# ALBERTIANA





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ALBERTIANA 24 was compiled and edited by Hans Kerp with the help of an editorial committee consisting of: Aymon Baud (Lausanne), Spencer G. Lucas (Albuquerque) Mike Orchard (Vancouver), Tim Tozer (Vancouver) and Henk Visscher (Utrecht). The editorial committee does not review contributions but provides - when needed - linguistic help to non-English speaking contributors.

The primary aim of ALBERTIANA is to promote the interdisciplinary collaboration and understanding among the members of the I.U.G.S. Subcommission on Triassic Stratigraphy. Within this scope ALBERTIANA serves both as a newsletter for the announcement of general information and as a platform for discussion of developments in the field of Triassic stratigraphy. ALBERTIANA thus encourages the publication of announcements, literature reviews, progress reports, preliminary notes etc. - i.e. those contributions in which information is presented relevant to current interdisciplinary Triassic research.

Opinions expressed in articles published in Albertiana are those of the individual author(s) alone; they do not necessarily represent the views or the policy of either the Subcommission on Triassic Stratigraphy or the newsletter editor.

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Cover: Equisetites arenaceus after Kelber & Van Konijnenburg-van Cittert (1998)

# SEE PAGE 85 FOR METHODS OF PAYMENT OF ALBERTIANA

# A. S. Dagys † and W. T. Holser †

It is with great sadness that I record the deaths of two long-standing members, Algirdas S. Dagys, a former Vice-Chairman of the Subcommission, and William ('Bill') T. Holser, a Voting Member of the Permian-Triassic Boundary Working Group.

I am grateful to E. S. Sobolev, Yu. D. Zakharov and Yin Hongfu for their appreciation of Algirdas Dagys and his work which appears elsewhere in this issue. Mary Ann Holser kindly supplied sources from which I have compiled the following appreciation of Bill.

Bill Holser (1920-1999) was born in Bakersfield, California. He attended the California Institute of Technology, gaining his bachelor's degree in 1942 and his master's in 1946; during the war he served in the U.S. Navy in the South Pacific theatre with the rank of Lieutenant Commander. His PhD was awarded from Columbia University in 1950. Bill had a distinguished career as a research geochemist, with a particular interest in the geochemistry of ancient oceans, an aspect which he pursued in relation to Permian-Triassic boundary successions, amongst others. His work yielded more than 150 published contributions. He worked for Chevron Oil Field Research from 1958 until 1970 when he became Professor in the Department of Geological Sciences in the University of Oregon, Eugene, where he was also departmental head from 1971 until 1974. On retirement in 1986 he became Emeritus Professor in the Department. Bill was an Honorary Life Fellow of the Mineralogical Society of America and a fellow of both the American Geophysical Union and the Society of Economic Geologists; in 1976 he was a Fulbright Fellow. He was editor of The American Mineralogist (1966-1972) and of the International Tables for Crystallography (1963-1965, 1971-1976). Bill married Mary Ann Harris in Grand Rapids, Michigan in 1954 and is survived by Mary Ann, their five children, four grand children and his brother Alexander.

In memory of Bill the Holser family have proposed The William T. Holser Visiting Scholar Fund. The purpose of this is to enable the Department of Geological Sciences in the University of Oregon to invite one distinguished scholar to the campus each year for one week to exchange ideas and information with students and faculty members and to give a lecture named in Bill's memory. Members who wish to support this initiative may send contributions to: Dr William T. Holser Visiting Scholar Fund, Department of Geological Sciences, 1272 University of Oregon, Eugene, OR 97403-1272, United States of America. Contributions should be payable to the UO Foundation/Department of Geological Sciences and marked 'in memory of William T. Holser'.

Geoffrey Warrington, STS Secretary

# In Memoriam - Algirdas-Zenonas Stanislovo-Dagys (1932 - 2000)

Algirdas-Zenonas Stanislovo-Dagys is no longer with us. A Professor of Geology, a prominent scientist, an outstanding paleontologist and stratigrapher, he died in Vilnius on January 7, 2000, after a long and serious illness.

A.S. Dagys was born on August 30, 1932 in Kaunas, Lithuania. After graduation from the Geological Department of Moscow University in 1955 he became a post-graduate student at the Institute of Geology and Geography in Vilnius but soon moved back to Moscow University where he specialized in paleontology. As a post-graduate student, Dagys studied the stratigraphy and brachiopod faunas of the Triassic of the north-western Caucasus. After university he

continued his research in Vilnius, presented a dissertation in January 1960, and received the degree of candidate in geology. In May 1960 Dagys came to Novosibirsk where the best and most fruitful period of his scientific activity was spent at the Institute of Geology and Geophysics. In 1989 he left Novosibirsk for Vilnius to stay at the Institute of Ecology of Lithuania, but until the very last days of his life he continued to work keenly on geological problems of Siberia.

His creative thinking and fervent striving for knowledge, his enthusiasm coupled with a persistent and whole-hearted nature and incredible efficiency made Dagys a brilliant expert in many theoretical and practical fields of geology. His activity encompassed an extremely wide range of problems in invertebrate paleontology and the Mesozoic stratigraphy and paleogeography of Siberia and the Far East, but brachiopods were his special interest. He investigated Triassic brachiopods from different regions of Russia, as well as Jurassic and Lower Cretaceous brachiopods from northern Middle Siberia. After revising the taxonomy and stratigraphy of world Triassic brachiopod records he distinguished over one hundred new highest-rank taxa, suggested an original interpretation of the ontogeny and phylogeny of several groups, and developed a new system of numerous brachiopod taxa, following their main evolutionary trends and investigating their stratigraphic significance. These works resulted in a doctorate thesis on Triassic brachiopods which was presented in 1970.

In the late 1970s, Dagys became involved in studies of ammonoids, another group of Triassic fossils important for the stratigraphy of Siberia, and soon arrived at notable achievements. Independently and in collaboration with other Siberian scientists, he studied Induan, Olenekian, Anisian, and Ladinian ammonoids, distinguished about fifteen new genera and over twenty new species, specified the taxonomy of Boreal ammonoids and investigated some important aspects of their evolution.

Dagys' work on Triassic and Liassic stratigraphy is of great importance. Work under his leadership, as well as his personal efforts, yielded a new scheme of zonal stratigraphy of Liassic deposits in Siberia, which is as detailed as those from the best documented regions of Western Europe. He headed research in the systematisation and correlation of Triassic zonal stratigraphy of north-eastern Asia and collaborated with Dr. E.T. Tozer of the Geological Survey of Canada on the development of a Boreal Triassic standard.

For many years Dagys was engaged in field studies of Triassic deposits in the eastern part of the Yenisei-Khatanga and Lena-Anabar basins in relation to the assessment of their petroleum potential. This work resulted in significant changes to the existing Boreal Triassic correlations and regional lithostratigraphic schemes, and pushed forward comprehensive paleontological research.

Studies of the geographic distribution of Triassic marine invertebrates and the biogeography of Triassic seas were of particular value as they validated the mobilistic hypotheses. On the basis of a thorough analytical investigation of faunal and geological data Dagys argued for the "suspect terrane" approach to Triassic formations of the Koryak Upland, South Sakhalin, and Sikhoteh-Alin. Combined lithological, geochemical, and paleontological research in cooperation with specialists from SNIIGGMS (Novosibirsk) permitted Dagys to make paleogeographic reconstructions for northern Middle Siberia and to infer the scenario of Triassic landscape history.

Dagys paid much attention to field observations and was himself an experienced field geologist. He spent almost every summer on field trips, examined tens of cross sections and made unique collections of fossils from regions of Siberia that are difficult of access.

Dagys was the author of about 200 publications, among which the most important are twelve monographs and three paleontological atlases that made him known as an outstanding expert in Mesozoic stratigraphy and paleontology.

In addition to his scientific activity, Dagys was involved in administrative matters. He was repeatedly elected as a Vice Chairman of the Subcommission on Triassic Stratigraphy of the International Commission on Stratigraphy. He was Principal Investigator of the Russian team of the project "Upper Triassic of the Tethys" which formed part of the UNESCO Geological Correlation Program. He was a member of the Departmental Committee on Stratigraphy as he entered the Bureau of its Triassic Section, and was the head of the same section in the Siberian Division of the Committee. He contributed a lot to the work of the 24th IGC in Moscow in 1984, both as a speaker and as an organiser of the excursion to Permian-Triassic boundary terranes in the eastern Verkhoyan area.

Above all Dagys was a remarkable teacher. From 1972 to 1974 he taught at the Kabul Polytechnical Institute in Afghanistan, and for years he was a professor at the Novosibirsk University.

Dagys left behind a number of disciples who continue working on Mesozoic paleontology and stratigraphy of Siberia and the Far East. He demanded a lot from his disciples, and was no less demanding of himself.

As a person, Dagys was very nice and easy going. His colleagues and students, as well as anybody who had ever met him at workshops or on field trips, will always remember this bright person, the Scientist and the Teacher.

Evgeny S.Sobolev, Yuri D. Zakharov, Yin Hongfu

# BALLOT FOR THE EXECUTIVE OF THE ICS

#### SUBCOMMISSION ON TRIASSIC STRATIGRAPHY

In accordance with ICS requirements the Chairman of the Subcommission on Triassic Stratigraphy has asked Voting Members of the Subcommission to vote on the officers who will form the Executive of the Subcommission from the period from 2000 until 2004. The present Chairman (M. Gaetani) and one Vice-Chairman (H. Rieber) wish to retire from the Executive in 2000.

The following were proposed as officers of the Subcommission for 2000-2004:

Chairman:	M. Orchard, Geological Survey of Canada, Vancouver
Vice-Chairman:	Yu. D. Zakharov, Vladivostock, Russia
Vice-Chairman:	Yin Hongfu, China University of Geosciences, Wuhan
Secretary-General:	G. Warrington, British Geological Survey, Nottingham

The results of the ballot are as follows: Responses: Proposed Chairman Proposed Vice-Chairman Proposed Vice-Chairman Proposed Secretary-General

18 (Y - For; N - Against; A - Abstention)					
(M. Orchard)	Y (18)	N (O)	A (0)		
(Yu. D. Zakharov)	Y (16)	N (1)	A (1)		
(Yin Hongfu)	Y (16)	N (1)	A (1)		
(G. Warrington)	Y (16)	N (1)	A (1)		

M. Gaetani Chairman, Subcommission on Triassic Stratigraphy G. Warrington Secretary-General, Subcommission on Triassic Stratigraphy

October 1999

# FROM THE CHAIRMAN

#### The Permian / Triassic boundary decided

The postal ballot within the Subcommission on Triassic Stratigraphy concerning the GSSP of the base of Triassic, defined in the section D of Meishan (China) at the base of bed 27c, gave the following results:

Voting Members: 31 - Votes received: 27 (87%)

- Yes: 22 (81%)
- No: 2
- Abstention: 2
- Yes for Meishan as GSS, but at different Point: 1.

Consequently the proposal is approved by the Subcommission on Triassic Stratigraphy. The results have been forwarded to the International Commission on Stratigraphy for final approval.

After 18 years of activity of the ad hoc WG, this is a good result, being the first GSSP of Triassic to be formally accepted.

Maurizio Gaetani

# **REPORT ON THE STS ACTIVITY**

### Maurizio Gaetani

My 4-year term of service as Chairman of the Subcommission on Triassic Stratigraphy will end at the meeting in Rio de Janiero in August, 2000. I would like to review some aspects of STS activity during my period of office.

The stage nomenclature for the Triassic was decided at the meeting in Lausanne in1991. This was not a decision made through a formal postal ballot but the names of the 7 stages have

been almost generally adopted and are not the subject of serious debate. The Series subdivisions have been commonly accepted for more than one century.

The task of the STS is to propose GSSPs for the stages to the ICS and to improve correlation through physical methods; a timescale for the Triassic is also of great interest.

#### GSSPs

As repeatedly stated by the Chairman of the ICS, the primary duty of every Subcommission is to define stages and their GSSPs, for the sake of stability of nomenclature and world-wide recognition. Not one Triassic GSSP had been defined in 1996 and in 2000 only that for the base of the Induan, marking the base of the Triassic, has reached the final stages in the approval process. I was convinced that other GSSPs could have been defined in the last few years. The situation regarding each of the Triassic stage boundaries is as follows;

#### Base of the Triassic (base of Induan)

The ad hoc Working Group proposed to the STS that Section D at Meishan, China, should be selected as the GSSP for this level, with the base of the Induan Stage, and of the Triassic, placed in bed 27c, at the appearance of Hindeodus parvus. This proposal has been subject of a postal ballot amongst the Voting Members of the STS and received a large majority of votes in favour, though some members considered Meishan inadequate because of low sedimentation rate. At the end of a long process, during which other candidates has been abandoned for various reasons, the proposal of Meishan as the GSSP has been now forwarded to the ICS for approval and ratification.

#### Base of Olenekian

Up to now, no significant sections have been described in the Tethyan realm. The best are undoubtedly in the Olenek river area and in the Taymir peninsula. However, access to sites in those areas presents considerable logistically difficulties. The Vice-Chairman of the STS, Yu. Zakharov, suggested that alternative sections should be sought near Vladivostok where access is easier. A proposal is awaited though additional research may be required.

#### **Base of Anisian**

During the Halle meeting of the STS (1998) it was decided to abandon the proposal made by Muttoni et al. (1994) of the Marathouvuno section (Chios) as a candidate GSSP. This section had also been proposed by Assereto (1974) as a reference section for the Aegean substage but it appears to be too condensed and to include some minor gaps. At Halle the STS decided to ask Romanian workers to publish their results on the Desli Caira section in order that it could be evaluated as a candidate. The boundary is fairly clearly defined by the appearance of the ammonoid genera *Japonites*, *Paradanubites*, *Paracrochordiceras* and of the conodont *C. timorensis* (evolute form) and magnetostratigraphy also allows recognition of the boundary interval, between the late Spathian largely reversed sequence and the early Anisian dominantly normal interval. The  $\delta$ 13 also show a very useful shift just above the boundary.

A workshop, organized by Dr. E. Gradinaru (Bucharest University), was held in Tulcea, N Dobrugea, Romania, from 7 to 10 June 2000 but no definitive results have yet been published. The scientific group preparing the documentation consists of: E. Gradinaru (general setting and

ammonoid biostratigraphy and taxonomy), A. Nicora (Milano) and M. Orchard (Vancouver) (conodonts, using also the previous work by E. Mirauta), J. Besse and Y. Gallet (Paris) magnetostratigraphy. L. Krystyn (Vienna) was involved with the magnetostratigraphy at an earlier stage.

We are eagerly awaiting publication of the results that could allow definition of the boundary which does not seem to offer major correlation problems. Ammonoids are important but often rare; conodonts will be probably the most useful biostratigraphic tool.

#### Base of the Ladinian

The ad hoc Working Group met in the field in Italy and Hungary in 1993, and it was followed by very active research that elucidated many points. However, it became apparent that no single obvious solution presented itself and that at least three or four possible definitions of the boundary were at our disposal. It also appeared that ammonoids often have wider correlation potential than the conodonts which are also biased by a very complex taxonomy. The Anisian/Ladinian boundary interval was a time of quick evolutionary changes and the interpretation of conodont specialists differs considerably on matters of species and subspecies definition.

An informal postal ballot within the Working Group resulting in rather balanced answers. A proposal to place the boundary at the base of the *Reitzi* Zone was favoured mostly by Hungarian workers; suggested use of the base of the *Secedensis* Zone was supported mainly by Italian workers; use of the base of the *Curionii* Zone probably received more widely distributed support than the other proposals. Amongst ammonoids, *reitzi* has perhaps the least correlation potential, being mostly known around the borders of Adria; *secedensis* has better potential, being present both in Tethys and in Nevada and corresponding to a major change in the ammonoid evolution, but it is not particularly common in the fossil record; *curionii* has the best correlation potential, but provides a less obvious boundary in relation to the condont data.

The magnetostratigraphy is fairly well known and various reversals may be recognised in the boundary interval. As far as candidate GSSPs are concerned, two have been proposed: Felsoors and Bagolino. Felsoors, in Hungary, is an artificial section which, in my opinion, should be supported only if the boundary is to be placed at the base of the *Reitzi* Zone; magnetostratigraphy is patchy. Bagolino is better, especially if the boundary is placed at the base of the *Curionii* Zone, but the section is remagnetized. However, good bed-by-bed correlation to the western Dolomites, where a detailed magnetostratigraphic scale has been established (Muttoni et al., 1998), is possible.

Thus in my opinion, the selection of the boundary is mostly matter of convention and good will is necessary to adopt a compromise solution.

#### Base of the Carnian

In recent years it has become clear that the conodont *P. polignathiformis*, often used to define the lower boundary of the Carnian, appears earlier than the ammonoid Trachyceras aon which was traditionally used to define this boundary. Recent researches have also demonstrated that other rare *Trachyceras* appear earlier than *aon*.

Loriga et al. (1998), proposed the use of the appearance of the ammonoid Daxatina to define the base of the Carnian, with a candidate GSSP at Prati di Stuores (Italy), the locality indicated as typical for the Cordevolian by Mojsisoviscs. In the Prati di Stuores section, the sedimentation rate is high and the conodont content is very diluted. Magnetostratigraphy is available. No other sections have been proposed in Europe. Balini et al. (1998) pointed out some problems

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with the Stuores section. Work is in progress in Spiti, Himalaya, in an attempt to elucidate some aspects that are not well expressed in the Stuores section. It is possible that, in 2001, the Stuores section will be proposed as the candidate GSSP, with an auxillary section in Spiti.

#### Base of the Norian

No Working Group has been established for this boundary, but activity is in progress in both North America and Europe. The future chairman of the STS, M. Orchard is aiming to establish an ad hoc WG. Possible candidate GSSPs for this boundary may be identified soon.

#### Base of the Rhaetian

After the Lausanne (1991) decision to keep the Rhaetian as an independent stage no work has taken place.

#### Physical correlations

The necessity to supplement biostratigraphy with physical stratigraphic tools to achieve improved correlations between Triassic sequences has been accepted in recent years. Considerable efforts have been made to build up a magnetostratigraphic scale based on biostratigraphically controlled successions. A first draft is now largely complete, with at least 90% of the Triassic covered by a magnetostratigraphic scale. Other techniques, such as chemostratigraphy, using  $\delta^{13}$ C or <sup>87</sup>Sr, have been investigated, but are still in a pioneering stage.

#### Numerical ages

The definition of numerical ages for the Triassic is far from being achieved and I think a major effort should be directed to this goal. There is fairly good agreement concerning the ages of both the base (c. 251 Ma) and the top (c.199 Ma) of the Triassic but the timescale for the internal subdivisions requires considerable improvement. The biostratigraphically well calibrated dates proposed by Mundil et al. (1996), placing the base of the Ladinian at c.241 Ma, indicate the potential significance of such dates. If this age is accepted, the implication is that the Induan, Olenekian and Anisian had a combined duration of no more than 10my, with the whole Lower Triassic being probably only slightly more than 5 my long. In this case, sedimentation rates for the Lower Triassic sequences at several places in the Alps and in the Caucasus would appear to have been excessively high. Also, the present lively discussion on the interpretation of the Latemar cycles is largely dependent on the time span attributed to the Ladinian.

### Cyclostratigraphy

The Newark lacustrine set of sediments have been thoroughly investigated by Olsen and Kent in recent years. These workers produced an astronomical calibration of the measured cycles that covers most of the Upper Triassic. It will be interesting to see whether the same cycles can be recognised in sections outside the paleo-equatorial belt of the Newark type of basins.

#### Which future for the STS?

In the last years, the IUGS Board and the ICS have begun to provide financial support for specific projects rather than for the steady activity of the Subcommissions. The small amount of

money that each Subcommission may receive in future (US\$ 1000-2000) should be used as seed-money for project aiming to develop into a specific topic, such as definition of a GSSP or refinement of the timescale, with scheduled dead-lines like any other scientific projects.

These are my views the challenges for the future. I was honoured to serve as Chairman of this Subcommission, and I hope to be able to continue to add my work to that of the many others who are endeavouring to improve our knowledge of the Triassic.

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#### **RESULT OF THE VOTE ON GSSP OF PERMIAN-TRIASSIC BOUNDARY**

#### PTB Working Group

On behalf of the Permian-Triassic Boundary Working Group (PTBWG), we report to you the result of the formal vote on the Global Stratotype Section and Point (GSSP) of Permian-Triassic Boundary. This vote by correspondence was taken during the period from October 25, 1999 to January 17, 2000. The proposal was to place the GSSP at the base of Bed 27c, Section D, Meishan, Changxing County, Zhejiang Province, China, where the conodont *Hindeodus parvus* first appeared. Among the 28 titular members of the PTBWG, Dr. Wang Yigang has long been unable to be contacted and no one knows where he is, and to our great sorrow Professor William T. Holser died recently. Therefore only 26 voting sheets were actually delivered. with the following result:

- Unresponsive votes: 3
- Responses: 23, responsive percentage 88.4%, exceeding the necessary 60%
- Negative responses (No): 3
- Positive responses (Yes): 20, positive percentage 87.0%, exceeding the necessary 60% guorum of support

According to the new regulation of ISC, this motion is passed by PTBWG. We now proceed to apply to STS for a formal vote on the same motion and hope it to be taken as soon as possible.

We also take this occasion to mourn the recent death of William T. Holser, professor of the University of Oregon, and Algirdas S. Dagys, professor of the Lithuanian Academy of Sciences. Along with other responsibilities, Prof. Holser was a voting member of PTBWG. His works on the geochemistry of the Permian-Triassic Boundary greatly contributed to the resolution of the boundary problem. Prof. Dagys is long known as the expert on Triassic, especially the Triassic of ex-USSR. His works on the Lower Triassic of NE Siberia remarkably advanced our knowledge of Permian-Triassic boundary. Their thoughtful ideas and always helpful attitude have been stimulating to our group. We express our profound grief to their family members and pray that they may be sustained by a Higher Power.

Yin Hongfu, Chairman of the PTBWG Yuri Zakharov Vice-chairman of the PTBWG

# FROM THE SECRETARY

# **Newsletter Editor**

Hans Kerp recently became one of the five standing members of the Deutsche Forschungsgemeinschaft review committee for palaeontology.

Hans has edited Albertiana for 10 years but has decided that increasing commitments and pressures of work make it impossible for him to continue as editor after the completion of this issue. Hans' contribution to the Subcommission has been the considerable effort and dedication necessary to prepare the newsletter copy and transmit it to the University of Utrecht for production and distribution; he has edited 17 issues of the newsletter and his contribution will be sorely missed.

### Members contact information

All members are requested to advise the Secretary immediately of any changes to their contact details (postal or e-mail addresses; phone or FAX numbers) to ensure that information from the Subcommission reaches them without delay. The following changes to information included in Albertiana 22 (February 1999) have been notified:

- Carter, E.S. e-mail: carter@pdx.edu
- Grant-Mackie, J. e-mail: jgrantmackie@glgnov2.auckland.ac.nz
- Kolar-Jurkovšek, T. Phone: + + 386 61 136 75 98; FAX: + + 386 61 136 75 96; e-mail: tea.kolar@geo-zs.si
- Silberling, N. e-mail: slbrlng@classic.msn.com
- Zakarov, Yu.D. e-mail: yurizakh@mail.ru
- Dr. Rosanna Martini should be added to the list of corresponding members. Her address is: Département de Géologie et Paléontologie, 13 rue des Maraîchers, CH-1211 Genève 4, Switzerland; Tel. + +41 22 702 66 12; Fax + +41 22 320 57 32
  E-Mail Rossana.Martini@terre.unige.ch http://www.unige.ch/sciences/terre/geologie/welcome.html

# FROM THE EDITOR

## A New Editor !

As has been announced the previous issue, I am stepping back as editor of ALBERTIANA. The main reason is that I currently have hardly any time to edit and compile this newsletter. I have recently been elected as one of the four standing reviewers for palaeontology of the German Science Foundation (DFG). This, together with other various other commitments, like the editorship of one of the leading journals in my own research discipline, administrative duties within my university, and last but not least teaching and research, take more time than I have. Another important point is that I feel that ALBERTIANA can use some fresh blood. I have been editor since 1990 and was responsible for 17 of the 24 issues of ALBERTIANA that have been published to date. Having been editor for such a long time, I was of course very concerned about ALBERTIANA's future. Therefore, I am very happy that an excellent successor has been found. I am very pleased that my good friend and colleague Dr. Wolfram KURSCHNER is willing to take over the editorship of ALBERTIANA. Wolfram is a palaeobotanist/palynologist and was originally trained as a geologist/stratigrapher and also worked in stable isotope geochemistry. Wolfram holds a lectureship at Laboratory of Palaeobotany and Palynology in Utrecht, an institute with a long tradition in Triassic research and the birthplace of ALBERTIANA. The Utrecht institute is willing to further support ALBERTIANA. Although IUGS makes a small contribution each year and readers are requested for donations, this does not cover the actual printing and mailing costs. Therefore, I am very pleased that the future of ALBERTIANA is secured now. I am sure that our new editor will further improve the quality of this newsletter.

Hans Kerp, (former) editor of ALBERTIANA

Although ALBERTIANA is scheduled to appear twice a year, this issue is published with a considerable delay. By the time the issue should have gone to press only very few contributions had been received. Therefore, it was decided to postpone publication. However, for various reasons I had very little time during the summer. Unfortunately, this led to further delay for which I apologize.

Hans Kerp

# ANNOUNCEMENTS

# 31st INTERNATIONAL GEOLOGICAL CONGRESS Rio de Janeiro, Brazil, 6-17th August 2000

A meeting of the Triassic Subcommission was scheduled for the 10<sup>th</sup> August during the IGC in Rio de Janeiro.

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# Carnian-Norian Boundary Working Group.

A Carnian-Norian boundary working group is being formed under the auspices of the Triassic Subcommission. Some researchers with a known interest and active research on this boundary have been contacted and invited to participate. Others who would like to be involved are invited to write and inform me (as Chair) of their interest and potential scientific contribution. Broad representation of researchers from both the marine and continental realms is sought, and individuals from as many countries as have a stake in proposing a potential GSSP are welcome to participate.

The composition of Working Group will be announced in the next Albertiana, along with a short list of potential GSSP sites. To this end, I also invite a brief summary statement of localities that might be considered in this exercise. These should include a note of their chief attributes, published accounts, and work in progress.

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Moroccan Triassic Pollen

Dear Collegue,

We are glad to inform you that, among the activities of the Moroccan Group of Permian and Triassic, a catalog of Moroccan Triassic pollen has been prepared. This catalog can be consulted online on the site: <http://fmedina.homepage.com/palynocatalog/palynocatalog.html>. Please note that, because the catalog was prepared by stratigraphers which are not palynologists, the names of genera and species are those given by the original authors and synonymies have not been studied.

Sincerely yours, Professor F. Medina

Scientific Institute, Rabat, Morocco

# THE CANDIDATES OF GLOBAL STRATOPYPE OF THE BOUNDARY OF THE INDUAN AND OLENEKIAN STAGES OF THE LOWER TRIASSIC IN SOUTHERN PRIMORYE

### Annual Report 2000 of IOBWG

# Yuri D. Zakharov, Yasunari Shigeta, Alexander M. Popov, Anatoly N. Sokarev, Galina I. Buryi, Vladimir V. Golozubov, Eugene S. Panasenko and Era A. Dorukhovskaya

#### Introduction

During the many years of investigations on the Lower Triassic several suggestions for stage and substage subdivisions have been made (e.g., Mojsisovics, 1882; Mojsisovics et al., 1895; Kiparisova & Popov, 1956, 1964a,b; Tozer, 1965, 1978; Vavilov & Lozovsky, 1970; Zakharov, 1973, 1978, 1986; Kozur, 1972, 1992; Kummel, 1973; Guex, 1978; Rostovcev & Dagys, 1984; Shevyrev, 1990). On the 29th International Geological Congress (Kyoto, 1992) Kiparisova & Popov's (1964a,b) scheme with a twofold division (Induan and Olenekian stages) has been approved at last. However, then another problem came up immediately: the choice of the Global Stratotype and Point for the boundary between these two stages. Therefore, a special working group (IOWG) was formed in 1997 with Prof. Yu.D. Zakharov (Vladivostok) as chairman and Dr. A. Baud (Lausanne) as vice-chairman.

The problem of the Induan-Olenekian boundary is complex because the Lower Triassic sections of the stratotype regions for the Induan (Hindustan, Indus River Basin) and Olenekian (Arctic Siberia, Olenek River Basin) cannot be used as boundary stratotypes for the base of the Olenekian and points for the following reasons:

- (1) The Induan Stage in the Olenek River basin (Boreal realm) consists of lagoonal and littoral, tuffaceous and poorly fossiliferous strata that are difficult to date.
- (2) In most Salt Range and Central Himalayan sections (Himalayan province) ammonoids are rare or absent, in Ceratite marls - Ceratite sandstone boundary beds, where the Induan-Olenekian boundary seems to have been recognized.

Hence, there are some problems with regard to the global correlation of the Lower Triassic, which concentrate on the Induan-Olenekian boundary sequence. However, we have representative Induan-Olenekian and Lower Olenekian sections (Burij, 1959; Korzh, 1959; Kiparisova, 1961, 1972; Zakharov, 1968, 1978, 1997) in the Ussuri province. This region is regarded as intermediate between the Boreal realm and the Himalayan province, having some common characters with both of them, and was often mentioned in discussions on problems of the Induan-Olenekian boundary by Kiparisova and Popov (1956, 1964 a,b). Most of these sections are located near Vladivostok in South Primorye.

Vladivostok was founded 1860 at Murav'ev, Amursky Peninsula as a military outpost. The construction of fortifications and a railroad necessitated geological investigations. The first geological studies there were carried out by Margaritov, a graduate from the St.- Petersburg

University, who arrived in Vladivostok in 1880 as mathematics teacher. He became an active member of the Society for the Investigation of the Amur Region, and head of several ethnographic and geological field parties, resulting in remarkable discoveries. For example, on the western coast of the Ussuri Gulf, between Tri Kamnya Cape and Shamara Bay (now Lazurnaya) he discovered, much to his surprise, some fossils, bivalves and ammonoids. Margaritov's collection fell into the hands of the President of the Russian Academy of Sciences, Karpinsky, a recognized expert in Late Paleozoic ammonoids, who distinguished Triassic bivalves (*\*Pseudo-monotis\**, *\*Avicula\**) and ceratitid ammonoids including *Meekoceras*; *«Ceratites\**.



Fig. 1. Location of Induan-Olenekian transition outcrops, South Primorye. A -Location of the investigated area (shaded), B - South Primorye. Sections: 1 - Atlasov Cape, 2 - Ayax Bay, 3 - Tri Kamnya Cape and Orel clift, 4 - Artyom SMID quarry, 5 - Artyomovka River, 6 - Kom-Pikho-Sakho Cape, 7 - Yuzhnorechensk (Shimeuza) station, 8 - Abrek Bay.

Later, Triassic marine deposits in the Vladivostok region were studied by Ivanov (1891), chief of a geological team carrying out reconnaissance studies for the construction of the Trans-Siberian railroad. He also collected mollusc remains in the Shamara Bay area and he was the first who collected bivalves and ammonoids on Russian Island. He recognized the following succession of Triassic sediments in the South Primorye (Ussuri) region: (1) basal conglomerate, (2) sandstone and clay sandstone member and (3) thin-bedded sandstone member with algae and worm remains. On Karpinsky's initiative, a representative collection of Ivanov's and a part of Margaritov's collections were sent to the Austrian paleontologist Diener who studied them together with more abundant material that he had collected from the Lower Triassic of the Himalayas. From the lower part of the section, described by Ivanov, Diener (1895) identified the Early Triassic ammonoids *Proptychites* and *Lytophiceras*, and from the middle part the Early Triassic ammonoids *Pseudosageceras*, Ussuria, Arctoceras (= «Meekoceras (Koninckites)»), Anaxenaspis (= «Xenaspis»), Kazakhstanites (= «Dinarites») and Xenoceltites (= «Ceratites»). From Ivanov's upper member he identified the Anisian forms Ussurites (= «Monophyllites»), Ptychites and Acrochordiceras. Diener paid great attention to the discovery of Triassic marine deposits in the western Pacific, because at that time the Himalayas, Alps and Arctic Siberia were the only well known areas for the occurrence of Early Triassic ammonoids.

Ivanov's bivalve and brachiopod collections were later investigated and described by Bittner (1899). Stratigraphical investigations by Margaritov and Ivanov in the South Ussuri area were continued by Wittenburg (1910, 1916), who distinguished the (1) *«Pseudomonotis»* (= *Eumorphotis*) *iwanowi*, (2) *«Terebratula»* (= *Fletcherithyris*) *margaritovi* and (3) *«Xenodiscus»* (= *Kazachstanites*) *nicolai* Zones in the Lower Triassic and (4) the *Ptychites kokeni* Zone in the Anisian (Middle Triassic).

The importance of Lower and Middle Triassic rocks in the southern Primorye increased after the publication of the monographs by Kiparisova (1961, 1972) and later works. Kiparisova (1961) described more than 30 Early Triassic, and 28 Middle and Late Triassic ammonoid taxa and presented the following zonal scheme of the Lower Triassic: (1) basal conglomerate, (2) *Proptychites* Zone (or *Meekoceras* Zone), (3) *Flemingites* Zone, (4) *Prosphingites* Zone, and (5) *Subcolumbites* Zone. The Induan-Olenekian boundary was first recognized at the top of the *Flemingites* Zone (Kiparisova, Popov, 1956; Burij, 1959; Korzh, 1959), but later at its base (Kiparisova & Popov, 1964a,b; Kiparisova, 1972); moreover, instead of two zones (*Flemingites* and *Prosphingites*) the use of only a single Zone was suggested.

The fossil material collected by the major collective of Far Eastern geologists (Prynada, Nozdreev, Belyaevsky, Burij, Vasilyev, Korzh et al.) formed the basis of Kiparisova's 1961 work. The first used collection was made in 1928. It is necessary to keep in mind that Kiparisova's personal collections were restricted to the main material from the Middle Triassic and that for the Lower Triassic stratigraphical scheme she used material collected by other contributors.

Zakharov's (1968) monograph, with descriptions of 90 species of Triassic ammonoids from South Primorye, for the first time discussed the considerable facies variability of the Lower Triassic of this area. This was not taken into account in earlier correlation attempts. Consequently some ammonoid assemblages of some Lower Triassic zones were misrespresented.

The following zonation scheme for the Lower Triassic of the Far East (Zakharov, 1968, 1978. 1997); Zakharov, Rybalka, 1887; Burij et al, 1972; Burij & Zharnikova, 1981) accepted on the IV<sup>th</sup> Interdepartmental Regional Stratigraphic Conference in Khabarovsk (1990) will be discussed below:

#### **Olenekian Stage**

Upper Substage (Russian)

- 7. Subcolumbites multiformis Zone
- 6. Neocolumbite insignis Zone
- Lower Substage (Ayaxian)
- Tirolites Amphistephanites Zone
   Tirolites ussuriensis beds
   Baiarunia dagysi beds
- 4. Anasibirites nevolini Zone
- 3. Hedenstroemia bosphorensis Zone
- Induan Stage
  - 2. Gyronites subdharmus Zone
  - 1. Glyptophiceras ussuriense beds.

In 1976 Burij and co-authors (Burij, 1997; Burij et al., 1976, 1977, 1993) established four horizons in Induan, Olenekian and Anisian strata of South Primorye: Lazurnian, Tobizin, Chernyshev and Karazin. Recently in connection with research of facies variability of Lower and Middle Triassic sediments in limits of this interval the formations (suites) (Zakharov, 1997) were follow-up established.

Buryi (1979) was the first who studied Early Triassic conodont assemblages from South Primorye, but it must be noted that the review of conodont data from Primorye and other regions revealed the scarcity of age-diagnostic Late Induan and Early Olenekian conodonts.

Recently Zakharov (1995, 1996) proposed the Tri Kamnya Cape section as a Global stratotype for the Induan-Olenekian boundary. This contribution aims to propose the Abrek Bay section as a second candidate for the Global Stratotype of the lower boundary of the Olenekian.

#### The Abrek Bay section

The section is located in the Abrek Bay (north-eastern coast), about 0.8 km N of Yunshi Cape, South Primorye, at 42°55' N and 131°36' E.

#### Biostratigraphy

Ivanov first noted the presence of Triassic bivalve and gastropod mollusks in clay sediments of Abrek Bay in Strelok Gulf (Diener, 1895). Kiparisova (1938) later described *Claraia aurita* Hauer, *Eumorphotis multiformis* Bittner *«Pecten»* (*= Chlamys?*) *kryshtofowichi* Kiparisova, *Myoconcha* aff. *goldfuss*i Dunk., and *Posidonia abrekensis* Kiparisova, collected in Abrek Bay by Wittenburg (1908-1923) and Kryshtofovich (1924). The first describtion of Triassic cephalopods of Abrek Bay area is from Kiparisova (1961). She described two Early Triassic nautiloid taxa (*Menuthionautilus* and *«Syringoceras»*) and seven Early Triassic ammonoid taxa (*Hedenstroemia, Arctoceras* (*= «Proptychites»*), *Gyronites* and *Meekoceras*), collected by Nozdreev, Trifonov, Burij and Korzh (1938-1956). She described also one ammonoid (Kiparisova, 1961) collected by Nozdreev (1936), which she believed to be the Anisian form *Discoptychites* aff. *compressus* Yabe et Shimizu, although no suture is visible.

Kiparisova (1972) noted essential discrepancies between the Triassic stratigraphic schemes of Abrek Bay of Nozdreev (Kiparisova, 1972), Burij (1959), Korzh (1959) and Vasilyev (Kiparisova, 1972). The boundary between the Induan and Olenekian stages would on one hand be defined by the appearence of *Hedenstroemia* and *Meekoceras*; on the other the change from a sandy facies to silty one. This, however, conflicts with Nozdreev's data, who found *Hedenstroemia* in the sandy facies of the Lower Triassic.

Dagys (1974) described a new brachiopod genus (*Abrekia*) from Burij's collections from Lower Triassic sandstone of Abrek Bay and also regarded it as Induan in age.

From top to bottom, the sequence of the Anisian, Olenekian and Induan in the Abrek Bay section investigated by Zakharov, Shigeta, Popov and Panasenko in summer 1997-98 (Fig. 2 and 3) is as follows:



Fig. 2. Sketch map locating the Abrek Bay section. 1 - Murgabian (Abrek Formation), 2 - Induan (lower and middle Lazurnaya Formation), 3 - Lower Olenekian, Ayaxian (upper Lazurnaya and lower Zhitkov Formations), 4 - Anisian (Karazin Formation), 5 - dykes of porphyrite, 6 - geological route, 7 - bed elements.

#### Anisian Stage

Phyllocladiscites basarginensis Zone (lower part) 19. Dark grey mudstone with large nodules without mollusk remains over 10 m Nodules contain abundant of pure preserved radiolarians (spherical Spumellaria; det: Panasenko) 18. Dark grey mudstone and siltstone with interbeds of grey fine-grained striped sandstones, calcareous-marly nodules and lenses 25.0 m With ammonoids (Leiophyllites sp.) in the lower part and small bivalves, gastropods, ammonoids (Cuccoceras sp. nov.) and nautiloids (Trematoceras sp.) in the upper part. Kiparisova (1961, 1972) has adduced information on a fragment of ceratitid ammonoid living chamber which was found by Nozdreev in dark-grey mudstone of Abrek Bay in association of Posidonia abrekensis Kiparisova. It was tentatively identified as the Anisian form Discoptychites. However, it rather may be Parahedenstroemia; representatives are known in both the Hedenstroemia bosphorensis and the Anasibirites nevolini of the Olenekian stage. Kiparisova (1938) was, apparently, right, when she firstly consider Posidonia abrekensis Kiparisova to be Early Triassic in age. (over 100 m in thickness) Unexposed interval **Olenekian Stage** Lower Olenekian (Ayaxian) Substage Anasibirites nevolini Zone 17. Grey, striped siltstone (metamorphic near the contact with dyke of diorite porfirite) 2-3 m 16. Dark grey mudstone with calcareous-marly nodules and lenses, intercalated with striped 5.0 m eiltetone Contains ammonoids (Arctoceras labogense Zharnikova), Pseudoprosphingites magnumbilicatum (Kiparisova), Koninckites timorensis Wanner, Parakymatites sp. nov., Meekoceras varaha Diener, Meekoceras sp. nov., Hemiprionites dunajensis Zakharov, Preflorianites cf. radians Chao. It is possible to speculate that Arctoceras abrekensis (Kiparisova) (1961) was found by Nozdreev just in the member 16. 15. Dark grey siltstone and mudstone with calcareous-marly nodules and thick lenses of coquinoid 35.0 m marl With brachiopods (Abrekia sulcata Dagys), small bivalves (Promyalina sp., Posidonia? sp.), ammonoids (Pseudosageceras longilobatum Kiparisova, Pseudosageceras sp., Arctoceras labogense (Zharnikova) (dominant), Arctoceras subhydaspis (Kiparisova), Arctoceras septentrionale (Diener), Pseudoprosphingites magnumbilicatum (Kiparisova), Owenites koeneni Hyatt et Smith, Gyronitidae gen. et sp. nov., Koninckites timorensis Wanner (dominant), Gurleyites sp., Anasibirites nevolini Burij et Zharnikova, Palaeokazakhstanites ussuriensis (Zakharov), Euflemingites prynadai (Kiparisova), Eophyllites sp. Hedenstroemia bosphorensis Zone 14. Dark grey siltstone and mudstone with calcareous-marly nodules and lenses and rare interbeds (up to 15 cm) of grey medium-grained sandstone 23.0 m With small bivalves (Velopecten minimus Kiparisova), small gastropods and ammonoids (Pseudoprosphingites magnumbilicatum (Kiparisova), Gyronitidae?, Koninckites timorensis Wanner, Meekoceras varaha Diener (dominant), Flemingites radiatus Waagen, Anaxenaspis cf. orientalis (Diener) at the base of member. 13. Greyish-green, striped (because of very thin interlayers of mudstone) siltstone with rare nodules 8.6 m of marl With ammonoids (Meekoceras varaha Diener, Meekoceras sp. nov.) 12. Greyish-green, fine-grained striped (because of presence of very thin interlayers of mudstone) sandstone with dark grey, calcareoun-marly boulders and lenses 10.0 m With bivalves (Palaeoneilo? prynadai Kiparisova, Pteria ussurica (Kiparisova), Eumorphotis iwanowi (Bittner), Promyalina sp., Anadontophora fassaensis (Wissman), ammonoids (Parahedenstroemia conspicienda Zakharov, Invoites spicini Zakharov, Arctoceras septentrionale Diener, Pseudoprosphingites magnumbilicatum (Kiparisova), Ambites sp., Koninckites aff. timorensis Wanner, Meekoceras boreale Diener, Meekoceras varaha Diener, Dieneroceras chaoi Kiparisova, Preflorianites cf. radiatus Chao.

11. Dark grey mudstone, intercalated with grey-green, fine grained striped sandstone (up to 20 cm thick) and grey medium-graines sandstone (5-10 cm thick)

2.7 m

10. Light grey, striped, medium-grained sandstone, intercalated with grey green, fine-grained sandstone (5 cm thick) and with calcareous-marly boulders Contains nautiloids ( <i>Gyronautilus praevolutum</i> (Kiparisova)) and ammonoids ( <i>Meekoceras boreale</i> Diener). <i>Hedenstroemia</i> sp. indet (Kiparisova, 1961) seems to be found by Korzh in the member 10 or just below.	8.0 m
<ol> <li>Grey, middle-grained sandstone intercalated with grey thin-grained, striped sandstone, with share acute-angled pieces of dark grey siltstone and thin (5 cm) layer of dark grey mudstone at the base Yield ammonoids (<i>Melagathiceratidae</i> gen. et sp. nov.)</li> <li>Light grey, medium-grained sandstone intercalated with grey, thin-grained, striped (because of second second</li></ol>	2.15 m
<ul> <li>Sandstone (up to 50 cm thick); the surface of beds show distincted asymmetric signs of ripples With brachiopods (<i>Lingula borealis</i> Bittner, <i>Orbiculates</i>, <i>Albrekia sulcata</i> Dagys (dominant), bivalves (<i>Promyalina</i> sp.), ammonoids (<i>Arctoceras?</i> sp. indet., Melagathiceratidae gen. et sp. nov.).</li> <li>Grey, medium-grained sandstone with rare and very thin layers of dark grey mudstone and</li> </ul>	1.8 m
siderite boulders and layer (30 cm) of grey, coquinoid calcareous sandstone at the base Yields bivalves ( <i>Promyalina</i> sp., <i>Entolium microtis</i> (Wittenburg), <i>Velopecten minimus</i> Kiparisova, Pectinidae gen. et sp. nov.), ammonoids ( <i>Meekoceras boreale</i> Diener, <i>Ambites</i> sp.), Nautiloids ( <i>Phaedrysmocheilus</i> sp.).	2.6 m
Induan Stage	
6. Greyish-green, medium-grained sandstone with very thin interlayers of dark grey mudstone, that appear within every 0.5-0.6 m, and a layer (30 cm) of coquinoid calcareous sandstone at the	5.0 m
Dase; asymmetric ripples are recognizable at beo surfaces With brachiopods (Lingula aff. borealiis Bittner, Orbiculoidea sp.), bivalves (Eumorphotis multiformis (Bittner), Neoschizodus laevigatus (Zieten), Anodontophora fassaensis (Wissman)), gastropods, ammonoids (Gvronites subdharmus Kinarisova), Ambites sp.	5.0 m
5. Greyish-green, medium-grained, micaceous sandstone with many thin layers (2-10 mm, rarely 40 mm) of dark grey mudstone and lenses (up to 30 cm) of coquinoid calcareous sandstone; asymmet ripples are recognizable at bed surfaces - and evidence of the SE (125°) flow	ric 6.0 m
With bivalves ( <i>Neoschizodus laevigatus</i> (Zieten), plant leafs 4. Greyish-green, medium-grained sandstone with lenses (up to 15 cm thick) of coquinoidal calca- regular sandstone and layer of grey, striped (because of presence of very thin (1-3 mm) layers of	
mudstone (sandstone, 5 m above the base) With brachiopods Lingula borealis Bittner, Orbiculoides sp.), bivalves (Claraia australasiatica Krumb., Promyalina putiatinensis (Kiparisova), Eupecten cf. ussuricus (Bittner), Entolium microtis Wittenburg), ammonoids (Gyronites subdharmus Kiparisova), arthropodes (crabs).	8.0 m
<ol> <li>Greyish-green, medium-grained sandstone with rare pebbles and rare lenses (up to 1-3 cm thick) of conglomerate and small, angular pieces of dark grey siltstone and rare fragments of bivalve</li> </ol>	
shells 19.0 2. Greyish-green, medium grained sandstone with many lenses (up to 1-3 cm thick) of	)-21.0 m
conglomerate 4 1. Conglomerate with small and intermediate sized pebble and greish-green, sandy matrix, which characterized by well sorted disintegrated material. Pebbles consist of mainly felsic and inter-	.0-4.5 m
mediate effusive rocks Triassic basal conglomerate overlies with unconformity and erosion Murgabian terrestrial sediment Abrek Formation, represented in its upper part by light-grey, coarse-grained, tuffaceous sandst gravelstone.	3 m ts of the cone and

#### Analysis of the faunistic assemblages

#### Radiolarians

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Triassic radiolarians in Far East (Sikhote-Alin, Japan) are to date only known from cherts in olistostrome strata. During our investigation in 1997 abundant pure preserved radiolarians (spherical *Spumellaria*) were found and identified by Panasenko in terrigenous sediments of the Lower Anisian (lower part of the *Phyllocladiscites basarginensis* Zone) in Abrek Bay (Zakharov et al., in press).

#### Brachiopods

Five to six species of Lower and Middle Triassic brachiopods are known from Abrek Bay (Zakharov, Popov, 1999); in the Induan only inarticulates were found. Lower Olenekian sediments are characterized by the appearance and mass development of articulate brachiopods like *Abrekia sulcata* Dagys. *Lingula borealis* Bittner and *Orbiculoidea* sp. are characteristic for the sandstone facies of both the Induan and Lower Olenekian, with a prevalence *Orbiculoidea* in the top of the Induan.

#### Bivalves

In the lower part of the Induan bivalves and other invertebrates are very rare (single and broken valves). Similar bivalve assemblages were recognized in the sandy facies of both the upper Induan and Iower Olenekian. Common species include *Entolium microtis* Wittenburg, *Neoschizo-dus laevigatus* (Zieten), and *Anodontophora fassaensis* (Wissman).

Among the dominant species occurring only in the Induan, only *Promyalina shamarae* Bittner and possibly also *Promyalina putiatinensis* (Kiparisova) can be mentioned here, although *Promyalina* sp., closely resemling *Promyalina putiatinensis* occurs in the Lower Olenekian.

#### Nautiloids

Nautiloid remains were discovered only in the Olenekian and Anisian of Abrek Bay. Three taxa of Olenekian nautiloids occur: *Phraedrysmocheilus* sp., *Menuthionautilus korzhi* Kiparisova and *Gyronautilus praevolutum* (Kiparisova). *Trematoceras* sp. is known from the Lower Anisian.

#### Ammonoids

Only two ammonoids are known from the Induan: *Gyronites subdharmus* Kiparisova (zonal species-index) and *Ambites* sp.

The base of the Olenekian *Hedenstroemia bosphorensis* Zone in the Abrek Bay section is determined by the first appearance of representatives of *Meekoceras*, which higher in the Zone associate with *Hedenstroemia* and some other typical Olenekian representatives. The ammonoid assemblage of the *Hedenstroemia bosphorensis* Zone consists of 18 species belonging to 14 genera (Fig. 3).

The base of the Anasibirites nevolini Zone in the section is marked by the first appearance of the zonal species-index. Further characteristic species of this zone are Arctoceras labogense (Zharnikova) (dominant), Arctoceras subhydaspis (Kiparisova), Arctoceras abrekensis (Kiparisova), Gurleyites sp., Palaeokazakhstanites ussuriensis (Zakharov), Hemiprionites dunajensis Zakharov, Eophyllites sp. and Parakymatites sp.nov. Many ammonoid taxa first occurring in this zone (e.g., Arctoceras septentrionale (Diener), Pseudoprosphingites magnumbilicatum (Kiparisova), Owenites koeneni Hyatt et Smith, Koninckites timorensis Zone of this section or in other sections in adjacent districts of South Primorye. Altogether the ammonoid assemblage of the Anasibirites nevolini Zone of Abrek Bay consists of 20 species belonging to 15 genera.

Ammonoids and other invertebrate groups are extremely rare in the Anisian part of the Abrek Bay section. They are represented by two forms only: *Leiophyllites* sp., *Cuccoceras* sp.nov. They are representatives of the *Phyllocladiscites basarginense* Zone (or *Leiophyllites pradyumna* and *Phylloclasiscites basarginensis* Zone).

#### Crustaceae

A crab claw was found in the sandy facies of the Induan.



#### Amphibians

The presence of amphibian remains in clayey sediments of the Anasibirites nevolini Zone is shown by small fragments of osteal tissue.

#### Paleomagnetic results

According to Sokarev & Golozubov's new data (Zakharov et al., in press) the at least several of the 17 stratigraphical levels of the *Gyronites subdharmus* (Fig. 3, levels I-IV), *Hedenstroemia bosphorensis* (levels V-XIII) and *Anasibirites nevolini* (levels XIV-XVII) zones show a normal polarity. This suggests that the enitre interval represents a uniform, extended normal polarity zone.

#### Induan-Olenekian boundary beds in some other sections of the Primorye region

#### 2.1 Tri Kamnya Cape

Recently, Zakharov (1994, 1996) discovered Hedenstroemia bosphorensis (Zakharov), Parahedenstroemia sp., Gyronites separatus Kiparisova, Gyronites aff. planissimus Spath and Ambites sp. in the basal part of the Olenekian in the Tri Kamnya Cape section (in the sandy facies). The most representative ammonoid assemblage of the Hedenstroemia bosphorensis Zone (Pseudosageceras, Parahedenstroemia, Ussuria, Arctoceras, Prosphingitoides, Paranannites, Ambites, Koninckites, Meekoceras, Anakashmirites, Flemingites and Euflemingites) was found stratigraphically higher, in the clay facies, in association with the condont Neospathodus dieneri Sweet (Buryi, 1979). The Anasibirites nevolini Zone has not been found in the section - the beds containing Palaeokazakhstanites and Priololobus (member 24) (Zakharov, 1996) could belong to this zone. Finds made during the last years in this section indicate that Meekoceras gracilitatis White occurs in the Hedenstroemia bosphorensis Zone, which is widespread in the western USA.

Fig. 3. Distribution ammonoids and some brachiopods and bivalves in the Induan, Olenekian and Anisian of Abrek Bay section. 1 - conglomerate, 2 - gravelstone, 3 - sandstone, 4 - sandstone with fragments of mollusk valves, 5 - coquinoid calcareous sandstone, 6 - siltstone, 7 mudstone, 8 - nodule of marl, 9 - dike of porphyrite, 10 - interval of species distribution (domination is indicated by a double ring), 11 - paleomagnetic zone (interval of normal polarity), 12 - uninspected interval, 13 - plant remains, 14 - erosion, 15 - tuf-interval.

Species: 1 - Gyronites subdharmus Kiparisova, 2 - Promyalina putiatinensis (Kiparisova), 3 - Promyalina schamarae (Bittner), 4 - Koninckites sp. indet., 5 - Promyalina sp., 6 - Ambites sp., 7 - Meekoceras boreale Diener, 8 - Abrekia sulcata Dagys, 9 - Hedenstroemia sp. indet., 10 - Arctoceras? sp. indet., 11 - Melagathiceratidae gen. et sp. nov., 12 - Inyoites spicini Zakharov, 13 - Koninckites aff. timorensis Wanner, 14 - Dieneroceras chaoi Kiparisova, 15 - Pseudoprosphingites magnumbilicatum (Kiparisova), 16 - Meekoceras varaha Diener, 17 - Parahedenstroemia conspicienda Zakharov, 18 - Arctoceras septentrionale (Diener), 19 - Preflorianites cf. radiatus Chao, 20 - Meekoceras sp. nov., 21 - Koninckites timorensis Wanner, 22 - Gyronitidae?, 23 - Flemingites radiatus Waagen, 24 - Anaxenaspis cf. orientalis (Diener), 26 - Anasibirites nevolini Burij et Zharnikova, 27 - Owenites koeneni Hyatt et Smith, 28 - Gyronitidae gen et sp. nov., 29 - Palaeokazakhstanites ussuriensis (Zakharov), 30 - Eophyllites sp., 31 - Pseudosageceras sp. indet., 32 - Arctoceras labogense (Zharnikova), 33 - Euflemingites rynadai (Kiparisova), 34 - Arctoceras subhydaspis (Kiparisova), 35 - Pseudosageceras longilobatum Kiparisova, 36 - Parakymatites sp. nov., 37 - Hemiprionites dunajensis Zakharov, 38 - Leiophyllites sp., 39 - Cuccoceras sp. nov.

#### 2.2. Orel cliff

This section is located at the western coast of the Ussuri Gulf, 2 km north of Tri Kamnya Cape. Induan-Olenekian transition strata are fully developed in the sandy facies of the Lazurnaya Formation. The upper Induan is here, like in the Tri Kamnya Cape section, characterized by *Gyronites subdharmus* (Kiparisova), associated with *Promyalina schamarae* (Kiparisova) and conodonts - *Neogondolella* cf. *carinata* juv. (Clark), *Neospathodus*? sp. indet., *Hindeodella* sp. indet., *Lonchodina* sp. indet. (the latter were recently discovered by G.I. Buryi). *Meekoceras* cf. *subcristatum* Kiparisova and *Gyronites separatus* Kiparisova have been discovered at the base of the Olenekian, from where Buryi identified some condonts (*Neospathodus* sp. indet., *Diplododella* sp. indet. and *Lonchodina* cf. *triassica* (Müller)).

Isotopic analyses have shown, that  $\delta^{13}$ C values in the upper part of the Induan reach + 1.2‰, are slightly reduced at the Induan-Olenekian boundary (up to +0.3‰), and do not exceed + 0.8‰ in the remaining exposed part of the lower Olenekian (Zakharov et al., 1999). It should be noted that in organogenic carbonates of the middle Olenekian (*Tirolites - Amphistephanites* Zone) of South Primorye anomalously high  $\delta^{13}$ C values (up to 4.9‰) were measured (Zakharov et al., 1999); this correlates well with middle Olenekian anomalies of the North Caucasus (Zakharov et al., 1999b, 2000).

#### 2.3. Kom-Pikho-Sakho Cape

The section (Fig. 1) has much in common with the Abrek Bay section. The Induan-Olenekian boundary also is located in the sandy facies at the first appearence of *Meekoceras*. An abundant early Olenekian ammonoid assemblage (*Pseudosageceras, Hedenstroemia, Parussuria, Metussuria, Tellerites, Arctoceras, Prosphingitoides, Juvenites, Owenites, Prionolobus, Meekoceras, Inyoites, Hemiprionites, Gurleyites, Preflorianites, Bandoites, Flemingites, Euflemingites) of the <i>Hedenstroemia bosphorensis* Zone is known from the lower part of the clay facies associated with the conodont *Furnishius triseratus* Clark (Burij, 1979). The main disadvantage of this section is the presence of a series of small faults at the Induan-Olenekian transition strata (5-10 m offset).

#### 2.4. Yuzhnorechensk (Shimeuza)

Like in a number of other sections (Abrek, Orel, Kom-Pikho-Sakho) the sandy facies is characterized by the occurrence of species of *Meekoceras (Hedenstroemia bosphorensis* Zone). In the clay facies that forms the upper part of this zone, ammonoids are extremely abundant and varied (*Hedenstroemia, Ussuria, Metussuria, Arctoceras, Prosphingitoides, Owenites, Dieneroceras, Koninckites, Prionolobus, Parakymatites, Meekoceras, Inyoites, Hemiprionites, Flemingites, Eophyllites*). Conodonts from this interval include Neospathodus discreta (Müller), N. zharnikovae Buryi, *Furnishius triserratus* Clark, *Parachirognatus symmetrica* (Staeshe), *Hadrodontina subsym-metrica* (Müller), *H. nevadensis* Müller, *Chirodella dinodoides* (Tatge), *Lonchodina triassica* Müller, *L. nevadensis* Müller (Buryi, 1979). In the overlying *Anasibirites nevolini* Zone the zonal index-species occurs together with *Arctoceras, Juvenites, Gurleyites* and *Melagathiceratidae* gen. et sp.nov. An major disadvantage of this section is that Induan deposits are absent.

#### 2.5. Artyom environs

We here present the first information on a section in the SMD quarry, 6 kms NE of the Uglovaya railway station. In northern part of the quarry the Anasibirites nevolini Zone is exposed. This zone is characterized by an abundance of ammonoids - e.g., Arctoceras labogense Zharnikova, Prosphingitoides ovalis (Kiparisova), Prosphingitoides sp. nov., Juvenites simplex (Chao), Prionolobus involutus Zakharov, Meekoceras sp. nov., Hemiprionites dunajensis Zakharov, Anasibirites nevolini Burij et Zharnikova, Xenoceltites sp. nov., Anaxenaspis sp. nov., Melagathi-

ceratidae gen. et sp. nov. -, and bivalves - Posidonia mimer Oeberg, Posidonia ussurica Kiparisova, Posidonia sp., Nuculana elliptica (Goldfuss), Pteria ussurica (Kiparisova), Leptochondria cf. bittneri Kiparisova, Atomodesma? sp. (det.: Dorukhovskaya). Underlying sediments, inluding sandstones, are not exposed here (only found in loose blocks). Judging from the occurrence of Leiophyllites and Hollandites? the southern part of the quarry consists of Anisian sediments. The relationship of this member to underlying sediments is still uncertain.

#### 2.6. Artyomovka River

Early Olenekian ammonoids are known from the clay facies of the Hedenstroemia bosphorensis Zone on the left bank of the Artemovka River (Arctoceras, Prosphingitoides, Juvenites, Owenites, Dieneroceras, Meekoceras, Hemiprionites, Anaxenaspis, and Eophyllites). Induan sediments are not exposed there. The ammonoid assemblage of the overlying Anasibirites nevolini Zone includes Parahedenstroemia, Arctoceras, Paranannites, Owenites, Arctoprionites, Hemiprionites, Wasatchites, Gurleyites, and Subalbanites. The following conodonts are known from the Anasibirites nevolini Zone: Neogondolella milleri (Müller), Neospathodus waageni Sweet, N. discreta (Müller), Furnishius triserratus Clark, Hindeodella nevadensis Müller, H. budurovi Buryi, H. raridenticulata Müller, Hadrodontina adunca Staesche, H. symmetrica (Staesche), H. subsymmetrica (Müller), Parachirognathus symmetrica (Staesche), Lonchodina triassica (Müller) This is the type section of the Anasibirites nevolini Zone in South Primorye (Burij et al., 1972; Zakharov, 1978).

#### 2.7. Ayax Bay

Ayax Bay is the only place on Russian Island, where the Induan-Olenekian transition in a sandy facies can be studied. The top of the Induan, approximately 2 m thick, exposed on the coast, contains ammonoids (*Gyronites?* sp.) bivalves (e.g., *Eumorphotis multiformis* (Bittner), *Promyalina shamarae* (Bittner)(Zakharov, 1996), and also conodonts (*Neospathodus pakistanensis* Sweet, *Parachirognathus* sp. (Buryi, 1979). An index-species of the *Gyronites subdharmus* Zone obviously occur at the same stratigraphical level in an adjacent section of Novik Bay.

Somewhat higher in the sequence (at the roadside, and cliff in the south coast of the Ayax Bay) sandstone with small ammount of coquinoid calcareous sandstone are found. This sandstone is supposed to be of early Olenekian age because of the presence of *Proharpoceras carinatitabula-tum* Chao and *Juvenites* cf. *simplex* (Chao). The little material from the Abrek Bay section and other Lower Triassic sections in South Primorye shows, that strata characterized by early Olenekian ammonoids are easily recognized. The major difficulty regarding the Induan-Olenekian transition in the area is its poor exposure in most of the sections.

#### Lithological facies of the Lower and Middle Triassic of South Primorye

There are two main lithologies in the Lower Triassic in South Primorye: (1) the polyfacies type and (2) the bifacies type. The first is characteristic for the western sections (Russian Island, western coast of the Amur Gulf between Alasov and Ugolnyi Capes), and the second for the eastern sections (Artyomovka River, Artyom environs, Kom-Pikho-Sakho Cape, Krasnorechensk (Shimeuza) station, Abrek Bay). The Tri Kamnya Cape section of western coast of the Ussuri Gulf lithologically holds an intermediate position between the series of sections but tends to the polyfacies type.

The sections of Russian Island are proposed as reference for the polyfacial type of the Lower Triassic in South Primorye. Zakharov (1997) recognized several formations there:

- (1) The Lazurnaya Formation, comprising the Induan and the lower part of the Olenekian Hedenstroemia bosphorensis Zone (it is primarily exposed in Ayax Bay area of Russian Island, but its stratotype is located at western coast of the Ussuri Gulf, between Lazurnaya (Shamara) Bay and Tri Kamnya Cape (Zakharov, 1968)
- (2) The Tobizin Formation, comprising the *Hedenstroemia bosphorensis* Zone (excluding its basal beds) and the *Anasibirites nevolini* Zone, with its stratotype at Tobizin Cape, Russian Island
- (3) The Schmidt Formation, only comprising the *Tirolites Aphistephanites* Zone with the stratotype at Schmidt Cape, Russian Island
- (4) The Zhitkov Formation comprising the Neocolumbites insignis and Subcolumbites multiformis Zones, with the stratotype at Zhitkov Cape, Russian Island. The latter is overlain there by the Anisian Karazin Formation, having its stratotype in the district of Karazin Cape, Russian Island.

The first three formations are represented mainly by sandy facies, but the Lazurnaya Formation (110 m) differs by the predominance of coarse, disintegrated rocks at its base and the appearance of bivalve coquinas in its middle and upper parts. The Tobizin Formation (180 m) is characterized by the development of cephalopod coquinoids and the appearance of the thin siltstone member. The Schmidt Formation (40 m) is characterized by the abundance of rather thick (up to 1.2 m) lenses of bivalve and brachiopod coquinoid calcareous sandstone and limestone. The Zhitkov Formation (85 m) is strongly differs from the underlying formations of the Lower Triassic in the extensive development of siltstone and mudstone with abundant remains of ammonoid and bivalve shells. The Karazin Formation is characterized by a predominance of banded and spotted sandy siltstone alternating with sandstone, including unusually light, arkose, lacking benthonic mollusc remains (excep the basal beds), but with radiolarian and ammonoid remains.

The Lower Triassic of the eastern sections comprise only two formations: the Lazurnaya and Zhitkov formations. The sharp boundary between these - see e.g. the Abrek Bay section (Fig. 3) - lies in the *Hedenstroemia bosphorensis* Zone. The sequential change of facies correlates with a lower subsidence of the basin in the western or southwestern parts than in the eastern part.

The deposition of the sediments of the Karazin Formation seems to have taken place on the deepest parts of a shelf as is evidenced by radiolarian accumulations in boulders at Abrek Bay; radiolarians are not known from the more shallow shelf facies of the Lower Triassic. Typical Far East Anisian facies are widespread - from Little Khingan in the northwest up to South Primorye and Kitakami in the southeast. The reduction of the number of benthonic remains in Anisian sediments could be related with to the accumulation in the deepest parts of a shelf with an oxygen deficit. For the benefit of various conditions of sedimentation in Early and Middle Triassic more expressed intensivity of phosphatogenes during Anisian can testify in comparison with Induan and Olenekian (Zakharov & Shkolnik, 1994).

#### Concluding remarks

Our analysis shows that in the present stage of biostratigraphic investigation only two candidates for a global stratotype of the Induan-Olenekian boundary can be proposed: (1) the Tri Kamnya Cape – Orel cliff section, and (2) Abrek Bay section. All other investigated Lower Triassic sections of the Lower Triassic, can, even when less favourable, be used for studying ammonoid assemblages of the Upper Induan and Lower Olenekian in order to get a better overall view, and thus may help to solve many problems with regard to global correlations.

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The position of the Induan-Olenekian boundary in South Primorye, the Himalayas, Siberia and Canada can be defined at first appearence of the ammonoid *Hedenstroemia*. The occurrence of *Meekoceras gracilitatis* White in association with *Flemingites* and other typical representatives of the *Hedenstroemia bosphorensis* Zone in South Primorye allows a sound correlation with both the *Meekoceras gracilitatis* Zone of Idaho and the *Flemingites flemingianus* Zone of the Salt Range. It recently became clear that *Euflemingites prynadai* (Kiparisova) and representatives of the genus *Arctoceras* occur throughout the lower two zones of the Olenekian in South Primorye. Because species of *Euflemingites* and *Arctoceras* are known from the Lower Triassic of the Boreal realm, there enable a more accurate correlation of the Smithian of the Boreal realm (Tozer, 1995) with the lower zones of the Ayaxian substage of the Tethys (Zakharov, 1997).

The extended interval of normal polarity assumed for the investigated part of the Olenekian in South Primorye and data the destribution of *Arctoceras* and *Euflemingites* could correspond to a large zone of normal polarity of Spitsbergen and Canada (Mørk et al., 1999) that has recently been established in the Smithian *Euflemingites romundary* (upper part) and *Wasatchites tardus* zones.

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# BIOCHRONOLOGICAL SIGNIFICANCE OF TRIASSIC NONMARINE TETRAPOD RECORDS FROM MARINE STRATA

#### Spencer G. Lucas and Andrew B. Heckert

We review 16 records of nonmarine Triassic tetrapod fossils from marine strata or from nonmarine strata closely intercalated with marine strata. Most of these records provide important points of cross correlation between nonmarine Triassic tetrapod biochronology and marine biochronology of the Triassic, which is based mostly on conodonts and ammonoids. Particularly important among these are records of tetrapod index taxa of the nonmarine timescale, which facilitates its cross-correlation to the standard global chronostratigraphic scale for Triassic time. These records thus allow cross-correlation of: Lootsbergian = middle-late Induan; Nonesian = Olenekian; Perovkan = early Anisian; Berdyankian = midlate Ladinian; Otischalkian = Carnian; and Revueltian = mid Norian.

#### Introduction

The standard global chronostratigraphic scale for Triassic time is based on marine invertebrate biostratigraphy, especially of conodonts and ammonoids. In nonmarine Triassic strata, tetrapods (amphibians and reptiles) provide a robust global biochronology with which to subdivide Triassic time (Lucas, 1998). Records of nonmarine tetrapods in Triassic marine strata thus can provide a direct cross-correlation of marine and nonmarine Triassic biochronology. Here, we review these records (Fig. 1) and establish their significance to such cross-correlation (Fig. 2). Note that we only review marine records of nonmarine tetrapods, not those of the marine tetrapod groups found in Triassic strata (Hupehsuchia, Nothosauria, Placodontia, Sauropterygia, Ichthyosauria, Plesiosauria and some Prolacertilia). Also, we have confined our review to records in true marine strata or to those records in nonmarine strata that are closely interbedded with well-correlated marine strata indirectly. Finally, although we hope ours is a complete list (given here in numerical order, from oldest to youngest), we seek comments/additions from interested parties.

#### **Early Triassic**

1. Wordy Creek Formation, eastern Greenland - Marine strata yield the temnospondyls Luzocephalus kochi (Säve-Söderbergh), L. johanssoni (Säve-Söderbergh), Wetlugasaurus groenlandicus (Säve-Söderbergh), Stoschiosaurus nielseni (Säve-Söderbergh) and Tupilakosaurus heilmani Nielsen (Säve-Söderbergh, 1935; Nielsen, 1954). The lowest occurrence (LO) of Luzocephalus is in the Ophiceras commune Ammonite Zone, and the genus extends up through the "Proptychites rosenkrantzi Zone." Most of the Wordy Creek amphibians are from the younger "Anodontophora fassarensis beds," which are the youngest Lower Triassic strata in this section (Nielsen, 1935; Säve-Söderbergh, 1935). This establishes a late Griesbachian-early Dienerian (middle Induan) range of Luzocephalus, but the other temnospondyl taxa are middle or late Dienerian (late Induan) in age (Trümpy, 1961, Silberling & Tozer, 1968; Tozer, 1994).

Luzocephalus, Tupilakosaurus, and Wetlugasaurus occur in the Vokhmian Horizon of the Vetlugian Series of the Russian Urals (Shishkin et al., 1995). This fauna includes Lystrosaurus, an index taxon of the Lootsbergian land-vertebrate faunachron, so the amphibians establish a middle-late Induan age for at least part of Lootsbergian time.



Fig. 1. Distribution of the 16 marine occurrences of Triassic nonmarine tetrapods in Pangea. Numbers are those used in the text

2. Sticky Keep Formation, Svalbard - Temnospondyls that co-occur here with early Olenekian (Smithian) ammonites (Buchanen et al., 1965; Tozer, 1967) are: Sasenisaurus spitsbergensis Wiman, Peltostega erici Wiman, P. wimani Nilsson, Aphaneramma rostratum Woodward, Lyrocephaliscus euri (Wiman), Teretrema acuta Wiman and Boreaosaurus thorslundi Nilsson (Wiman, 1910, 1915; Nilsson, 1942, 1943; Cox & Smith, 1973). These trematosaurs are believed to have been euryhaline amphibians that may have actually lived in marine environments. They also reflect a high diversity and abundance of trematosaurs characteristic of the Nonesian. However, the Svalbard trematosaur taxa are mostly endemic and thus only provide stage-of-evolution evidence for an Olenekian-Nonesian cross-correlation.

3. Andavakoera Formation, northwestern Madagascar - the upper part of the marine Andavakoera Formation (lower Dienerian) yields a diverse assemblage of temnospondyls: ?Benthosuchus madagascanensis Lehman, ?Wetlugasaurus sp., Mahavisaurus dentatus Lehman, M. australis (Lehman), Aphaneramma sp., Alfasaurus elongatus Lehman, Tertrema sp., Tertremoides ambilobensis Lehman, Trematosaurus madagascariensis Lehman, Wantzosaurus elongatus Lehman and Deltacephalus whitei Swinton (Swinton, 1956; Lehman, 1961, 1966, 1979). The Benthosuchus and Wetlugasaurus identifications have been debated (Cosgriff, 1984), but if correctly determined, the record of these Lootsbergian index taxa in the Andavakoera Formation provides a Lootsbergian-Dienerian (late Induan) cross-correlation. The diverse trematosaurs in the Andavakoera Formation also parallel the Sticky Keep Formation record. Indeed, some of the same taxa occur in both the Sticky Keep and the Andavakoera, which reinforces the cross correlation of the Lootsbergian and Dienerian.

4. Mangyshlak Peninsula, western Kazakstan - Lozovsky and Shishkin (1974) documented Parotosuchus sequester Shishkin from marine upper Olenekian strata that yield *Tirolites* and other ammonites. Parotosuchus (sensu stricto) is an index taxon of Nonesian time, with numerous nonmarine records. This provides a direct Nonesian-late Olenekian cross-correlation.

#### **Middle Triassic**

5. Gogolin Formation (lowermost Muschelkalk), Polish Silesia - fragmentary temnospondyl and archosaur fossils include the types of Mentosaurus waltheri Röpke, Eurycervix posthumus Huene, and "Xestorrhytias perrini" Meyer, all of which are indeterminate mastodonsaurids, and therauisuchian Zanclodon silesiacus Jaekel, based on a single tooth. Ammonite biostratigraphy places the Gogolin Formation in the lower Anisian (e.g., Kaim & Niedźwiedzki, 1999). The tetrapod material, however, is too fragmentary to be of much biochronological significance. Nevertheless, it closely resembles some of the tetrapods from the Upper Buntsandstein of southwestern Germany-eastern France, and thus supports a Perovkan-early Anisian correlation.

6. *Röt Formation (upper Buntsandstein), southwestern Germany-eastern France* - these strata are lower Anisian marginal marine to interbedded nonmarine/marine facies of well-established age because of their close physical relationship to the lower Muschelkalk. The common amphibian from the Röt Formation, *Eocyclotosaurus*, is an index taxon of the Perovkan found in both Europe and the western United States (e.g., Ortlam, 1970; Morales, 1987). The Röt records of *Eocyclotosaurus* thus provide a Perovkan-early Anisian cross -correlation.

7. Partnach Formation, Austria - The early Ladinian Partnach Formation of western Austria yielded a temnospondyl jaw fragment that Sander & Meyer (1991) identified as cf. Cycloto-saurus sp. However, this specimen could just as well belong to Mastodonsaurus (cf. Schoch, 1999), so it is of limited biochronological significance.

8. Badong Formation, Hunan, China - Zhang (1975) described the unusual archosaur Lotosaurus adentus from the Badong Formation of Hunan, which yields primitive species of the ammonite *Proganoceratites* and the marine bivalve Leptochondria subillyrica and is of Anisian age (H. Yin, written comm., 2000). Lotosaurus is endemic to this record, so it is of no current biochronological significance.

9. Upper Muschelkalk (Meissner Formation and equivalents), southwestern Germany - the uppermost Muschelkalk contains several bonebeds (Hagdorn & Reif, 1988). These include records of Mastodonsaurus (Schoch, 1999), a Dinodontosaurus-like dicynodont (Broili, 1921) and rauisuchians ("Zanclodon scheutzi" Fraas), among other terrestrial tetrapods. These records, which are early Ladinian in age, provide an important cross-correlation of the Berdyankian (index taxon = Mastodonsaurus) to part of Ladinian time.

10. Lettenkeuper, southwestern Germany - parts of the lower Keuper include marine, marginal marine and evaporitic strata and yield a prolific vertebrate record dominated by Mastodonsaurus (Schoch, 1999). This provides cross-correlation of part of the Berdyankian to the late Ladinian (Longobardian).

#### Late Triassic

**11.** *Raibler Schichten, Austria* - Koken (1913) described *Metoposaurus santaecrucis* from a conglomeratic sandstone in the upper part of the Raibler Schichten. This is a Julian record, and thus cross-correlates part of the Otischalkian (index taxon = *Metoposaurus*) to the early Carnian.

12. Opponitzer Schichten, Austria - Huene (1939) described a skull fragment of the phytosaur *Paleorhinus* (= *Francosuchus*) from the lower part of the Opponitzer Schichten (Kalk) near Lunz, Austria. The occurrence is of late Carnian (Tuvalian) age (Janoscheck & Matura, 1980), but it cannot be tied precisely to a particular ammonite zone. *Paleorhinus* is an index taxon of the

Otischalkian and has a broad distribution across Pangea (Hunt & Lucas, 1991; Lucas, 1998). The Opponitzer Schichten record of *Paleorhinus* thus cross-correlates part of the Otischalkian to the Tuvalian.

ſ	Per.		Age	LVF	MARINE RECORDS OF NONMARINE
-			Rhaetian	Anachean	
		Late	Norian	Revueltian	Mystriosuchus, Aetosaurus, Edennasaurus, Drepanosaurus, Megalancosaurus, Macrocnemus, Eudimorphodon, Peteinosaun Preonodactylus, Sikannisuchus
	Triassic		Carnian	Adamanian	
				Otischalkian	Paleorhinus, Metoposaurus
		ldle	Ladinian	Berdyankian	Mastodonsaurus, cf. Cyclotosaurus aff. Dinodontosaurus, "Zanciodon"
		Mid	Anisian	Perovkan	Eocyclotosaurus, large mastodonsaurids "Zanclodon", Lotosaurus
		arly	Olenekian	Nonesian	Parotosuchus, Sasenisaurus, Peltostega, Lyrocephaliscus, Aphaneramma, Tertrema, and other temnospondyls
		ш	Induan	Lootsbergian	Wellugasaurus, Tupilakosaurus, Stoschiosaurus, Luzocephalus

Fig. 2 Triassic nonmarine tetrapods showing cross-correlations with the marine chronostratigraphic scale. Index taxa of land-vertebrate faunachrons indicated in bold type.

13. Lunz Schichten (Sandstone), Austria - Stur (1873) reported Mastodonsaurus giganteus Jaeger? from the Lunz Sandstone in the Austrian Alps. This is an early Carnian (Julian) record, broadly correlative to the German Schilfsandstein. However, we have examined the material Stur described, and it is not diagnostic of *M. giganteus*, and could just as well belong to *Cyclotosaurus*. Therefore, this record is of limited biochronologic significance.

14. Pardonet Formation, British Colombia - Nicholls et al. (1998) described Sikannisuchus huskyi, an archosaur of uncertain affinities, from the Pardonet Formation of northeastern British

Columbia, Canada. Associated conodonts indicate the record is early Norian (*triangularis* Conodont Zone). Nevertheless, *Sikannisuchus* is endemic to this location, so the record is of no current significance to cross-correlation.

15. Zorzino Limestone, Lombardian Alps, Italy - The Zorzino Limestone (Calcare de Zorzino) has been correlated to the mid-Norian Himavatites columbianus Ammonite Zone (Jadoul et al., 1994; Roghi et al., 1995). Nonmarine tetrapods from this unit at the Cêne and Endenna quarries in Lombardy are the diapsid Endennasaurus acutirostris Renesto; a sphenodontian, Diphydontosaurus; the drepanosaurids Drepanosaurus unguicaudatus Pinna and Megalancosaurus preonensis Calzavara, Muscio & Wild; the phytosaur Mystriosuchus planirostris Meyer, the aetosaur Aetosaurus ferratus Fraas; a new species of Macrocnemus; and the pterosaurs Eudimorphodon ranzii Wild and Peteinosaurus zambelli Wild. Mystriosuchus and Aetosaurus are Revueltian index taxa, and this provides an important Revueltian-mid Norian cross-correlation (Lucas et al., 1998).

16. Forni Dolomite, Veneto Prealps, Italy - the Forni Dolomite (Dolomia di Forni) in northeastern Italy is the same age as the Zorzino Limestone (Roghi et al., 1995). Its nonmarine tetrapods are the drepanosaurids Drepanosaurus unguicaudatus Pinna and Megalancosaurus preonensis Calzavara, Muscio & Wild; and the pterosaurs Eudimorphodon rosenfeldi Dalla Vecchia, Eudimorphodon sp. and Preonodactylus buffarinii Wild (Dalla Vecchia, 1995). These tetrapods are endemic to northern Italy, so they are of little significance to biochronology beyond reinforcing the cross-correlation provided by the Zorzino Limestone.

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# THE MIDDLE TRIASSIC STRATIGRAPHY AND SEDIMENTARY PALEOGEOGRAPHY OF SOUTH CHINA

# Tong Jinnan and Liu Zhili

The Middle Triassic was the great turning period of South China from marine sedimentary basins to continental deposits or erosion. This paper summarizes the distribution and variation of the stratigraphic sequences, lithofacies and biotas in the various Middle Triassic depositional basins of South China. The close relationship between the biotic paleoecology and the lithofacies as well as the sedimentary facies, thus the paleogeography, is demonstrated. The process of the transition from the depositional paleogeography and its relation to the tectonic settings is concluded therefore.

During the Middle Triassic a great turn took place in the development of sedimentary basin of South China. Following the final suture of Cathaysia Block with Yangtze Block (including the Lower Yangtze region), Yangtze Block matched completely with North China Block (Yin et al., 1999), while the extensive Indosinian Movement wreaked havoc in the eastern Tethys. Then the sediments in the main part of South China transformed gradually from marine to terrestrial. As a result the most remarkable changeover of stratigraphic structure and sedimentary paleogeography in South China occurred in the Middle Triassic. It would be of great importance to clarify the stratigraphic structure of this region and its sedimentary paleogeographic pattern for fully understanding this great geologic turning process.

#### 1. The Middle Triassic sedimentary sequences and lithofacies in South China

The South China mainly mentioned in this paper includes Yangtze Block, including the Lower Yangtze region, to the east of Kangdian Oldland and Cathaysia Block as well as the depression region between the blocks. Considering no Middle Triassic records have been reported from southern Guangdong and Hainan, the Indochina-South China Sea Block will not be discussed here. The northern border of South China is based upon the boundary of the Stratigraphic Realm used in the Multiple Classification and Correlation of the Stratigraphy of China (e.g. Zhao and Ding, 1996).

South China is subdivided into four sedimentary provinces, according to the sedimentary sequences, the regional tectonic difference and the development of sedimentary basin in the Middle Triassic. Each sedimentary province has similar stratigraphic sequence and unique lithofacies, but the difference between the Anisian and Ladinian is apparent (Fig.1 and Table 1).

#### 1.1 Cathaysia Sedimentary Province

The Middle Triassic in this province occupied the Cathaysia Block and its neighboring areas of Yangtze Block such as Guangdong, southern Jiangxi and southeastern Hunan. Its boundary to the Lower Yangtze sedimentary province shifted from Jiangshan-Shaoyang fault northward to Jiande-Changsha deep fault in the Middle Triassic (Wu et al., 1994). The Middle Triassic of this province consists mainly of terrestrial and littoral clastic rocks. The marine sediments increased from southeast to northwest and decreased to disappear from the Anisian to Ladinian. In the southwestern Fujian the Middle Triassic is the Anren Formation composed mostly of red clastic

rocks. Huangben Formation in northern Guangdong and Yangjia Formation in central Jiangxi are also dominated by clastic sediments but they contain some eurytropic fossils (Nan and Zhou, 1996). The Middle Triassic of southeastern Hunan consists mainly of carbonates and its lower part, Sanbao'ao Formation, has some interbeds of siltstone and mudstone while the upper part, Shijing Formation, is dominated by evaporate carbonate rocks with more purplish red clastic interbeds.



Fig. 1 The Middle Triassic sedimentary basins and typical stratigraphic sequences in South China: 1. sandstone; 2. siltstone; 3. argillaceous sandstone; 4. arenaceous mudstone; 5. silty mudstone; 6. mudstone; 7. marl; 8. limestone; 9. argillaceous limestone; 10. bio-clastic limestone; 11. oolitic limestone; 12. nodular limestone; 13. dolomite intercalating gypsum beds; 14. dolomitic limestone; 15. dolomite; 16. dolomitic solution-breccia; 17. old land; 18. boundary between sedimentary provinces; 19. typical section and point

#### 1.2 Lower Yangtze Sedimentary Province

This province includes the Middle and Lower Yangtze to the east of Wuhan in Yangtze River drainage area, and the Middle Triassic sequences are basically accordant in the whole province. The Anisian Zhouchongcun Formation is composed mainly of evaporate carbonate rocks intercalated with gypsum beds, though Lushuihe Formation in the Middle Yangtze area contains more clastic rocks (Zhang et al., 1986). In the Ladinian, the entire province was covered by coastal-fluviolacustrine clastic sediments, i.e. Huangmaging Formation and Pugi Formation.
### 1.3 Upper Yangtze Sedimentary Province

This province covered the Upper Yangtze platform of Yangtze Block occupied by the Middle Triassic carbonate rocks, including western Hubei, Chengdu-Chongqing basin, northern and western Guizhou and eastern Yunnan. The Middle Triassic is made mostly of carbonate rocks and dolomite is commonly a notable component of it. The Anisian is widely distributed in the province, called Leikoupo Formation in the Chengdu-Chongqing basin and Guanling Formation (s.s.) in Guizhou and eastern Yunnan (Dong, 1987). However, many red clastic beds are intercalated in Hubei, northern Hunan, Chongqing, eastern Sichuan and northeastern Guizhou so that Badong Formation is named here. In the mean time, a narrow carbonate belt of "reefoid formation", whose core is called Bojishan Formation (Tong, 1997) or Poduan Formation (Dong, 1987), developed in the front of the carbonate platform. The breccia limestone in the south of the "reefoid" belt is Qingyan Formation. During the Ladinian, many caliche sediments of "agatelike" structure (Fang and Wen, 1992) overlie this "reefoid" formation, and Longtou Formation is named. Neither bindstone and framestone are recorded, nor well-developed breccia limestone in its south is observed though Songzikan Formation is used here in the Ladinian (Tong, 1997). The Ladinian carbonate rocks of platform facies are widespread in Sichuan and Guizhou, though the Yangliujing Formation contains much evaporate dolomite in eastern Yunnan to central Guizhou. Tianjingshan Formation is composed of normal carbonate rocks in Chengdu-Chongqing basin, which might be greatly influenced by the western Tethys.

### 1.4 Youjiang Sedimentary Province

It was a pull-apart chasmic trough behind Yangtze Block when it moved northward (Yin et al., 1999) and locates at the juncture of (south) Guizhou, (northwest) Guangxi and (southeast) Yunnan. The Middle Triassic consists of terrigenous clastic rocks of big thickness, and carbonate sequences occur in some isolated carbonate buildups within the basin. In the depressed clastic basin, the Anisian is named separately as Xinyuan Formation, Banna Formation, Baifeng Formation and Xuman Formation due to the different composition in various areas, while the Ladinian is called Bianyang Formation and Lanmu Formation. The Anisian carbonate rocks on the buildup platform in Guangxi is Guohua Formation, which is overlapped by the Ladinian terrigenous clastic rocks of Lanmu Formation.

In addition, the Middle Triassic acid volcanic and pyroclastic rocks, Banba Formation, are in Pingxiang-Dongxing, southern Guangxi.

As a whole, the Anisian carbonate rocks are mainly on Yangtze Block and dominated by dolomite and dolomitic limestone, including Zhouchongcun Formation of Lower Yangtze, Leikoupo Formation and Guanling Formation of Upper Yangtze, and Bojishan Formation and Gingyan Formation at the southern edge of Upper Yangtze. The Anisian clastic sediments are mostly distributed in Cathaysia sedimentary province, Anren Formation, Huangfen Formation and Yangjia Formation, and the depressed Youjiang sedimentary province, Xinyuan Formation, Banna Formation, Baifeng Formation and Xuman Formation. However, there exist carbonate sediments, Guohua Formation, on the buildup platforms in Youjiang province, and terrigenous clastic rocks interbedded in Yangtze carbonate platforms (Badong Formation). However, the mixed sequences of carbonate and clastic rocks mainly occur at the transitional areas between the sedimentary provinces, such as Sanbao'ao Formation in southeastern Hunan and Lushuihe Formation in southeastern Hubei.

Table 1 The Middle Triassic lithostratigraphic units, basic lithology and major fossils in South China

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Stage	Lower Yangtze sedim	entary province		Upper Yangtza	sedimentary province	
Ladinian	Huangmaqing Formation Sediments dominated by arena- ceous clastics. Grey fine sandstone and silistone in the lower part and purplish psepholite and mudstone in the upper Psepholite and mudstone in the upper Danaeopsis-Bernoullia Flora and charophytes and ostracods	Puqi Formation Argilitaceous and are- naceus clastic sedi- ments. Purptish red mudstone, sandstone. Yielding some plant fossils	Badong Formation Mixed carbonate and clastic sediments. Grey mari and dolo- mitic limestone in- terbeddon mudstone and sitistone sitistone sitistone sitistone sitistone sitistone sitistone sitistone sitistone celadon mudstone and sitistone sitistone sitistone celadon mudstone and sitistone celadon mudstone sitistone sitiste faitolium dis- cites, Unionites spe- cites, Unionites spe- proconceratine sup-	Tianjingshan Formation Carbonate sediments. Grey thick-beddad lime- stone. Yielding bivatves: Carbing bivatves: Anaetina engostanformis Rhaetina angustanformis	Yangjiujing Formation Evaporate carbonate sedi- ments. Grey massive dolomite and limestone. limestone. <i>Bilyrica. Unionies spp., and brachipods. Mentzellia</i> sp., Nudispririferina sp.	Longtou Formation Carbonate sediments Grey limestone, agate-like' limestone and bioclastic limestone Yielding bivarves: Entokium sp., Ptenta sp.
Anisian	Zhouchongcun Formation Sediments of evaporate car- bonates and clastics with gypsum. Yellowish grey limestone, dolomite and gypsum-solution slither rocks in the lower part, and mudstone intercalated with marl and sand- stone in the upper. Yielding bivalves: Costatoria radiata. C. submutistriata, Asoella discrites, and ammonoids. Lenotropites sp. Ussurites sp.	Lushtuthe Formation Carbonale and clastic sediments. Grey limestone and dolomite in the lower part, and grey mustone and dolomite in the upper. Yielding bivalves: Ascella illyrica crassistriata, Neoschizodus laewigata, Myrius sp., Pteria sp., Bakevellia sp., Pteria Sp., Bakevellia sp.		Guanting Formation (Leikoupo Formation) Evaporate carbonale sedim Grey limestone, argillaceou mudstone, gypsum and hali Yielding bivaves: Costatori mansuyi, Asoella iliyrica, A. mansuyi, Asoella iliyrica, A.	ents. s dolomite intercalating te. a goldfussi. C. goldfussi a puradoxica. Pleuromya Progonoceratites putchar	Bojishan Formation Carbonate sediments Grey bioclastic innestone, calcirudite and biodstone Yielding bivarves: Neconrphotis spp., and ammonolds. <i>Laponites</i> sp., and brachlopods: Nuclisprifiente minime

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(continued)

ormation	Cathaysia sedi Huangben	mentary province Shijing Formation	Blanyang Formation	Youjiang sediment	ary province	Banba
	Formation (Yangjia Formation) Arenaceous and argillaceous clastic sediments. Purplish red mud- filme sandstone. Yielding bivalves: Asoalla illyrica, A. Paradoxica, Neo- schizodus spp. Ger- villia sp., Gostatoria sp., Enol.ium sp., Pieria sp., and plants.	Carbonate mixed with fine clastic sediments Greyish and lilac limestone and dolomitic limestone, purplish calcareous sittstone and mudstone interbeded in the upper part	Terrigenous (lastic turbi Gery sandstone intercal Gery sandstore intercal ammonoids: <i>Protract</i> yoo ammonoids: <i>Protract</i> yoo	die sediments. aing calcareous mudst alla spp., <i>Posidonia</i> spp aras sp.	one. ., <i>Halobia</i> spp., and	Formation Volcanics and volcanics clastic sediments sediments sediments pophyry, lava, ash tuff interbedded mutsione beds. Posidonia sp. Posidonia sp.
			Xinyuan Formation (BannaFormation) Argillaceous fine clastic sediments. Greytsh green mud- stone and sitistone in- ter-calating some lime- stone and sitistone in- ter-calating some in- banation in the source sopp. Leipphylifes so., Acrochedriceras sp.	Balfeng Formation (Xurman Formation) (Xurman Formation) Fine clastic turbidite sediments. Cetadon sandstone intercalating mud- intercalating mud- therealiting bivalves: Vielding bivalves: Daonella spp., 1°ost- donia spp., and am- monoids: Balatoniles spp., ducco-ceras sp., Acrochonticeras sp., Acrochonticeras sp.,	Guohua Formation Carbonate sedi- ments. Grey limestone and oolith: limestone in- tercatating mudstone and dolemile. Yielding bivalves: Unioniles sp., Chlamys spp., Postoonia sp., and gastropods: Worthenia sp.	
		Sanbao'ao Formation Carbonate mixed with clastic sediments. Grey thin-bedded limestone and mart intercatating sillstone and mudstone beds. Yielding bhavles: Asoolia lilynca, A. subil. Ayrica, A. albertil, A. paradoxica, Posidonia				

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Table 1

In the Ladinian, carbonate sediments were obviously limited, mainly in Upper Yangtze sedimentary province, Yangliujing Formation, Tianjingshan Formation and Longtou Formation. Cathaysia province and Lower Yangtze province were deposited of terrigenous clastics, and mainly terrestrial red sediments. In the depressed Youjiang province, terrigenous clastic rocks, Lanmu Formation and Bianyang Formation, extended even over the Anisian carbonate buildup platforms.



Fig. 2 The Middle Triassic lithofacies and paleogeography in South China: 1. nondepositional area, 2. terrestrial lacustrine clastic deposit, 3. littoral clastic deposit, 4. littoral mixed clastic and carbonate deposit, 5. shallow shelf argillaceous deposit, 6. deep shelf clastic turbidite deposit, 7. open platform carbonate deposit, 8. restricted platform salty carbonate deposit, 9. boundary between lithofacies and paleogeographic units.

### 2. The Middle Triassic biotas in South China

The Middle Triassic contains rich fossils in South China and the biotic ecological differentiation is clear. Bivalves were especially diversified and widespread, and they were of distinctive assemblages and associated biotic groups in various lithofacies. They are clearly similar and related to lithofacies differentiation.

According to the ecological features of dominant biotas, the Middle Triassic biotas of South China can be subdivided into two ecological groups, which are particularly characteristic of bivalve groups. One is shallow ecological group, which occupied Cathaysia, Lower Yangtze, Upper Yangtze sedimentary provinces as well as the carbonate buildups in Youjiang sedimentary province. It is the predominant biologic group in both carbonate and clastic facies of these provinces. The other ecological group is characterized by deep-water nektonic and nektobenthic organisms and distributed mainly in the deep-water facies of terrigenous clastic sediments in Youjiang sedimentary province.

In shallow ecological group, Costatoria and Asoella are the most characteristic forms, among which the typical species are C. goldfussi, C. goldfussi mansuyi, C. submultistriata, A. illyrica, A. subillyrica, and A. paradoxica, and they have the widest distribution. Other common forms include some species of such genera as Unionites, Neoschizodus, Entolium, Pleuromya, Mytilus and Pteria. According to the ecological features and body structures of these forms, two ecological subgroups can be distinguished. One is composed of endobenthic and movable epibenthic forms, which are characteristic of relatively thick, weighty and considerable convexity of shells such as Costatoria, Neoschizodus, Unionites, and Pleuromya. The other subgroup is byssus-fixing or freely lying forms of thin and compressed shell such as Entolium, Asoella, Pteria, and Mytilus, and some have also certain swimming ability by means of the clapping of their shells. The former ecological subgroup usually dominated littoral and neritic carbonate facies, while the latter was common in the littoral detrital area. They had also associated with different biotic taxa in different areas and lithofacies. In region the former, associated sometimes with Progonoceratites, gastropods and few brachiopods, was predominant in Upper Yangtze, and the latter mainly in Lower Yangtze and Cathaysia sedimentary provinces, occasionally in the strata of terrestrial flora. On the whole, the ecological subgroup of Costatoria was extensive in South China during the Anisian, and the subgroup of Asoella was predominant during the Ladinian. The Costatoria subgroup was, however, mostly in semi-closed shallow sea, while the Asoella subgroup was rich in open littoral facies.

Daonella was the most characteristic of the deep-water ecological group. It was motive epibenthic group against high pressure and less oxidizing conditions (Kobayashi, 1967) and lived only in the Middle Triassic deep-water facies (Tong, 1992). The typical bivalves in this ecological group include *Daonella* as well as most species of *Posidonia* and *Halobia*, and they are commonly associated with nektonic ammonoids. *Posidonia* and ammonoids are the most important markers of this group in the early Anisian when *Daonella* did not develop to some degree. *Halobia* joined them in the late Ladinian. The bivalves in this ecological group are characteristic of thin and flat shells, and low biotic diversity but high abundance (Tong, 1997). They lived in the deeper water of the depressed Youjiang sedimentary province, predominant in the terrigenous clastic facies and especially rich in the strata of turbidite.

However, there is a band of mixed ecological groups at the southern edge of the carbonate Upper Yangtze sedimentary province contiguous to the clastic Youjiang basin. The "reefoid formation" in this belt is characterized by the fossils of shallow bank facies, including algae forming the Anisian bindstones, some hexacorals and bryozoans, as well as rich bivalves, gastropods, brachiopods, and even ammonoid shell-beds (Fang and Wen, 1992; Tong and Huang, 1992; Lehrmann et al., 1998).

Concerning as the spatial and temporal distribution of the ecological groups and subgroups, Cathaysia sedimentary province was occupied by *Asoella* subgroup but a few members of *Costatoria* subgroup in the northwest during the Anisian and more terrestrial plants in the late Middle Triassic. Lower Yangtze sedimentary province had a certain elements of *Costatoria* subgroup in the early Anisian but *Asoella* subgroup was predominant in the Anisian. Terrestrial plants, charophytes and ostracods developed well in most parts of the province during the Ladinian. Upper Yangtze sedimentary province is characteristic of widespread *Costatoria* subgroup though a certain elements of *Asoella* subgroup existed at the juncture of Sichuan, Hubei and Guizhou as well as Chongqing City. In Youjiang sedimentary province, *Daonella* group and ammonoids are the most distinctive biota, but *Costatoria* subgroup occupied the carbonate buildups as well in western Guangxi and southern Guizhou during the Anisian.

In a word, the Anisian marine ecological groups were widespread in South China, especially the members of the abnormal marine *Costatoria* subgroup nearly everywhere throughout the region. The marine ecospace reduced remarkably in the Ladinian when the epibenthic ecotypes replaced the predominant endobenthos, while the terrestrial ecospace extended considerably. Meanwhile, the ecospace of the deep-water *Daonella* ecological group enlarged to the areas of the early isolated carbonate buildups.

### 3. The Middle Triassic sedimentary facies and paleogeography in South China

During the Pangea time of the Paleozoic-Mesozoic transition, South China was composed of several northward-drifting blocks in Tethys, which constantly adjoined and coupled to the northern Laurasian blocks (Yin et al., 1999). Cathaysia Block was uplifted prior to Yangtze Block so that it received terrestrial sediments earlier in the Middle Triassic. The main body of Yangtze Block was also uplifted gradually from marine to continental facies, from restricted salty marine sediments to terrestrial fluviolacustrine deposits (Fig. 2). But at the edges of Yangtze Block, marine sedimentation sustained much longer. In Youjiang depression at the south of Upper Yangtze the normal marine sequences extend up even into the Upper Triassic.

As matter of the fact, the Cathaysia Block and Lower Yangtze sedimentary province belonged a single sedimentary paleogeographic unit while the Upper Yangtze and Youjiang sedimentary provinces were another affiliated unit in the Middle Triassic according to the differentiation of the sedimentary sequences, lithofacies and biotas.

In Cathaysia and Lower Yangtze sedimentary provinces, the essential pattern of the Middle Triassic paleogeography and the differentiation of sedimentary facies are in SE-NW direction. The southeastern part, including most Zhejiang, Fujian and Guangdong, which is the major part of Cathaysia sedimentary province, was uplifted to be denuded except for a relict lacustrine clastic facies in southern Fujian. The denudation was continuously expanding northwestward during the Middle Triassic. In the northwestern part, including western Zhejiang, central Jiangxi, southeastern Hunan and northwestern Guangdong, extensive littoral clastic deposition happened in the Anisian, but most parts of the area became denuded in the Ladinian and only few littoral clastic lakes remained in central Jiangxi and southeastern Hunan. At the marginal area of Yangtze Block, where Lower Yangtze sedimentary province and Cathaysia Block adjoin, semirestricted to restricted lagoonal carbonate facies and evaporate sediments developed well in the Anisian. With the continuous compression and elevation between Yangtze Block and North China Block, this area became littoral clastic facies in the late Anisian and final terrestrial fluviolacustrine facies in the Ladinian.

Accordingly, in the Middle Triassic, the total paleogeographic pattern of the Cathaysia and Lower Yangtze provinces was a continent-marginal sedimentary basin declining northwestward. Denudation was expanding steadily from the Anisian to Ladinian while the sedimentary facies zones migrated northwestward rapidly. The whole region finished the transformation from sea to land in the latest Anisian.

In the Upper Yangtze and Youjiang sedimentary provinces, the Middle Triassic paleogeography was a typical pattern of continental margin deepening from north to south, accompanied by an accordant differentiation of sedimentary facies. The main body of Upper Yangtze was an enormous shallow carbonate platform, from the Chengdu-Chongqing basin, eastwards to western Hubei and northwestern Hunan, southwards to northern and southwestern Guizhou and southeastern Yunnan, even including some parts of northwestern Vietnam (Vu Khuc, 1994). However, the lithofacies difference inside the platform is notable. There mixed lots of littoral clastic sediments in the eastern part, while a narrow zone of detrital facies occurred in front of Kangdian Oldland. Evaporites with gypsum scatter in central Sichuan and Nanchong. A narrow reefoid carbonate formation located on the southern edge of the platform, facing the depressed Youjiang basin. This kind of reefoid carbonate sediments appeared as well on some isolated buildup platforms in Youjiang sedimentary province. Some organisms capable of reef-building and related sedimentary structures came to pass in this belt during the Anisian (Tong and Huang, 1992; Lehrmann et al., 1998), but it evolved only a passive shallow bank finally in the Ladinian (Liu et al., 1987; Tong and Huang, 1992; Fang and Wen, 1992; Enos et al., 1997). In front of carbonate platform was a narrow slope, which yielded gravitative sediments rich of carbonate breccia.

In southern Guizhou and northern Guangxi of Youjiang province subsisted the biotas and clastic sediments of deep-water facies. Except for the isolated carbonate buildup of Bangen, Guizhou, and platform of Tiandong-Baise, Guangxi, clastic turbidites scattered in the basin, especially at the juncture of Guizhou, Yunnan and Guangxi, where turbidites were in both Anisian and Ladinian. Nevertheless, the silty and argillaceous sediments of shallow shelf were the main components in the most areas of southern Guizhou and central Guangxi during the Middle Triassic. Meanwhile, a vast amount of intermediate-acid volcanic rock of island-arc type appeared at Qinzhou, southern Guangxi (Zhao and Ding, 1996), and intense depression happened at Baise-Qiubei of northwestern Guangxi and southeastern Yunnan during the Ladinian (Feng et al., 1997).

On the whole, sedimentary paleogeography of Upper Yangtze and Youjiang sedimentary provinces became further diversified during the Ladinian. On the Upper Yangtze platform, clastic sediments decreased and carbonate facies became more shallow and salty. In the Youjiang clastic basin turbidity sedimentation was very active and formed a big thickness of rocks, even expanding over the carbonate platforms (Enos et al., 1998). The extensive geographic differentiation and speedy basin-filling indicate the forthcoming of the great turn in the development of basin. The end of the Ladinian was therefore the great turning point of the basin (Yin, 1982; Tong, 1997). >From the Late Triassic on, the entire sedimentary basin was uplifted so that the paleogeographic pattern of platform-basin did not exist any more. The Kangdian Oldland upraised for a very long time began to receive sediment but Guizhou and Guangxi were gradually elevated, thus a new pattern of lithofacies and paleogeography in east-west direction was formed.

#### 4. Conclusion

- 1. The Middle Triassic was a special period in the sedimentary paleogeographic history of South China. It has completely recorded the course of all sedimentary provinces from sea to land and their interrelationship, which is of great importance to study the regional tectonics and geological history of South China.
- 2. The spatial difference and temporal change of the lithofacies, biotas and sedimentary paleogeography in Middle Triassic of South China was clearly related. The variation of ecological types and the alteration of biotic composition give exact expression to the history of the regional paleogeographic change and the development of sedimentary basin in this region.
- 2. Catheysia-Lower Yangtze and Upper Yangtze-Youjiang were two separate distinct sedimentary basins, in which the sedimentary and paleontological records were interrelated. But the two basins had quite different evolutionary histories, which indicates that they had different comamics in the transition from sea to land.

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# FOSSIL DATA AND THEIR BEARING ON DEFINING A CARNIAN-NORIAN (UPPER TRIASSIC) BOUNDARY IN WESTERN CANADA<sup>3</sup>

M.J. Orchard, E.S. Carter, and E.T. Tozer

#### Abstract

The newly-described successions of nasellarian radiolarians around the Carnian-Norian (Upper Triassic) boundary in Queen Charlotte Islands indicates their potential as tools for global correlation. The boundary interval reflects a time of gradual radiolarian change, with new taxa appearing synchronously with both Communisti and Primitius conodont zone faunas. The base of the Communisti Zone and the Macrolobatus ammonoid Zone are broadly coincident and hence this datum can be recognized with all three fossil groups. The base of the Primitius Zone falls within the Macrolobatus Zone and does not correspond to a clear ammonoid datum in North America, whereas the base of the succeeding Kerri ammonoid Zone does not correspond to a unequivocal microfossil signal. *Norigondolella navicula*, a conodont formerly used to subdivide the Primitius Zone and identify the Norian, appears facies controlled and caution is suggested in its use as an index to the base of the Norian. A case is therefore made for drawing the Carrian-Norian boundary at the datum common to the base of the Macrolobatus ammonoid Zone and Communisti conodont Zone.

#### Introduction

Western Canada has provided a wealth of Upper Triassic biochronological data. This was demonstrated initially by the synthesis of a standard zonation based on ammonoid and some bivalve faunas (Tozer, 1967, 1994). Later, conodonts were shown to have great utility (Mosher, 1973; Orchard, 1983, 1991a, b), all the more because they were fully intercalibrated with the ammonoid successions (Orchard and Tozer, 1997). More recently, radiolarians were added to this scheme through the richly fossiliferous oceanic successions preserved in the Wrangell terrane (Carter et al., 1989, Carter 1993), whilst ichthyoliths isolated from the conodont samples promise to provide a further stratigraphic tool (Johns et al., 1997).

### Carnian-Norian Boundary (CNB)

The Carnian and Norian stages were named in the 19th Century from fossil occurrences in Austria, representative of Tethys. Most of the fossils concerned were ammonoids obtained from isolated localities. Little was known about the faunal sequence. In the 20th Century many new data on Triassic ammonoid successions were found in North America, Europe and Asia. From the data in Nevada and British Columbia, Silberling and Tozer (1968, p. 16) proposed that a Carnian-Norian boundary be recognized between the Macrolobatus and Kerri ammonoid Zones. Type locality for the former (index species *Klamathites macrolobatus*) is in Nevada, for the latter (index species *Stikinoceras kerri*) in northeastern British Columbia. Their sequence is demonstrable in both Nevada and British Columbia. More recently, new data from Tethys localities have been acquired and interpreted by Krystyn (1980, p. 72), who draws the Carnian-Norian

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boundary between the "Anatropites-Bereich" and the Guembelites jandianus Zone. Anatropites occurs in the Macrolobatus Zone, Guembelites in the Kerri Zone. It thus seems that the Carnian-Norian boundary drawn by Silberling and Tozer in North America is at least approximately coeval with the boundary recognised by Krystyn in Tethys.



Fig. 1. Map of Queen Charlotte Islands showing important conodont/radiolarian localities relevant to this study. Inset shows the location of northeast British Columbia sections.

At present, the only definition of the Carnian-Norian Boundary (CNB) is in terms of the ammonoid faunas. In cratonal areas of western Canada, the boundary interval also approximates a time of significant change in sedimentary regime: shallow water carbonates of the Baldonnel Formation are succeeded by deeper water facies of the Pardonet Formation. On the west coast, on Queen Charlotte Islands, the boundary lies entirely within the 'oceanic' slope deposits of the Peril Formation, part of the allochthonous Wrangell Terrane.

The purpose of this review is to discuss microfaunal changes (conodonts and radiolarians) within the marine realm of western Canada that may potentially be used in global correlation and definition of the CNB, and thus contribute towards the resolution of historical events that date from that time. Detailed correlations with Tethys and with the continental realm are not attempted here.

### Northeast British Columbia: ammonoid-conodont intercalibration

The ammonoid succession about the CNB comprises the zones of *Tropites welleri* (2 subzones), *Klamathites macrolobatus* (undifferentiated), and *Stikinoceras kerri* (2 subzones) (Tozer, 1994, p. 37-40). Relational superposition of the Kerri Zone above the Macrolobatus Zone at Pardonet Hill on Williston Lake is discussed by Tozer (op. cit.). In British Columbia, representative faunas of the Macrolobatus Zone are variable and their differentiation is not possible at this time, although associated conodonts suggest a range of ages.

The conodont zonation employed here was established largely in northeastern British Columbia. The taxonomy and nomenclature of the conodont species about the CNB are still in a state of flux but criteria presented previously (Orchard, 1991a, b) serve to adequately define successive zones that embrace potential levels for definition of the CNB, namely the Nodosus, Communisti, and Primitius zones. Upper Carnian radiation of metapolygnathid conodonts through the Macrolobatus ammonoid Zone produced at least two separate lineages that are useful in subdividing the interval. The older lineage comprises *Metapolygnathus lindae-M. zoae-M. samueli-M. pseudoechinatus* (encompassing the Welleri-Macrolobatus zones), whereas the younger lineage led from *M. nodosus* directly to *M. primitius* (Macrolobatus-Kerri zones). *Metapolygnathus communisti* variants are related to the latter stock and range largely within the Macrolobatus Zone.

Metapolygnathus primitius appears in the Macrolobatus Zone and ranges upward through most of the Kerri Zone, where the species invariably dominates the conodont faunas, except where 'floods' of Norigondolella occur. The common appearance of Norigondolella navicula within the range of *M. primitius* has formerly been taken to mark the base of the Upper primitius Zone and of the Norian Stage (Orchard, 1983, 1991b; also cf. Krystyn, 1980). This datum has been used as a working base for the Norian because its diagnostic conodonts are known in association with many occurrences of ammonoids of the Kerri Zone. However, Norigondolella is sometimes absent from Primitius Zone faunas of Kerri Zone age, which cautions against reliance on the taxon as an indicator of basal Norian strata.

### Queen Charlotte Islands: conodont-radiolarian intercalibration

One remarkable feature of the Upper Triassic sections outcropping on Queen Charlotte Islands (QCI) is the outstanding successions of conodont and radiolarian microfossils contained within the Peril Formation of the Kunga Group (Carter et al., 1989; Orchard, 1991a; Desrochers and Orchard, 1991; Carter, 1991, 1993). The Late Triassic biostratigraphic succession (Upper Carnian to Rhaetian) is extraordinarily complete and contains significant occurrences of conodonts and radiolarians, but ammonoids and bivalves are less common than in northeast B.C. and calibration with the ammonoid zonation is therefore often indirect and via associated conodonts (Orchard et al., 1995).

Carnian-Norian boundary microfaunas occur in fine-grained micrite concretions in the Peril Formation. The most complete sequences are present at Sadler Point and Frederick Island on northern Graham Island (Fig. 1). At these localities, macrofauna is limited to poorly preserved ammonoids and/or occurrences of the bivalve *Perihalobia alaskana*. The latter has been regarded as an indicator of the Lower Norian *Stikinoceras kerri* Zone (Tozer, 1967, p. 36). Additional radiolarian collections from Shields Island, Kunga Island, Crescent Inlet, Huxley Island, Huston Inlet, and Kunghit Island (Fig. 1) provide supplementary information on the Carnian-Norian boundary microfaunas. Ammonoids of the uppermost Carnian *Klamathites macrolobatus* Zone are known at both Huxley Island and Kunghit Island, which thus provides direct tie-in with the ammonoid zonation (Orchard, 1991a, fig. 5).

Representatives of each of the CNB conodont zones are present on QCI (Orchard, 1991a). Good examples of the both the Communisti and Primitius Zones are associated with Macrolobatus Zone ammonoids, leading to an effective differentiation of those ammonoid faunas. Primitius Zone conodonts are associated with *Perihalobia*. However, *Norigondolella navicula* unexpectedly occurs prior to the Primitius Zone. It is suggested that the earlier appearance of *Norigondolella* in the deeper water facies of the Wrangellian Peril Formation compared with the epicratonic seas of western Pangaea is a result of environmental factors. Hence, modification of the zonal scheme established in northeast B.C. may be necessary.

The radiolarian successions of QCI have been documented in a preliminary fashion (Carter, 1991; Orchard et al., 1990) and only the diverse Rhaetian succession has been documented in detail (Carter, 1990, 1993; Carter and Guex, 1999; Dumitrica and Carter, 1999). The CNB succession at several key localities has been summarized in a recent web-based publication (Carter and Orchard, 2000); this contribution repeats the essential features of the succession.

The radiolarian faunas are well preserved, diverse and contain many well known forms along with a variety of new species. Spumellarians overwhelmingly dominate the fauna, comprising upwards of 80% of individuals with genera such as *Capnodoce* De Wever, *Capnuchosphaera* De Wever, and *Sarla* Pessagno being the most common. The vast numbers and diversity of spumellarians, some possibly endemic, suggests they were well adapted to the region. Only the abundant nassellarian fauna have been studied thus far: these display greater variety of shape and form and may prove more useful for global correlation. Over 90 species are recognized in the 33 samples studied; the distribution and abundance of 54 of the most common nassellarians (plus one spumellarian) from Sadler Point and Frederick Island is shown in Carter and Orchard (2000, tables 1 and 2).

Radiolarians from QCI are associated with conodonts of the Communisti and Primitius zones of Orchard (1991a), those from the latter zone being the more common. A single collection from the underlying Nodosus Zone has been partly documented to provide a lower datum. Radiolarians are common in strata equivalent to the Nodosus and Primitius zones. Coverage is much more limited in the Communisti Zone, an interval of rapid evolution in the condont faunas. The radiolarian assemblages are also dated by comparison with existing zonations of Blome (1984) and Sugiyama (1997), although both schemes are imprecise in terms of independent dating.

The most abundant nassellarian genera in the Queen Charlotte assemblages are Canesium Blome, Canoptum Pessagno, Corum Blome, Multimonilis Yeh, Poulpus De Wever, Syringocapsa Neviani, Triassocampe Dumitrica, Kozur and Mostler, and Trilatus Yeh. Numerous species described from Oregon (see Blome, 1984; Yeh, 1989) are present in varying abundance, including Bulbocyrtium tubum Yeh, Canesium lentum Blome, Canoptum farawayense Blome, C. macoyense Blome, Castrum perornatum Blome, Corum speciousum Blome, Latium paucum Blome, *Multimonilis pulcher* Yeh, *Pachus longinquus* Blome, *Pseudosaturniforma minuta* Blome, and *Triassocampe immaturum* Blome. The dominance of these species in both Oregon and Queen Charlotte Islands implies that the two areas were in close proximity in the Late Triassic Panthalassan Ocean. It is also noteworthy that some of these species have been found in Japan (Sugiyama, 1997) and in the accreted terranes of southern British Columbia (Cordey, 1998).

The rare occurrence of some demonstrably global indicators described from southern Europe, Japan, and the Russian Far East is judged to be more important for correlation. These include: *Bulbocyrtium reticulatum, Hozmadia spinosa, Pentactinocarpus acanthicus, Pseudosaturniforma carnica, Pseudotriassocampe hungarica, Triassocampe sulovensis*, and *Xiphotheca longa,* described by Kozur and Mostler (1979, 1981, 1994) and Dumitrica et al. (1980) from areas in Austria, Hungary and Italy; *Poulpus pansus, P. phasmatodes, P. piabyx, Syringocapsa batodes,* and *Xiphotheca karpensionensis,* described by De Wever (in De Wever et al., 1979) from Greece; *Triassocampe coronata* from the Russian Far East (Bragin, 1991); and, from Japan, *Haeckelicyrtium* sp. A, *Poulpus carcharus, Veles vulgaris, Xipha nodosa,* and Nassellarian indet. A , described by Sugiyama (1997), and *Trilatus robustus,* described by Nakaseko and Nishimura (1979). Distribution data for these species are presented in Carter and Orchard (2000, tables 1, 2). The balance of the Queen Charlotte fauna is new and consists mostly of species of *Annulopoulpus* Kozur and Mostler, *Poulpus* De Wever, *Sanfilippoella* Kozur and Mostler, *Trilatus* Yeh, *Veghia* Kozur and Mostler, and several indeterminate nassellarians.

Distributional data from all localities sampled indicates that over two-thirds of nassellarian species studied range through the Communisti and Primitius conodont zones, suggesting that the Carnian-Norian boundary interval was a time of gradual, rather than dramatic radiolarian change. This change is apparent more in the increasing abundance of certain genera and species than in abrupt extinctions and the appearance of successor taxa. For example, some genera arising in strata equivalent to the Communisti Zone, e.g. *Pachus* Blome and *Syringo-capsa* Neviani, are rare and represented by a single species whereas in the younger Primitius Zone they are more abundant and diverse. This phenomenon is true also for *Corum* Blome, which occurs sporadically in the lower part of Primitius Zone strata but a little higher becomes very abundant and diverse.

The succession of conodont and radiolarian faunas is best demonstrated in the stratigraphic sequence at Sadler Point, which is the most complete anywhere in QCI. The range of 20 of the most abundant nassellarian species with respect to the conodont zones is shown in Figure 2, which also incorporates overall ranges suggested by supplementary data from Burnaby Island, Shields Island and Kunghit Island. Against the background of fairly gradual radiolarian evolution across the boundary, four new appearances are recorded in the Communisti Zone and seven in the lower part of the Primitius Zone. The last appearance of *Bulbocyrtium* aff. *reticulatum* (which ranges down to the Nodosus Zone) occurs in the Communisti Zone, whereas *Multimonilis pulcher*, *Veles vulgaris*, *Triassocampe coronata*, and *Poulpus carcharus* go extinct in the Primitius Zone. *Xipha nodosa* appears to be restricted to Primitius Zone in QCI; its range in Japan is similarly short, although somewhat older (see Sugiyama, 1997).

### Summary

Preliminary observations on the radiolarian succession in QCI indicate that the potential for global correlation around the CNB using Late Triassic nassellarians is quite good. Broadly, over two-thirds of total radiolarian species studied range through the Communisti and Primitius





Albertiana 24, September 2000

conodont zones indicating the CNB interval was a time of gradual, rather than dramatic radiolarian change. Nevertheless, new taxa are recognized at the base of both the Communisti and Primitius zones, either of which could serve as a datum for boundary definition.

The Communisti Zone corresponds to a position coincident with, or approximating the base of the Macrolobatus ammonoid Zone, based on occurrences on QCI (GSC loc. C-157382, Kunghit Island) and northeast British Columbia (GSC loc. 68202, Mt. McLearn) (Orchard, 1991a, fig. 5; Orchard and Tozer, 1997, p. 684).

Data from both the Queen Charlottes (GSC locs. C-157119, C-157123, Huxley Island) and northeastern British Columbia (GSC locs. 64616, 64628, Pardonet Hill; 94738, Mt. Laurier) demonstrate that the base of the Primitius Zone falls within the Macrolobatus Zone (Orchard, 1991a, fig. 8; Orchard and Tozer, 1997, p. 685). Hence, although the use of the Primitius Zone as the datum for the CNB has clear microfossil characteristics, it has the effect of including some Macrolobatus Zone ammonoid faunas within the Norian. Differentiation within that ammonoid zone in British Columbia is not currently possible based on the ammonoid fauna alone. This lack of a well defined ammonoid signature corresponding to the base of the Primitius Zone therefore constitutes a problem for recognizing such a boundary based on ammonoids.

Use of the base of the succeeding Kerri ammonoid Zone as the boundary datum, as has been customary in North America, apparently does not correspond to a clear or reliable conodont or radiolarian signal. Samples from the Kerri Zone invariably yield a Primitius Zone conodont fauna, but it may or may not include *Norigondolella navicula*, a taxon used formerly to differentiate Lower and Upper parts of the Primitius Zone (Orchard, 1983, 1991a, b). Apparent facies control of this species cautions against its indiscriminate use as an index to the CNB.

Use of the base of the Communisti Zone as the datum for the Carnian-Norian boundary has the advantage of providing contemporaneous ammonoid, conodont and radiolarian indices for its recognition.

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Fig. 2 Range chart for selected Late Triassic radiolarians in strata of the Nodosus (Nod.), Communisti (Com.) and Primitius conodont zones on Sadler Point. Notations: 1 = range lowered to Nodosus Zone as suggested by data from Burnaby Island; 2 = range extended higher and lower in the Primitius Zone as suggested by data from Frederick Island; 3 = range lowered to Communisti Zone as suggested by data from Shields Island; 4 = range lowered to Communisti Zone as suggested by data from Kunghit Island. CARTER, E.S., ORCHARD, M.J., & TOZER, E.T., 1989. Integrated ammonoid - conodont - radiolarian biostratigraphy, Late Triassic Kunga Group, Queen Charlotte Islands, British Columbia. in: Current Research, Part H; Geological Survey of Canada, Paper 89-1H, p. 23-30.

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## **BRITISH TRIASSIC PALAEONTOLOGY: SUPPLEMENT 24**

## G. Warrington

Since the completion of the writer's previous supplement (No.23; ALBERTIANA, 23: 43) on British Triassic palaeontology, the following works relating to aspects of that subject have been published or have come to his notice:

- BLOOS, G. & PAGE, K.N. 1999. The basal Jurassic ammonite succession in the north-west European province - review and new results. GeoResearch Forum, 6: 27-39.
- BUCKMAN, J.O., DOUGHTY, P.S., BENTON, M.J. & JERAM, A.J. 1999. Palaeoenvironmental interpretation of the Triassic sandstones of Scrabo, County Down, Northern Ireland: ichnological and sedimentological studies indicating a mixed fluviatile-aeolian succession. Irish Journal of Earth Sciences, 16 (1997/8): 85-102.
- CLARK, N.D.L. 1999. The Elgin Marvel. Open University Geological Society Journal, 20 (2) Symposium Edition 1999: 16-18.
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- DINELEY, D.L. & METCALF, S.J. 1999. British Triassic fossil fishes sites. Pp.325-351 in Dineley, D.L. & Metcalf, S.J. Fossil Fishes of Great Britain, Geological Conservation Review Series, 16. Joint Nature Conservation Committee, Peterborough, xxi+675pp.
- EDWARDS, R.A. 1999. The Minehead district a concise account of the geology. Memoir of the British Geological Survey, 1:50000 geological sheet 278 and part of 294 (England & Wales). London: The Stationery Office, xii + 128pp.
- HOPKINS, C. 1999. New finds in the Hopeman Sandstone. Open University Geological Society Journal, 20 (2) Symposium Edition 1999: 10-15.
- LUCAS, S.G., HECKERT, A.B., FRASER, N.C. & HUBER, P. 1999. Aetosaurus from the Upper Triassic of Great Britain and its biochronological significance. Neues Jahrbuch für Geologie und Paläontologie Monatshefte, Jg 1999, Heft 9: 568-576.
- SWIFT, A. & MARTILL, D.M. (eds). 1999. Fossils of the Rhaetian Penarth Group. Field Guide to Fossils No.9. The Palaeontological Association, 312pp.
- WARRINGTON, G., WILSON, A.A., JONES, N.S., YOUNG, S.R. & HASLAM, H.W. 1999. Stratigraphy and sedimentology. Pp.10-40 in PLANT, J. A., JONES, D. G. & HASLAM, H. W. (editors), The Cheshire Basin: Basin evolution, fluid movement and mineral resources in a Permo-Triassic rift setting. Keyworth, Nottingham; the British Geological Survey, xvii+263pp.

This contribution is published with the approval of the Director, British Geological Survey (N.E.R.C.).

## FINAL CIRCULAR

## OMAN PANGEA SYMPOSIUM AND FIELD MEETING

Information and Inscription directly on web site: http://www.geoconfoman.unibe.ch

### On the occasion of the International Conference on the Geology of Oman organised at Sultan Qaboos University, Seeb/Muscat, January 12 to January 16, 2001, an Oman Pangea Symposium and field meeting is scheduled

This Oman Pangea Symposium and field meeting wil be co-sponsored by the Global Sedimentary Geology Program (chairman Dr. Benoit Beauchamp), by the International Subcommission on Permian Stratigraphy (chairman Dr. Bruce R. Wardlaw) and by the International Subcommission on Triassic Stratigraphy (chairman Prof. Maurizio Gaetani). The symposium will take place within the Southern Tethys and Arabian Continental Margin topic of the Conference (Prof. Alastair Robertson).

### SCIENTIFIC ORGANISERS OF THE SYMPOSIUM AND FIELD MEETING

Dr. Aymon Baud and Prof. Jean Marcoux, with the help of the BRGM and other experts.

### OBJECTIVE

With the presentation of new and recent results on Permian and Triassic sediments of Oman, the aim of the Symposium and the three fieldtrips are to provide a forum to geologists who are interested in the time interval of Pangea for discussing global changes related to Pangea integration, North Gondwana and Central Tethys evolution; It will be an unique oportunity for sedimentologists, statigraphs and paleontologists who are working within Permian and Triassic time interval, biotic crisis, extinction, recovery and evolution at the Paleozoic- Mesozoic transition to discuss, to look and to sample at the spectacular Permian and Triassic outcrops belonging to the Oman former continental margin, from shallow shelf to deep marine sediments and seamounts. For the petrograph-geochimists, Oman is a key area for the study of the magmatism linked with the Permian Neotethys opening and with the Triassic intra-oceanic seamounts.

#### GENERAL THEME

Pangea and Tethys, moving Plates and environmental Changes.

### SECONDARY THEMES

- Progress in the Permo-Triassic Stratigraphy and Palaeontology of the Central Tethys and its Gondwana margin.
- Comparison between the Permo-Triassic continental margins of Oman, Arabia, Iran, N India (Himalayas) and N Australia.

Further Informations by Aymon Baud, Geological Museum, UNIL-BFSH2, CH-1015 Lausanne, Switzerland, tel.: xx41 21 692 44 71, fax xx41 21 692 44 75, e-mail aymon.baud@sst.unil.ch

#### Pre-Conference Excursion No. A01

### PERMO-TRIASSIC DEPOSITS: FROM THE PLATFORM TO THE BASIN AND SEAMOUNTS

Leaders: A. Baud, <u>F. Bechennec.</u> F. Cordey, L. Krystyn, <u>J. le Métour.</u> J. Marcoux & R. Maury Dates: January 8 - 11, 2001 Cost: US*\$500* 

The mountainous belt located in the eastern part of the Arabian Peninsula, the Oman Mountains, expose a segment of the Gondwanian margin interpreted as a flexural upper plate. During the end of the Cretaceous, this segment was sliced and brought on the Arabian continent with the obduction of the ophiolite, part of the Tethyan ocean. Following a lower Permian rifting phase and middle Permian break-up (birth of the Neotethys), a wide carbonate platform developed during late Permian and Triassic times on the inner part of the margin. This Permian-Triassic sequence is exceptionally well exposed in the Jebel Akhdar Mountains, as part of the "autochthonous" which crops out in a large tectonic window. The Permian and Triassic shallow water carbonate rocks occurring in this area belong to the Akhdar Group, with two main lithologic units: the Saig and Mahil Formations. The Saig Formation, about 700 m thick and made up of three transgressive - regressive cycles unconformably overlies Precambrian strata, documenting the upper Permian marine transgression. The following 800 m thick Triassic dolomitic Mahil Formation confirms the cyclic and restricted shallow marine environment upward.Carbonates derived from the platform represented the major source for the thick sequence of slope carbonates deposited near the platform margin. On more distal parts, the basinal and oceanic sedimentation resulted in various types of carbonate, cherts and siliciclastic deposits, presently found in the Hawasina Nappe. Middle Permian radiolarites and red ammonoides limestones as Middle Triassic black marls and limestones deposited on lavas are croping out as blocks of various dimensions, the Oman Olistolits, both sides of the "autochthonous" tectonic window. Also new results on Permian and Triassic magmatism will be presented.

Spectacular and recently studied outcrops in Wadi Wasit, Ba'id, Aq Quil, Jebel Misfah, Jebel Misht and Jebel Akhdar areas allowed to reconstruct the former geometry of the margin during Late Permian and Triassic times.

### Pre-Conference Excursion No. A02

## LOWER TO MIDDLE PERMIAN SEDIMENTATION ON THE ARABIAN PLATFORM: THE HUQF AREA (S. CENTRAL OMAN) AND THE JEBEL AKHDAR (OMAN MOUNTAINS)

Leaders:	L. Angiolini, J. Broutin, S. Crasquin & JP. Platel
Dates:	January 7 - 11, 2001
Cost:	US\$625

This excursion will provide a unique opportunity to see and sample the Peri-Gondwanan Permian successions of the Sultanate of Oman. In the spectacular scenarios of the mountains and the desert, different faunal and floral associations and depositional environments from platform to shallow basin will be visited.

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Starting in the desert of the Interior Oman, the excursion will visit the Huqf area, a region marked by gentle deformed and uplifted Palaeozoic formations. Here, the Early to Middle Permian is represented by two mega-sequences separated by a regional unconformity, recording two major transgressive events respectively controlled by the last phase of the Gondwanan deglaciation and by the opening of the Neotethys. The first sequence consists of Lower Permian glacio-lacustrine deposits of the Al Khlata Formation succeeded by the transgressive marine deposits of the Saiwan Formation, marking the complete deglaciation of the region. The latter unit, of late Sakmarian age, yelds a rich and well preserved brachiopod (L. Angiolini), bivalve, gastropod, crinoid and bryozoan fauna.

Resting unconformably, the upper sequence is composed at the base of a thick fluvial terrigenous unit, the Gharif Formation. This sequence terminates with the highly fossiliferous [brachiopods, ostracodes, conodonts, bivalves, gastropods, cephalopods, trilobites (L. Angiolini & S. Crasquin)] transgressive marls and bioclastic limestones of the Khuff Formation, of which only the Wordian part is exposed below the angular unconformity of the Triassic continental Minjur Formation.

The Huqf succession represents a key-section for the intercalibration of Early to Middle Permian marine and continental biostratigraphical scales. In fact, if on one hand the fauna shows a marked transitional character, being represented by cosmopolitan, Gondwanan, Tethyan and endemic taxa, on the other the newly named "Gharif Paleoflora" (J. Broutin) is erected as a standard for the Arabian Peninsula. This warm humid assemblage is of outstanding palaeogeo-graphic significance, because it comprises associated Gondwanan, Cathaysian and Laurasian floral elements.

Moving to the the Oman Mountains, this excursion will examine together with the excursion A01 the Permian succession cropping out in the north-western part of the Jebel Akhdar window, along the Wadi Sahtan. Here, the Permian is represented by the Wordian marine Saiq Formation, lying with a spectacular angular unconformity on the Proterozoic-Lower Paleozoic autochthone series. The Saiq Formation consists of conglomerates at the base overlain by bioclastic limestones and reef limestones which capped by dolomites. This unit marks the transgression on the newly formed Neotethyan margin.

### Post-Conference Excursion No. B01

## PERMO-TRIASSIC DEPOSITS: FROM SHALLOW WATER TO BASE OF SLOPE AND BASIN

Leaders: A. Baud, F. Bechennec, F. Cordey, J. Marcoux, R. Maury & J. le Metour Dates: January 17 - 20, 2001 Cost: US\$500

The mountainous belt located in the eastern part of the Arabian Peninsula, the Oman Mountains, expose a segment of the Gondwanian margin, interpreted as a flexural upper plate. The Permian-Triassic sequence deposited on the inner part of this margin is exceptionally well exposed in the Saih Hatat Mountains, as part of the "autochthonous" which crops out in a large tectonic window. The Permian and Triassic shallow water carbonate rocks occurring in this area belong to the Saiq and Mahil Formations. The Saiq Formation, about 400 m thick, consists of transgressive - regressive cycles of shallow carbonate and lava flows unconformably overlying Precambrian strata and documenting the upper Permian marine transgression and rift opening.

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The following Triassic dolomitic Mahil Formation confirms the cyclic and restricted shallow marine environment upward.

Carbonates derived from the platform represented the major source for the thick sequence of slope carbonates (the Sumeini Group) deposited near the platform margin, cropping out in the Sumeini area near the border between Oman and the United Arab Emirates. The lower part of this group (about 1700 m thick) is included in the Maqam Formation, late Permian to late Triassic in age. Key section of the Oman margin architecture, the Wadi Maqam has been re-investigated in terms of biochronology, sequence and isotope stratigraphy. On more distal parts, the basinal and oceanic sedimentation resulted in various types of carbonate, cherts and siliciclastic deposits, presently found in the Hawasina Nappe. Middle Permian radiolarites and red ammonoides limestones as Middle Triassic black marls and limestones deposited on lavas are croping out as blocks of various dimensions, the Oman Olistolits, both sides of the "autochthonous" tectonic window. Also new results on Permian and Triassic magmatism will be presented.

Spectacular and well studied outcrops in Saih Hatat, Rustaq, Buday'ah, Wadi Maqam and Jebel Sumeini areas allowed to reconstruct the former geometry of the margin during Late Permian and Triassic times.

Excursion Information and Inscription directly on web site: http://www.geoconfoman.unibe.ch

## FIRST CIRCULAR AND CALL FOR PAPERS

THE INTERNATIONAL SYMPOSIUM ON THE GLOBAL STRATOTYPE OF THE PERMIAN-TRIASSIC BOUNDARY AND THE PALEOZOIC-MESOZOIC EVENTS

## 10-13 August 2001 to be held in Changxing, Zhejiang Province, The People's Republic of China

For updates consult: http://www.cug.edu.cn/cugnew/overview/dept/dxy/ptb/index.htm

## SPONSORS

- China Geological Survey
- China University of Geosciences
- Global Sedimentary Geology Project
- International Subcommission of Permian Stratigraphy
- International Subcommission of Triassic Stratigraphy
- International Working Group of Permian-Triassic Boundary
- Nanjing Institute of Geology and Paleontology, Academia Sinica
- National Natural Science Foundation of China

- Paleontological Society of China
- Stratigraphic Commission of China

## **ORGANIZERS:**

- China University of Geosciences
- China Geological Survey
- Government of Changxing County, Zhejiang Province

## ORGANIZING COMMITTEE:

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 Yin, Hongfu: Chairman of International Working Group of Permian-Triassic Boundary, Member of the Academy of China, President of China University of China (Wuhan)

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- Wardlaw, Bruce R.: Chairman of International Subcommission of Permian Stratigraphy
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- President of Changxing County, Zhejiang Province
- Secretariat:
- Dr. Tong Jinnan (Correspondence)
  - Faculty of Earth Science, China University of Geosciences, Wuhan 430074, China Tel: +86-27-8748 2031; Fax: +86-27-8780 1763 Email: jntong@public.wh.hb.cn

### **OBJECTIVES:**

This symposium is designed to provide a forum to all kinds of scientists who are interested in the Permian-Triassic boundary and its related great events for examining the key section of the Permian and Triassic boundary at Meishan, Zhejiang Province and discussing the great transition between the Paleozoic and Mesozoic and its associated events.

The field excursions provide you opportunity to visit some typical sequences from the Carboniferous to Lower Triassic and/or some paralic and continental Permian-Triassic boundary sections in South China.

### DATE, VENUE AND LANGUAGE:

Pre-symposium Field Excursion:	8-9 August 2001
Symposium:	10-13 August 2001
During-symposium Field Excursion:	11 August 2001
Post-symposium Field Excursion 1:	14-15 August 2001
Post-symposium Field Excursion 2:	14-18 August 2001
Place:	Changxing, Zhejiang Province
Language:	English will be the official language for all presentations

## IMPORTANT DATES:

Deadline for submission of response to first circular
Deadline for submission of abstracts for the proceedings
Deadline for submission of pre-registration
Deadline for submission of papers for the special symposium volume

### THEMES:

The symposium will be structured into four main themes:

- The global stratotype of the Permian-Triassic boundary and its geological setting;
- Stratigraphy of the Permian and Triassic boundary and its global correlation over various facies;
- Tectonics, paleogeography, paleoclimatology and paleoecology during the Paleozoic and Mesozoic transition;
- Biotic crisis, mass extinction and recovery, and connected events across the Permian and Triassic boundary.

### FIELD EXCURSIONS:

Pre-Symposium Field Excursion: Guangde, Anhui Province and Changxing, Zhejiang Province (8-9 August 2001)

This two-day field excursion will provide you an overview of the geological setting in Meishan area, Changxing County. You will visit some typical sections from the Devonian to Triassic, which well recorded the evolution of the eastern Tethys during the Pangea from late Paleozoic to Triassic. The differentiation of the Changhsingian facies and some key boundaries will be observed as well.

During-Symposium Field Excursion: Meishan Section, Changxing, Zhejiang Province (11 August 2001)

During the symposium we will spend one day at the well-known Meishan Section of the Changxing Limestone and Permian-Triassic boundary to examine the sequence and discuss its related aspects.

Post-Symposium Field Excursion 1: Chaohu, Anhui Province (14-15 August 2001)

The Permian and Triassic stratigraphical and paleontological sequence at Chaohu, Anhui Province is one of the best and well-studied sections in the Lower Yangtze region. The Changhsingian and Lower Triassic here were formed on deep shelf (or slope) while Meishan was on shallow shelf. Here you will visit an excellent Permian and Triassic sequence, and especially the Lower Triassic as well as the Middle Permian is quite exemplary. In addition, we might have a stop in Nanjing, Jiangsu Province, where you could observe a section situated in the transitional facies from Meishan to Chaohu.

Post-Symposium Field Excursion 2: Liuzhi-Weining, Guizhou Province (14-18 August 2001)

This excursion supposes to provide 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. The paralic Permian-Triassic boundary sections are located in the central-western Guizhou Province. During the excursion you will visit a series Permian and Triassic boundary sections from marine to continental via paralic facies in the central-western Guizhou Province so that you might figure out a correlation between the marine and continental boundaries.

## PUBLICATIONS:

We anticipate that refereed and accepted papers will be published either as a book or as a special issue of an international journal. The paper must be presented (either orally or in poster) before being considered for publication. But all abstracts will be collected into the Proceedings of the Symposium, which will be delivered to every participant at the Symposium. All the papers and abstracts must be in English and submitted to the secretariat before the deadlines. Refer to the second circular for the details of the submission of the papers and abstracts.

### **REGISTRATION:**

Registration should be made to the registration form attached on the second circular, which will be sent to all who respond to the first circular. Registration fee for the symposium (including the Proceedings, morning and afternoon teas, and the during-symposium field excursion and during-symposium sightseeing in Changxing County) will be \$200 US Dollars. Pre-Symposium field excursion fee (including field guidebook, transportation and meals) will be \$100 US Dollars. The post-symposium field excursion 1 to Chaohu costs \$150 US Dollars (including field guidebook, transportation, and accommodation). The post-symposium field excursion 2 to Guizhou will be \$450 US Dollar (including field guidebook, accommodation, transportation during the field excursion in Guizhou, and a single flight from Nanjing to Guiyang). Refer to the second circular for the details.

### HOTEL ACCOMMODATION:

Several hotels in the downtown of Changxing County are arranged for participants. Room rate ranges from \$20 to \$50 US Dollars per night for standard double rooms and \$15 to \$30 US Dollars per night for standard single rooms. Details and reservation forms for hotels will be distributed in the second circular.

### TRANSPORTATION:

Changxing is located in the northern Zhejiang Province, to the west of Taihu Lake, bordering on Jiangsu and Anhui provinces. It is in the mid-way of the Nanjing-Hanzhou freeway, 110 km to Hanzhou and 200 km to Nanjing. A highway also connects it to Shanghai in about 150 km. The Hanzhou-Chaohu railway goes through Changxing City with a few trains daily from Hanzhou.

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Pre-Registration Form for:

# The GSSP of the Permian-Triassic Boundary and the Paleozoic-Mesozoic Events

Forename:			
Initial(s):			
Surname:			
Sex (M/F):			
Title:			
Institution:			
Full Address:			
Country:			
Telephone:			
Fax:			
Email:			
I plan to attend	the Symposium (Please tio	ck)	
	very probably	🗅 probably	🗅 unlikely
l plan to contrib	oute with an		
	🗅 oral paper	D poster	
Tentative title:			
I plan to attend	the pre-Symposium field e	xcursion	
	very probably	🗅 probably	🗅 unlikely
l plan to attend	the post-Symposium field	excursion 1 to Chaohu	
	very probably	probably	🗅 unlikely
I plan to attend	the post-Symposium field	excursion 2 to Guizhou	
	very probably	□ probably	🗅 unlikely
Comments/Sug	gestions:		
Date:			

Signature:

## NEW TRIASSIC LITERATURE

## Hans Kerp, Henk Visscher and Geoffrey Warrington<sup>1</sup>

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The continuous Help of Mrs. Gaby Schwenzien (Münster) and Dr. Zwier Smeenk (Utrecht) in tracing relevant Triassic literature is gratefully acknowledged. Thanks are also due to all authors who sent information on their recent publications. Some references have been traced from secondary sources. Therefore, diacritical signs may sometimes be missing. Titles of congress abstracts - even those published in regular journals - are not included.

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- 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 mention, the genus name may be abbreviated to its initial letter if there is no danger of confusion with some other genus beginning with the same 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), 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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