, A., McKinley, J. M. & Evans, R. 2004. Distinguishing faults from flooding surfaces on spectral gamma-ray logs. Bulletin of the American Association of Petroleum Geologists, 88 (9): 1239-1254.

Salamon, M.A., Eagle, M.K., Niedzwiedzki, R., 2003. A new ceratite record from Upper Silesia (Poland). Geological Quarterly, 47: 281-287.

Sánchez-Fernández, D. López-Gómez, J. & Martín-Chivelet, J. 2004. El Pérmico y Triásico del anticlinal de La Rodana, SE de la Cordillera Ibérica (Valencia). Geogaceta, 35: 3-6.

Sander, P.M., Faber, C., 2003. The Triassic marine reptile *Omphalosaurus*: Osteology, jaw anatomy, and evidence for ichthyosaurian affinities. Journal of Vertebrate Paleontology 23: 799-816.

Schandelmeier, H., Bremer, F. & Holl, H.-G. 2004. Kinematic evolution of the Morondava rift basin of SW Madagascar – from wrench tectonics to normal extension. Journal of African Earth Sciences, 38 (4): 321-330.

Schlagintweit, F., Rünstler, H. & Gawlick, H.-J. 2003. On the occurrence of *Physoporella pauciforata* (GÜMBEL 1872) STEINMANN 1903 (Dasycladales) from the Gutenstein Formation (Anisian) of the Rabenkogel (Salzkammergut Region, Austria). Jahrbuch der Geologischen Bundesanstalt, 143 (4): 605-612.

Schlegel, A. & Brockamp, O. 2003. Zyklizität, stratigraphie und tektonik in der Randfazies des Nordschwarzwälder Buntsandsteins. Jahreshefte des Landesamts für Geologie, Rohstoffe und Bergbau Baden-Württemberg, 39: 111-144.

Schmid, S., Worden, R. H. & Fisher, Q. J. 2004. Diagenesis and reservoir quality of the Sherwood Sandstone (Triassic), Corrib Field, Slyne Basin, west of Ireland. Marine and Petroleum Geology, 21 (3): 299-315.

Schwab, V., Spangenberg, J.E. 2004. Organic geochemistry across the Permian-Triassic transition at the Idrijca Valley, Western Slovenia. Applied Geochemistry, 19: 55-72.

Scott, A. C., Anderson, J. M. & Anderson, H. M. 2004. Evidence of plant – insect interactions in the Upper Triassic Molteno Formation of South Africa. Journal of the Geological Society, London, 161 (3): 401-410.

Seidler, L., Steel, R. J., Stemmerik, L. & Surlyk, F. 2004. North Atlantic marine rifting in the Early Triassic: new evidence from East Greenland. Journal of the Geological Society, London, 161 (4): 583-592.

Selden, P. A. & Nudds, J. R. 2004. Evolution of Fossil Ecosystems. London: Manson Publishing Ltd., 160pp.

Shang, Q.H., Vachard, D., Caridroit, M., 2003. Smaller foraminifera from the late Changhsingian (latest Permian) of southern Guangxi and discussion on the Permian-Triassic boundary. Acta Micropalaeontologica Sinica, 20: 377-388.

Sharapov, V.N., Vasil'ev, Y.R., Al'mukhamedov, A.I., Medvedev, A.Y., 2003. Local and regional variability in composition of Permo-Triassic effusive traps of the Siberian platform. Geologiya i Geofizika, 44: 741-752.

Shi, R.P., Huang, B.C., Zhu, R.X., Ren, S.M., 2004. Paleomagnetic study on the Early Triassic red beds from Jiaocheng, Shanxi Province - Local rotation and tectonic significance. Science in China, Series D, Earth Sciences, 47: 108-114.

Shipilov, E.V., 2003. Interference of tectonic-geodynamic regimes in permian-triassic evolution of the arctic periphery of north Eurasia. Doklady Earth Sciences 393A: 1215-1220.

Sidor, C. A. & Smith, R. M. H. 2004. A new galesaurid (Therapsida: Cynodontia) from the Lower Triassic of South Africa. Palaeontology, 43 (3): 535-556.

Simon, T. 2003. Ergebnisse der Forschungsbohrung im Muschelkalk bei Kirchberg an der Jagst (Baden-Württemberg). Jahreshefte des Landesamts für Geologie, Rohstoffe und Bergbau Baden-Württemberg, 39: 145-175.

Sittig, E. 2003. Die Lichtental-Formation von Baden-Baden und das Normalprofil des Schwarzwälder Rotliegenden. Jahreshefte des Landesamts für Geologie, Rohstoffe und Bergbau Baden-Württemberg, 39: 177-238.

Stevens, C.H., Stone, P., Greene, D.C., 2003. Correlation of Permian and Triassic deformations in the western Great Basin and eastern Sierra Nevada: Evidence from the northern Inyo Mountains near Tinemaha Reservoir, East-Central California: Reply. Geological Society of America Bulletin, 115: 1309-1311.

Steyer, J.S., 2003. A revision of the early Triassic "capitosaurs" (Stegocephali, Stercospondyli) from Madagascar, with remarks on their comparative ontogeny. Journal of Vertebrate Paleontology, 23: 544-555.

Steyer, J. S., Laurin, M., Castanet, J. & de Ricqlès, A. 2004. First histological and skeletochronological data on temnospondyl growth: palaeoecological and palaeoclimatological implications. Palaeogeography, Palaeoclimatology, Palaeoecology, 206 (3-4): 193-201.

Stiller, F., Chen, JH., 2004. *Eophilobryoidella sinoanisica* new genus and species, an early philobryid bivalve from the Upper Anisian (Middle Triassic) of Qingyan, southwestern China. Journal of Paleontology, 78: 414-419.

Stiller, F. & Chen Jinhua. 2004. *Eophilobryoidella sinoanisica* new genus and species, an early philobryid bivalve from the Upper Anisian (Middle Triassic) of Qingyan, southwesten China. Journal of Paleontology, 78 (2): 414-419.

Stone, D.S., Therriault, A.M., 2003. Cloud Creek structure, central Wyoming, USA: Impact origin confirmed. Meteoritics & Planetary Science, 38: 445-455.

Sues, H.D., Olsen, P.E., Carter, J.G., Scott, D.M., 2003. A new crocodylomorph archosaur from the Upper Triassic of North Carolina. Journal of Vertebrate Paleontology, 23: 329-343.

Sues, H.D., Olsen, P.E., Carter, J.G., Scott, D.M., 2003. A new crocodylomorph archosaur from the Upper Triassic of North Carolina. Journal of Vertebrate Paleontology 23: 985-985.

Surkov, M. V. & Benton, M. J. 2004. The basicranium of dicynodonts (Synapsida) and its use in phylogenetic analysis. Palaeontology, 43 (3): 619-638.

Szurlies, M., Menning, M., Nowaczyk, N. R. & Bachmann, G. H. 2000. Magnetostratigraphy and cyclic stratigraphy of the Lower Buntsandstein (Central Germany). Terra Nostra, 10: 105-107..

Szurlies, M., Bachmann, G. H., Menning, M., Nowaczyk, N. R. & Käding, K. 2003. Magnetostratigraphy and high-resolution biostratigraphy of the Permian-Triassic boundary interval in Central Germany. Earth & Planetary Science Letters, 212: 263-278.

Tabor, N. J., Montañez, I. P., Zierenberg, R. & Currie, B. S. 2004. Mineralogical and geochemical evolution of a basalt-hosted fossil soil (Late Triassic Ischigualasto Formation, northwest Argentina): potential for paleoenvironmental reconstruction. Geological Society of America Bulletin, 116 (9-10): 1280-1293.

Tao Ming-hua, Wang Hui-zheng, Ma Bing-xun & Tao Ming-ling. 2004. Enrichment patterns of disaccites and palaeoclimate change in eastern China since Carboniferous. Acta Micropalaeontologica Sinica, 21 (1): 85-99.

Tari, G., Molnar, J. & Ashton, P. 2003. Examples of salt tectonics from West Africa: a comparative approach. Geological Society, London, Special Publications, 207: 85-104.

Taylor, S. & Barker, R. 2002. Resistivity of partially saturated Triassic Sandstone. Geophysical Prospecting, 50: 603-613.

Thomas, B. M., Willink, R. J., Grice, K., Twitchett, R.J., Purcell, R. R., Archbold, N. W., George, A. D., Tye, S., Alexander, R., Foster, C. B. & Barber, C. J. 2004. Unique marine Permian-Triassic boundary section from Western Australia. Australian Journal of Earth Sciences, 51 (3): 423-430.

Tišljar, J., Vlahoviæ, I., Veliæ, I. & Sokaè, B. 2002. Carbonate platform megafacies of the Jurassic and Cretaceous deposits of the Karst Dinarides. Geologia Croatica, 55 (2): 139-170.

Tomasovych, A. 2004. Microfacies and depositional environment of an Upper Triassic intra-plafform carbonate basin: the Fatric Unit of the West Carpathians (Slovakia). Facies, 50: 77-105.

Tomašových, A. 2004. Effect of extrinsic factors on biofabric and brachiopod alteration in a shallow intraplatform carbonate setting (Upper Triassic, West Carpathians). Palaios, 19 (4): 349-371.

Tong, J., Zakharov, Y.D., Orchard, M.J., Yin, H.F., Hansen, H.J., 2003. A candidate of the Induan-Olenekian boundary stratotype in the Tethyan region. Science in China Series D - Earth Sciences, 46: 1182-1200.

Tripathi, A. 2004. Palynology evidences of hitherto unrecognised Jurassic sedimentation in Rajmahal Basin, India. Rivista Italiana di Paleontologia e Stratigrafia, 110 (1): 35-42.

Twitchett, R. J. & Barras, C. G. 2004. Trace fossils in the aftermath of mass extinction events. Geological Society, London, Special Publications, 228: 397-418.

Twitchett, R. J., Krystyn, L., Baud, A., Wheeley, J. R. & Richoz, S. 2004. Rapid marine recovery after the end-Permian mass-extinction event in the absence of marine anoxia. Geology, 32 (9): 805-808.

Ulièný, D. 2004. A drying-upward aeolian system of the Bohdašín Formation (Early Triassic), Sudetes of the NE Czech Republic: record of seasonality and long-term palaeoclimate change. Sedimentary Geology, 167 (1-2): 17-39.

Vecchia, F.M. dalla. 2004. First record of the rare marine reptile Tholodus schmidi from the Middle Triassic of the Southern Alps. Rivista Italiana di Paleontologia e Stratigrafia, 110: 479-492.

Velledits, F., Forian-Szabo, M., Berczi-Makk, A., Piros, O., Jozsa, S., 2003. Stratigraphy and origin of the Kisfennsik Nappe (Bukk Mountains, NE Hungary). Is the Silica Unit really present in the Bukk Mountains? Geologica Carpathica, 54: 189-198.

Vega-Dias, C. & Schultz, C. L. 2004. Postcranial material of *Jachaleria candelariensis* Araújo and Gonzaga 1980 (Therapsida, Dicynodontia), Upper Triassic of Rio Grande do Sul, Brazil . PaleoBios, 24 (1): 7-31.

Ventura, B., Lisker, F., 2003. Long-term landscape evolution of the northeastern margin of the Bohemian Massif: apatite fission-track data from the Erzgebirge (Germany). International Journal of Earth Sciences 92: 691-700.

Veselovsky, R.V., Gallet, Y., Pavlov, V.E., 2003. Paleomagnetism of traps in the podkamennaya Tunguska and Kotui River Valleys: Implications for the post-Paleozoic relative movements of the Siberian and East European platforms. Izvestiya Physics of zhe Solid Earth, 39: 856-871.

Vlahoviæ, I., Tišljar, J., Veliæ, I. & Matièec, D. 2002. The karst Dinarides are composed of relics of a single Mesozoic Platform: facts and consequences. Geologia

Croatica, 55 (2): 171-183.

Walkden, G. 2004. Deep impact. Planet Earth, Autumn 2004: 16-18.

Wall, G. R. T. & Jenkyns, H. C. 2004. The age, origin and tectonic significance of Mesozoic sediment-filled fissures in the Mendip Hills (SW England): implications for extension models and Jurassic sea level curves. Geological Magazine, 141 (4): 471-504.

Walsh, S. L., Gradstein, F. M. & Ogg, J. G. 2004. History, philosophy, and application of the Global Stratotype Section and Point (GSSP). Lethaia, 37 (2): 201-218.

Waltham, A. C., Simms, M. J., Farrant, A. R. & Goldie, H. S. 1997. Karst and Caves of Great Britain. Geological Conservation Review Series, No.12. Joint Nature Conservation Committee, Peterborough, xvi+358pp.

Waltham, A. & Howard, A. S. 2004. Landmarks in the geology of the East Midlands: Castle Rock, Nottingham. Mercian Geologist, 16 (1): 37-42.

Wandres, A. M., Bradshaw, J. D., Weaver, S., Maas, R., Ireland, T. & Eby, N. 2004. Provenance analysis using conglomerate clast lithologies: a case study from the Pahau terrane of New Zealand. Sedimentary Geology, 167 (1-2): 57-89.

Wang Cheng-yuan, Qu Yong-gui, Zhang Shu-qi & Zheng Chun-zi. 2004. Finding of the Late Triassic holothurian sclerites from the Mujiucuo area in Xianza (Shenzha) County, North Tibet and its geological significance. Acta Micropalaeontologica Sinica, 21 (1): 17-24.

Wang Guoqing & Xia Wenchen. 2004. Conodont zonation across the Permian-Triassic boundary at the Xiakou section, Yichang city, Hubei Province and its correlation with the Global Stratotype Section and Point of the PTB. Canadian Journal of Earth Sciences, 41 (3): 323-330.

Ward, P. D., Garrison, G. H., Haggart, J. W., Kring, D. A. & Beattie, M. J. 2004. Isotopic evidence bearing on Late Triassic extinction events, Queen Charlotte Islands, British Columbia, and implications for the duration and cause of the Triassic/Jurassic mass extinctions. Earth and Planetary Science Letters, 224 (3-4): 589-600.

Weibel, R. & Friis, H. 2004. Opaque minerals as keys for distinguishing oxidising and reducing diagenetic conditions in the Lower Triassic Bunter Sandstone, North German Basin. Sedimentary Geology, 169 (3-4): 129-149.

West, G. 2004. Discussion of ‘Destructuring and disaggregation of Mercia Mudstone during full-face tunnelling’ by J H Atkinson, P G Fookes, B F Miglio & G S Pettifer *Quarterly Journal of Engineering Geology and Hydrology* Vol. 36, 293-303. Quarterly Journal of Engineering Geology and Hydrogeology, 37 (2): 165-167. Reply by Atkinson et al., Quarterly Journal of Engineering Geology and Hydrogeology, 37 (2): 167-168.

Wignall, P. B. & Newton, R. 2004. Reply (to Retallack, G. J., Palaios, 19 (1): 101-102). Palaios, 19 (1): 103-104.

Wignall, P.B., Newton, R., 2004. Comment - Contrasting deepwater records from the Upper Permian and Lower Triassic of South Tibet and British Columbia: Evidence for a diachronous mass extinction (Wignall and Newton, 2003) - Reply. Palaios, 19: 102-104.

Wu, X.C., Li, Z., Zhou, B.C., Dong, Z.M., 2003. A polydactylous amniote from the Triassic period. Nature, 426: 516-516.

Xia Wenchen, Zhang Ning, Wang Guoqing & Kakuwa, Y. 2004. Pelagic radiolarian and conodont biozonation in the Permo-Triassic boundary interval and correlation to the Meishan GSSP. Micropaleontology, 50 (1): 27-44.

Xiao, L., Xu, Y.G., Chung, S.L., He, B., Mei, H.J., 2003. Chemostratigraphic correlation of Upper Permian lavas from Yunnan province, China: Extent of the Emeishan large igneous province. International Geology Review, 45: 753-766.

Xiao Long, Xu Yigang, Xu Jifeng, He Bin & Franco, P. 2004. Chemostratigraphy of flood basalts in the Garzê-Litang region and Zongza Block: implications for western extension of the Emeishan Large Igneous Province, SW China. Acta Geologica Sinica, 78 (1): 61-67.

Yang, Y.T., Ritts, B., Zou, C.N., Xu, T.G., Zhang, B.M., Xi, P., 2003. Upper Triassic-Middle Jurassic stratigraphy and sedimentology in the NE Qaidam Basin, NW China: Petroleum geological significance of new outcrop and subsurface data. Journal of Petroleum Geology, 26: 429-449.

Yaroshenko, O.P., Lozovsky, V. R. 2004. Palynological assemblages of continental Lower Triassic in Eastern Europe and their interregional correlation. Paper 1: Palynological assemblages of the Induan stage. Stratigraphy and Geological Correlation, 12: 275-285.

Zaragüeta Bagils, R., Lelièvre, H. & Tassy, P. 2004. Temporal paralogy, cladograms and the quality of the fossil record. Geodiversitas, 26 (3): 381-389.

Zattin, M., Stefani, C., Martin, S. 2003. Detrital fission-track analysis and sedimentary petrofacies as keys of alpine exhumation: The example of the Venetian foreland (European Southern Alps, Italy). Journal of Sedimentary Research, 73: 1051-1061.

Zavattieri, A.M.., Herbst, R., Bravo, J.M., 2003. Microflora of the Panguipulli formation (Upper Triassic) at Licen Ray, Lake Calafquen, 10th Region, Chile. Ameghiniana, 40: 585-600.

Zerfass, H., Lavina, E.L., Schultz, C.L., Garcia, A.J.V., Faccini, U.F., Chemale, F., 2003. Sequence stratigraphy of continental Triassic strata of Southernmost Brazil: a contribution to Southwestern Gondwana palaeogeography and palaeoclimate. Sedimentary Geology, 161: 85-105.

Zerfass, H., Chemale, F., Jr., Schultz, C. L. & Lavina, E. 2004. Tectonics and sedimentation in Southern South America during Triassic. Sedimentary Geology, 166 (3-4): 265-292.

Zhang Ke-xin, Yu Jian-xin, Lin Qi-xiang, Jing Ya-li & Chen Bin. 2004. Palynological assemblage from Section D of Meishan, Changxing, Zhejiang and its significance for global correlation. Earth Science – Journal of China University of Geosciences, 29 (3): 253-262.

Zhang Zhaochong, Hao Yanli, Wang Fusheng & Mahoney, J. J. 2004. Petrology, mineralogy and geochemistry of the Emeishan Continental Flood basalts, SW China: evidence for activity of mantle plumes. Acta Geologica Sinica, 78 (1): 40-51.

Zhang Zu-hui & Hong Zu-yin. 2004. Smaller foraminiferal fauna from the Changsing Formation of Datian, Fukian. Acta Micropalaeontologica Sinica, 21 (1): 64-84.

Zhu, D., Luo, T.Y., Gao, Z.M., Zhu, C.M., 2003. Differentiation of the Emeishan flood basalts at the base and throughout the crust of southwest China. International Geology Review, 45: 471-477.

Ziegler, A. M., Eshel, G., McAllister Rees, P., Rothfus, T. A., Rowley, D. B. & Sunderlin, D 2003. Tracing the tropics across land and sea: Permian to present. Lethaia, 36 (3): 227-254.

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British Triassic palaeontology: supplement 30

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Since the completion of the writer's previous supplement (No.29; ALBERTIANA, 29: 61) on British Triassic palaeontology, the following works relating to aspects of that subject have been published or have come to his notice:

Goodenough, K. & Bradwell, T. 2004. Rum and the small isles – a landscape fashioned by geology. Perth: Scottish Natural Heritage, 39pp.

Hesselbo, S. P., Robinson, S. A. & Surlyk, F. 2004. Sea-level change and facies development across potential Triassic-Jurassic boundary horizons, SW Britain. Journal of the Geological Society, London, 161 (3): 365-379.

Holliday, D. W., Holloway, S., McMillan, A. A., Jones, N. S., Warrington, G. & Akhurst, M. C. 2004. The evolution of the Carlisle Basin, NW England and SW Scotland. Proceedings of the Yorkshire Geological Society, 55 (1): 1-19.

Hounslow, M. W., Posen, P. E. & Warrington, G. 2004. Magnetostratigraphy and biostratigraphy of the Upper Triassic and lowermost Jurassic succession, St. Audrie's Bay, UK. Palaeogeography, Palaeoclimatology, Palaeoecology, 213 (3-4): 331-358.

Radley, J. D. 2003. Section of the Langport Member (Lilstock Formation, Triassic) near Loxley, Warwickshire. Proceedings of the Cotteswold Naturalists' Field Club, 42 (3): 185-186.

Twitchett, R. J. & Barras, C. G. 2004. Trace fossils in the aftermath of mass extinction events. Geological Society, London, Special Publications, 228: 397-418.

Wall, G. R. T. & Jenkyns, H. C. 2004. The age, origin and tectonic significance of Mesozoic sediment-filled fissures in the Mendip Hills (SW England): implications for extension models and Jurassic sea level curves. Geological Magazine, 141 (4): 471-504.

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

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

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

The name of the fossil or fossils chosen to designate a biozone should include the genus name plus the specific epithet and also the subspecies name, if there is one. Thus Exus albus Assemblage Zone is correct. After the first letter; for example, Exus albus may be shortened to E. albus. On the other hand, the use of the specific epithet alone, in lowercase or capitalized, in italics or not (albus Assemblage zone, Albus Assemblage zone, albus Assemblage zone, or Albus Assemblage zone), is inadvisable because it can lead to confusion in the case of frequently used species names. However, once the complete name has been cited, and if the use of the specific epithet alone does not cause ambiguous communication, it may be used, in italics and lowercase, in the designation of a biozone; for example, uniformis Zone.”

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

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